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Effluent Irrigation Manual

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P R E F A C E

Most States now require an irrigation system which utilises effluent to be designed and managed in a way which minimises the risk of causing pollution. These requirements are not necessarily difficult to achieve, but do require that the effluent disposal system be given the same amount of management attention as other key engineering systems within an abattoir, such as the conveyor chains and cold storage.

This manual has been prepared to assist abattoir and other meat processing works manage the disposal of their effluent by irrigation in an environmentally responsible manner.

Disposal of effluent by irrigation is the last link in a chain of events which produce a volume of effluent carrying various pollutants. Many of the "problems" associated with effluent disposal have their origins in earlier links in the chain:

- *The volume of wastewater generated in the abattoir.*
- *The pollutants carried in the wastewater.*
- *The degree of treatment given to the waste.*

A significant reduction in the demands placed on the effluent disposal system can be achieved by reduction in the volume of water used, reduction in the waste load carried by the water and improved treatment of the effluent prior to irrigation. These topics are outside the scope of this manual ***but they are matters which must be considered alongside any action to improve the performance of the irrigation system.***

The manual is intended to provide basic guidelines and technical information for those responsible for management of irrigation systems which utilise effluent from meat processing plants. The manual provides a compendium of information and is not intended to be read from cover to cover. Separate sections of the manual deal with the main topics necessary for successful management of irrigation using abattoir effluent. Each section is intended to be almost self contained and to allow the reader to study that topic without needing to have read all the previous sections. For this reason, there is some overlap between sections and some duplication of information.

The manual is <u>not</u> a complete "do it yourself" guide to every aspect of the planning, design and management of an irrigation system suitable for disposing of abattoir effluent. It provides background information to give the reader a general understanding of the issues involved and the principles which should be followed. Every abattoir faces its own unique situation because of its location, climate, soils and the quantity and quality of effluent produced. This manual does not attempt to cover every eventuality. Inevitably there will be some conditions where outside expert advice will be necessary. This manual should help the person responsible for the irrigation system to know enough to recognise when help is needed.

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Finally, a special note of gratitude to Dr Mike Johns, University of Queensland, for his enthusiasm and encouragement throughout the preparation of this manual.

Steve Perrens
November 1995

What's in this Manual

The manual is designed primarily for use by the person within the abattoir who has responsibility for "disposing" of effluent from the plant. This will usually be the Abattoir Engineer or Environmental Manager who usually has many other responsibilities. The manual tries to make life easier by setting out:

- The sort of information which needs to be gathered to help Abattoir Managers meet their commitments for environmental reporting to regulatory authorities.
- Typical work schedules and checking which should be carried out by the person who reports to the Abattoir Engineer or Environmental Manager and who has day to day responsibility for operating the effluent irrigation system.
- Action to be taken to correct faults or inadequacies.

How much of the manual needs to read at one time is up to the reader's own interest and background knowledge. The manual is not intended to provide complete answers to *all* the issues and problems which occur. The manual should however provide you with sufficient information for routine operation and maintenance including correction of minor faults and allow you to judge when help is needed from experts.

The manual is divided into three main sections, each of which is clearly marked (to help you find it) and its own table of contents. The three main sections are:

■ ***Section A - Getting Started***

The majority of this section is made up of some "review" tests designed to help you assess how satisfactory your irrigation system is and identify the main areas which might require attention. At the same time it provides a useful opportunity to "brush up" on a range of topics which are important to effective management of effluent irrigation. After you have worked through Section A, you should have a clear idea of how much you know and which aspects of your effluent irrigation system require attention first.

The main topics in Section A are:

- ***Neighbours and Regulators*** - are you at risk?
- ***Plant Nutrients*** - are they in balance?
- ***Irrigation Area and Water Storage*** - are they sufficient?
- ***Hydraulic Loading*** - how much can the land take?
- ***Groundwater*** - will it get polluted?
- ***Surface Runoff*** - what protects the local creek?
- ***Emergencies*** - what happens when things go wrong?

For each of these topics there is a "check list" form to work through which should give you an idea of how your system is performing. After each of the forms there are about three pages of notes which provide a brief background to the important topics and provide some guidance on how to fill in the forms.

- ***Section B - Technical Manual***

This part of the manual contains a lot of the technical details which need to be understood for successful management of effluent irrigation. The main topics covered in this section are:

B-1 ***Site Characteristics*** - soils as a medium in which plants grow and which store nutrients and water.

B-2 ***Requirements for Plant Growth*** - how water and nutrients are used by plants.

B-3 ***Climate*** - which controls the way an effluent system is managed.

B-4 ***Water Quality*** - which controls the amount of effluent which can be applied.

B-5 ***Irrigation Systems*** - the characteristics of different methods of irrigation and why some methods are better than others.

B-6 ***Irrigation Management*** - what must be done and when to ensure best use of the available land.

B-7 ***Monitoring*** - which must be done to manage the irrigation and to meet the regulatory requirements.

It is not essential that you read all of these chapters in sequence. If you have a background in the earth or environmental sciences you may be able to skip Chapters B-1 and B-2. On the other hand if your expertise is in engineering, then you may find that Chapter B-5 has limited value.

N.B. The two chapters which every user of this manual should read are Chapters B-6 and B-7.

- ***Section C - Appendices***

Section C is the reference section of the manual which contains useful data and blank forms which have been designed to be adapted by each abattoir in setting up their own management system to monitor the performance of their irrigation system. The appendices are:

C-1 ***Environmental Regulations and Guidelines***

C-2 ***Irrigation Area and Wet Weather Storage***

C-3 ***Forms and Records***

C-4 ***Formulae and Conversions***

Ten Commandments

For successful irrigation of effluent there are ten basic rules and requirements which will be discussed in more detail throughout the manual.

How many of these rules does your effluent system live up to?

1. *The crops grown must be capable of using the **nutrients** added during the year.*
2. *The application of **irrigation must be scheduled** to meet the water requirements of the crop as they vary with the season and rainfall.*
3. *Water storage must be provided to **store the effluent flow during wet weather** and hold the effluent until dry weather returns.*
4. *To maximise nutrient removal, the **crop should be harvested and removed** from the irrigation area.*
5. *All **surface runoff** from the irrigation area should be captured and re-used*
6. ***Records must be kept** of all inputs and outputs on the effluent irrigation area (effluent quantity, effluent quality, rainfall, crop harvest, stocking rate).*
7. ***Regular checks** should be made of soil and groundwater conditions.*
8. *If salt accumulates in the soil, water application must be managed to allow the **leaching of salts** from the soil.*
9. ***Sub-surface** drainage should be provided if there is a risk of water percolating to the groundwater. The drainage flow must then be disposed of safely.*
10. *As a safety precaution, irrigation areas should be **"rested" for three months** in any year.*

SECTION A

GETTING STARTED

SECTION A

CONTENTS

FORMS TO BE FILLED IN

NOTE: **SPARE COPIES OF THESE FORMS ARE LOCATED IN APPENDIX C-3 AT THE BACK OF THE MANUAL**

CHAPTER A-1: OBJECTIVES AND RISKS

This chapter is concerned with a number of basic questions which need to be considered:

Q 1. What is the purpose of the effluent irrigation system?

Q 2. What are the risks that something might go wrong and lead to problems such as:

- *pollution of the creek or groundwater?*
- *being forced to stop operations because of withdrawal of an operating licence?*
- *degradation of the irrigation area so that it is unusable in, say five years time?*
- *persistent objections about foul odours?*

The manual starts with these topics because it is important to have a clear idea of the purpose of irrigating with effluent and how to approach the task in a safe and responsible manner.

A-1.1 Objectives

In most cases effluent irrigation is seen as the cheapest or only practical method of getting rid of effluent. If it was cheaper to send the effluent to be treated in the municipal sewage treatment works, it would be done that way. So, costs are important.

However, keeping the business going as a commercial operation is not much use, if the operation is closed down because it can no longer meet the environmental standards required. The fact is that these standards will only get tougher and penalties for breaches increasingly harsh.

The long term business plan for any abattoir must therefore include ways to achieve both commercial and environmental objectives.

It is unfortunate that disposal of effluent to land is thought of as irrigation. The word "irrigation" implies to most people that crops are being watered to help them grow.

In most cases, the amount of abattoir effluent which can be used for irrigation is controlled by the plant nutrients in the effluent, not the water. Water simply provides the means to transport the nutrients.

Plant nutrients are, in controlled amounts, essential for plant growth. They are also pollutants which can "contaminate" the soil, and pollute the local environment. The objective must be to irrigate using the effluent whilst minimising the risk of pollution.

A-1.2 Risks

Abattoir effluent is a potential pollutant. It only becomes a pollutant, however, when it escapes into the environment in an uncontrolled manner. An effluent irrigation system must therefore be managed to minimise the environmental and other associated risks which include:

- contamination of creeks, rivers and groundwater;
- nuisance caused by unacceptable odours;
- increased soil salinity or decline in soil structure;
- public health risks from pathogens;
- concentration of residues in food and animals.

The environmental and public health risks associated with effluent use raise a variety of legal issues for the **producers** of the wastewater and the **owners** and **occupiers** on whose land wastewater is reused. In situations where the abattoir does not own the land on which the effluent is being used it is essential that the abattoir manager has a clear understanding of who has what responsibility relating to environmental and public health matters. **The fact that a contract has been entered into with a landholder to take the effluent does not mean that the abattoir has handed over all its responsibility for the safe disposal of the waste.**

A-1.3 Water Pollution

Both surface and ground waters are vulnerable to pollution from the disposal of effluent onto land. It is important that the disposal system is operated to minimise these risks.

As a general rule, there should be no effluent runoff from the irrigation area to the local creek, and the opportunity for percolation to groundwater should be minimised. To achieve this, the amount of effluent water applied plus the rainfall must be no more than can be removed by evapotranspiration from the vegetation.

In addition, a collection system is required to capture and store a "first flush" of runoff from the irrigation area to prevent it from entering the local creek.

A-1.4 Air Pollution

Disposal of effluent by irrigation can cause three types of air pollution problems:

- Odour nuisance to neighbours,
- Health risks from spray drift carried outside the irrigation area;
- Health and safety issues because of the possible effect of air-borne pathogens on the operators.

CHAPTER A-2: EFFLUENT MANAGEMENT OVERVIEW

This section asks you to compile a "portrait" of the effluent irrigation system at your abattoir. It has been designed to give a summary of the components of the irrigation system and their performance.

This section is intended to provide the basis for a report to the Abattoir Manager on the status of the effluent irrigation system. An annual report based on the information in this section would provide a sound basis for reviewing the performance of the system.

By the time you have read this section and filled in the blanks in the tables, you should have:

- *A good appreciation of the major factors which govern the successful management of an abattoir irrigation system*

- *Identified those aspects of the effluent irrigation system which are most at risk of causing environmental problems.*

INSTRUCTIONS:

Chapters A-3 to A-9 deal with topics of importance to abattoir effluent irrigation. Each Chapter contains a simple form which has a number of questions to be answered and calculations to be performed. At the end of each form you will total up a score to be transferred to the summary form (Form A-1). The main points to bear in mind are:

1. The forms should, preferably, be completed by someone who is <u>not</u> involved in the day to day management of effluent disposal, for example the Production Manager. (It is very difficult to be impartial and objective if you are involved on a day to day basis).

2. The forms are designed to help you understand what is actually happening with the effluent disposal system and identify problem areas. Where possible they should be completed by reference to written evidence on file and direct observation of performance. Do not just rely on someone's memory or ideas about what should be happening.

3. Fill in as much as you can in Form A-2.1, A-2.2 and A-2.3. This will provide you with most of the information you will need to fill in the detailed forms in Chapters A-3 to A-9. These forms provide a checklist of the sort of "overview" information that most regulatory authorities will want to see.

4. As you complete Forms A-3 to A-9, transfer your score to the summary in Form A-1.

5. Chapters A-3 to A-9 also provide some guidance on the principal issues which govern satisfactory performance of an effluent irrigation system.

6. The value of these forms are that they will show what is being done correctly and highlight problem areas. To get the most out of the procedure, you should carry out the following steps following completion of the overview:

   - Review the scores for each of the forms in order to identify the main weaknesses. Those where the score was zero would be a starting point. Also look for individual questions where there was a low score. (The maximum score for a question is a guide to its importance.)

   - Work through Section B of the manual, particularly in those areas where you are uncertain about technical matters or where your effluent irrigation system scored poorly. Use Section B of the manual to work out solutions which need implementing to overcome these problems.

   - Prepare a one, two, or three year program which step by step sets out the key dates on which the solutions will be implemented. Cost estimates should be included to confirm the viability of the program.

   - This manual is designed to cover the common problems facing abattoirs which irrigate with effluent. If a problem appears too complex or is not adequately covered in the manual, professional help should be sought. A firm of consulting engineers or scientists who specialise in irrigation and groundwater will be able to assist.

7. Review your operations by repeating the review at the end of each year of your program.

FORM A-1 EFFLUENT IRRIGATION REVIEW SUMMARY

Abattoir :	
Review compiled by:	**Date:**

ISSUE	CHAPTER	POSSIBLE SCORE	YOUR SCORE
Licences and Records	A-3	20	
Nutrient and Chemical Management	A-4	45	
Irrigation Area and Wet Weather Storage	A-5	30	
Soil Moisture Management	A-6	40	
Groundwater Pollution	A-7	20	
Surface Runoff	A-8	20	
Emergency Preparedness	A-9	25	
TOTAL SCORE		200	

1. This summary table provides an overview of the main factors which govern the level of risk associated with the operation of an effluent irrigation system.

2. The column labelled "Chapter" tells you where to find information on each particular issue and where to find the detailed table from which to get your score.

3. Check your score against the table on page A-6 and decide where to start your performance improvement program.

How does the land disposal of effluent from your abattoir rate?

If your total score is:

- **150 to 200** It is likely that your effluent disposal operation is well designed and managed, and only causing minor environmental impact. A brief review of the remaining sections of the manual is probably all that is required. This will ensure that all detailed aspects of the operation have been properly addressed.

- **120 to 150** It is likely that your effluent disposal operation is performing adequately, but there is room for improvement. Look carefully at the scores for the individual Forms and see where your plant scored poorly. Focus your efforts on improving these aspects.

- **60 to 120** A thorough review of the effluent irrigation system is required. The low score suggests that the irrigation system itself is inadequate (and skilled professional advice is probably needed) and that there are operational problems (for which solutions are to be found in this manual). Start by using Section B to identify the weakest points for attention. Prepare an action program to significantly improve the score within 12 months.

- **<60** You've got problems! This situation must not be allowed to linger on or be put into the "too hard" basket. Prompt action is needed to rectify the main problems within 6 months. Review the areas where you scored lowest and, if the problems are not ones you can sort out yourself, get some expert advice.

FORM A-2.1 INFORMATION SUMMARY (1)

Checklist of data and information you will need to build up a dossier and complete the review

1.	**General Data**	
1.1	***Maps, Plans and General Data***	
	Abattoir site plan showing effluent drains and pumps	☐
	Plans of effluent treatment system showing pipelines and valves	☐
	Irrigation area site contour map showing channels, pipelines, valves, drains and fences	☐
	Recent aerial photograph of effluent irrigation area	☐
	Soils map of the irrigation area and soil descriptions	☐
	Local topographic map showing creeks, waterways and wetlands	☐
	Dimensions, depths and capacities of all ponds	☐
	Geological map of the area	☐
	Map showing groundwater bores in the locality	☐
1.2	***Licences, Permits and Records***	
	Copies of all operating licences required for effluent irrigation	☐
	Copies of monitoring <u>data</u> for the last 12 months	☐
	Copies of monitoring <u>summary reports</u> for past 5 years	☐
	Copy of complaints register	☐
	Names and contact details of all neighbours	☐
	Names and contact details of all environmental authorities	☐
	Irrigation system procedures manual	☐
	Irrigation system emergency procedures	☐
	Irrigation operation daily log	☐

FORM A-2.2 INFORMATION SUMMARY (2)

2.0	**Abattoir Production and Effluent Quality**
2.1	***Production*** Annual head killed: Cattle .... ☐ Sheep .... ☐ Pigs .... ☐ Other .... ☐ Total annual dressed weight of product (tonnes) .... ☐
2.2	***Water Supply and Use*** Total water supplied to abattoir from all sources - preferably daily totals (kL) .... ☐ Salinity of water supply (mg/L) .... ☐ Volume irrigated - preferably daily volume (kL) .... ☐
2.3	***Effluent Processing and Storage Facilities*** Details of: Solids (paunch and sludge) de-watering facilities .... ☐ Screens and savealls .... ☐ Dissolved air flotation (DAF) units .... ☐ Nutrient reduction facilities: · activated sludge .... ☐ · sequenced batch reactor .... ☐ · chemical dosing .... ☐ Aerated ponds .... ☐ Anaerobic lagoons/ponds .... ☐ Aerobic/facultative (oxidation) ponds .... ☐ Aerated ponds .... ☐ Wet weather storage ponds .... ☐
2.4	***Effluent Quality*** Plan showing location of routine effluent sampling points .... ☐ Laboratory analysis reports for all samples taken during last 12 months .... ☐

FORM A-2.3 INFORMATION SUMMARY (3)

3.0	Irrigation System	
3.1	***Irrigation System and Operations***	
	Plan of irrigation layout	☐
	Irrigation records for each field or block	☐
	Operating manuals for irrigation equipment	☐
	Crop history in each paddock	☐
	Stock records for each paddock	☐
	Soil moisture monitoring records	☐
3.2	***Climate***	
	Rainfall records from abattoir or irrigation area	☐
	Long term rainfall records from nearest town (50 years minimum)	☐
	Evaporation records (nearest available or a map)	☐
3.3	***Environmental Monitoring***	
	Laboratory analysis reports for water samples from drains, creeks and dams	☐
	Laboratory analysis records for groundwater samples	☐
	Laboratory analysis records for soil samples	☐
	Water level records for monitoring bores (full historic records)	☐

CHAPTER A-3: LICENCES AND RECORDS

Most effluent disposal systems require a variety of licences and permits to operate. In addition there is usually an obligation to monitor the performance and to keep good records.

When you have completed this section you should have:

- ☐ *Identified what licences and permits you need to hold*
- ☐ *Checked that the required licences are current*
- ☐ *Assessed the status of records you are obliged to keep*
- ☐ *Reviewed any complaints received from the public or regulators.*

Start by working through Form A-3 and evaluating some of the key factors on which your environmental performance might be judged by regulatory authorities and your neighbours. Following Form A-3 is a brief outline of why some of the issues raised in the form are important

The general requirements for complying with legislation are that an abattoir:

- ☐ ***Holds valid permits/licences,***
- ☐ ***Carries out its operation in accordance with the conditions stated in the permit/ licence which usually include:***
  - ***monitoring***
  - ***keeping records***

A good system of record keeping is essential to:

- ☐ ***Know how the system is operating.***
- ☐ ***Meet regulatory requirements.***

FORM A-3. LICENCES AND RECORDS

ISSUE AND SCORING	WORKING	SCORING METHOD	YOUR SCORE
1. Planning Approval			
1.1 What are the permitted uses of the land? *(Check with local Council if unsure)*	________	If answer to either 1.2 or 1.3 is:	
1.2 Is effluent irrigation specifically allowed without planning consent?	Yes/No/Unknown	Yes = 4 No = 0 Unknown = 0	
1.3 If "no" do you have planning consent?	Yes/No/Unknown		______
2. Pollution Permits/Licences			
2.1 Either: Do you need a pollution control licence for operating an effluent treatment plant? *(Check with EPA or other environmental agency)* Or: Do you need a pollution control licence for discharging effluent to land? *(Check with EPA or other environmental agency)*	Yes - *go to Q 2.2* No - *go to Q 3.1* Unknown - *go to Q 2.2*	Yes = 0 No = 6 Unknown = 0	______
2.2 Are all the required licences/permits current? *(Check the files!)*	Yes/No/Unknown	Yes = 3 No = 0 Unknown = 0	______
2.3 Are you complying with all the conditions of the licence/permit?	Yes/No/Unsure	Yes = 3 No = 0 Unsure = 0	______
3. Inspections			
3.1 How many visits have you had in the last year from inspectors regarding the irrigation system?	______		
3.2 How many of those visits were because of an "incident" or complaint?	______	0 - *go to Q 4.1* 1 or more - *go to Q 3.3*	
3.3 Have all matters noted by the inspectors been fixed?	Yes/No/Unsure	Yes = 3 No = 0 Unsure = 0	______
4. Neighbours			
4.1 How close is the nearest residence to the boundary of the irrigation area?	______	>500 m = 3 300 - 500 m = 2 100- 300 m = 1 <100 m = 0	______
4.2 How many written or telephone complaints have you received in the last year relating to: • odour? • spray drift? • runoff into creeks? **Total complaints**	______ ______ ______ ______	Total complaints: 0 - 5 = 2 6 - 10 = 1 >10 = 0	______
5. Records			
Do you have a complete set of records of irrigation volume, water quality, soil conditions and cropping?	Yes/No/Unsure	Yes = 2 No = 0 Unsure = 0	______
TOTAL SCORE FOR THIS TABLE			______

A-3.1 Regulations

Even if your operation is not causing any pollution, nuisance or public health problems, you still will need a number of permits or licences for:

- ***Development*** - particularly construction of a meat processing plant with waste disposal facilities.
- ***Pollution*** - for the discharge of water or air, or the creation of noise.
- ***Conservation*** - to control soil degradation and environmental harm; and
- ***Public Health*** - controls on the sale of food, limits on pesticide residues in foodstuffs and public health risks associated with effluent disposal.

In most States, the application of effluent to the land is specifically regulated by a complex set of rules. Typically these require an abattoir which irrigates with its effluent to:

- Hold a ***current licence*** to dispose of effluent.
- Carry out ***regular tests of water quality*** in the effluent being irrigated, the neighbouring creeks and shallow groundwater.
- Carry out periodic ***soils analyses*** (at least every three years) to check on nutrient levels, salinity and soil structure.

If you do not hold the required permits or are not carrying out the necessary tests, you can face heavy fines in most States. Even if you are carrying out the necessary tests you must also ***keep good records***.

Most State legislation is supported by various non-binding policies, codes of practice and guidelines. You need to ensure that you have copies of the relevant guidelines from the agencies in your State responsible for:

- environmental protection;
- water resources;
- agriculture.

There is an enormous volume of environmental laws and regulations relating to abattoir operation. A comprehensive review of environmental legislation relating to the meat processing industry entitled "Australian Meat Processing Environmental Legislation Review" has been prepared by Freehill, Hollingdale & Page and published by Australian Meat Technology for the Meat Research Corporation. A brief summary of legislation of particular relevance to effluent irrigation is contained in Appendix C-1.

A-3.2 Neighbours

Whilst government regulators have the responsibility for protecting the broad community's environmental interests, each abattoir has to manage its own relationships with the local community - particularly its neighbours.

Effluent disposal has the potential to cause nuisance and harm to neighbours. Their comments and complaints must be taken seriously and problems resolved if possible. Most regulatory agencies expect you to keep a register of all complaints received and action taken to correct the problem.

A-3.3 Records

Regulators expect you to not only monitor the local environment but to keep complete records. In addition you need to keep your own management records. If you are operating an effluent irrigation system, the system ***must*** be managed if it is to work successfully. As with any aspect of management you need to ***monitor and record*** what is happening - otherwise you will not know when things are going wrong. Good records are essential for two purposes:

- Recording the operation of the irrigation system so that you can have confidence that everything is on track.
- Recording key environmental indicators so that the regulators can check that the system is not causing environmental degradation.

CHAPTER A-4: NUTRIENT AND CHEMICAL MANAGEMENT

Strange though it may seem, the management of effluent irrigation has more to do with managing the supply of nutrients than water. The management of the land and how it is cropped or grazed will dictate how much effluent can be applied from year to year. The water becomes important only if the soil is already saturated from rainfall or a high watertable and effluent must be stored temporarily.

No-one is too worried about excess water flowing into a creek - this happens naturally in times of heavy rainfall. People are likely to get upset, however, if that water carries pollutants with it. For an effluent irrigation system the pollutants which are usually of concern are nitrogen, phosphorus, salt and sediments.

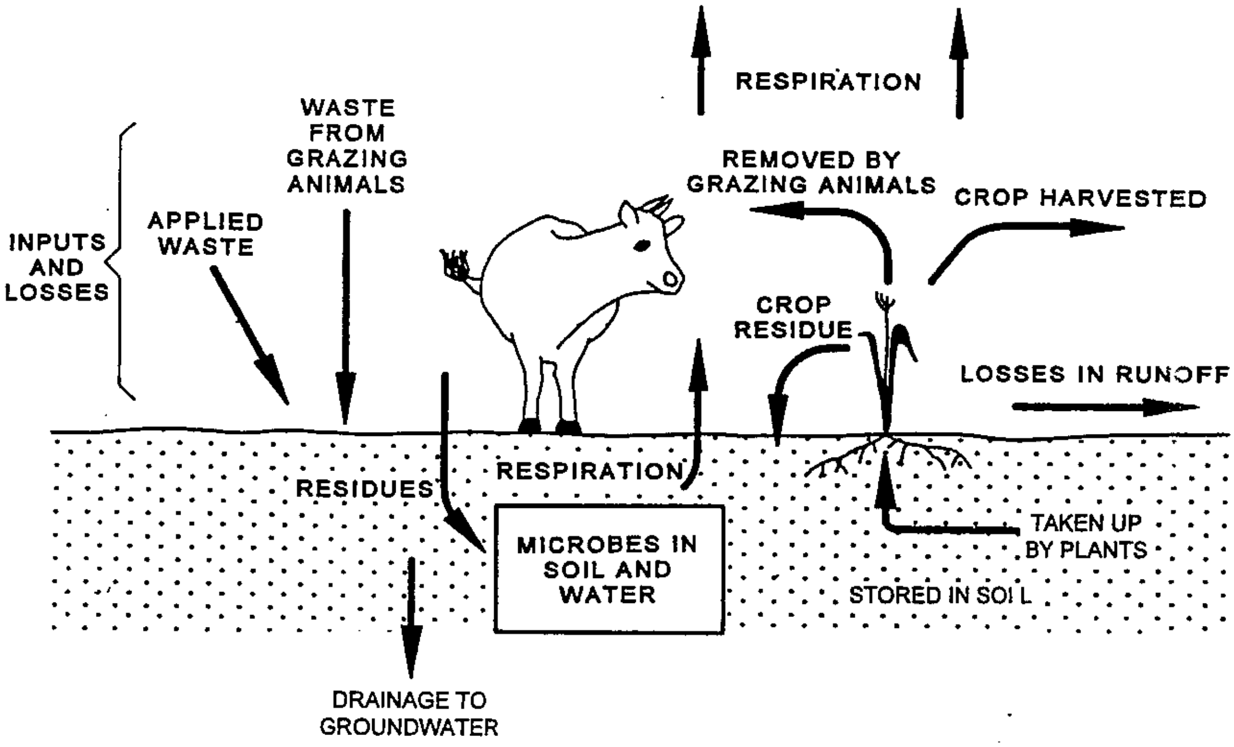


Figure A-4.1 ***Plant nutrients and other chemicals are added by effluent and animal wastes and removed by harvesting, grazing, runoff or drainage. Some can be temporarily stored in the soil.***

DON'T PUT IN MORE THAN IS TAKEN OUT

FORM A-4.1 NUTRIENT AND CHEMICAL MANAGEMENT (1) - NITROGEN

No	ISSUE AND SCORING	WORKING	EXAMPLE	YOUR SCORE
1.0	**Nitrogen (N)**			
1.1	What is the average total nitrogen content of the effluent irrigated onto the land expressed in mg/L or ppm? *(Actual measurements preferable. Otherwise use Table A-4.1)*	______	200	
1.2	How many days per year does the abattoir operate?	______	250	
1.3	What is the average daily output of effluent (in kL/day)? *(Use Table A-4.2 to convert imperial units to kL/day)*	______	500	
1.4	Calculate the total yearly output of nitrogen (kg) = (Q 1.1 x Q 1.2 x Q 1.3) / 1,000[1]	(____x____x_____)/1000 = ______	(200 x 250 x 500)/1,000 = 25,000	
1.5	What is the total area irrigated in one year (ha)?	______	50	
1.6	Calculate the average nitrogen loading (kg/ha/year) = (Q 1.4 / Q 1.5)	_____ / _____ = ______	25,000 / 50 = 500	
1.7	Calculate your score: 1) Effluent only receives **primary** treatment, irrigation area is **grazed** and: • Q 1.6 is less than 400 Score = 25 • Q 1.6 = 400 to 600 Score = 10 • Q 1.6 is more than 600 Score = 0 2) Effluent only receives **primary** treatment, irrigation area is **cropped** and: • Q 1.6 is less than 700 Score = 25 • Q 1.6 = 700 to 1,000 Score = 10 • Q 1.6 is more than 1,000 Score = 0 3) Effluent receives **secondary** treatment, irrigation area is **grazed** and: • Q 1.6 is less than 200 Score = 25 • Q 1.6 = 200 to 300 Score = 10 • Q 1.6 is more than 300 Score = 0 4) If your effluent receives **secondary** treatment, the irrigation area is **cropped** and: • Q 1.6 is less than 350 Score = 25 • Q 1.6 = 350 to 500 Score = 10 • Q 1.6 is more than 500 Score = 0 **Note: Take land as grazed unless crop is harvested and removed from the land.**		Primary treated effluent on grazed land 500 kg/ha Score = 10	______

[1] "Q" refers to question number in left hand column
See Section A-4.2 for more details and worked example

FORM A-4.2 NUTRIENT AND CHEMICAL MANAGEMENT (2) - PHOSPHORUS

No	ISSUE AND SCORING	WORKING	EXAMPLE	YOUR SCORE
	Carried forward from Form A-4.1		Score = 10	____
2.0	**Phosphorus (P)**			
2.1	What is the average total phosphorus content of the effluent irrigated onto the land expressed in mg/L or ppm? *(Actual measurements preferable. Otherwise use Table A-4.1)*	____	30	
2.2	How many days per year does the abattoir operate? Same as Q 1.2	____	250	
2.3	What is the average daily output of effluent (in kL/day)? Same as Q 1.3	____	500	
2.4	Calculate the total yearly output of phosphorus (kg) = (Q 2.1 x Q 2.2 x Q 2.3) / 1,000	(____x____x____)/1000 = ____	(30 x 250 x 500)/1,000 = 3,750	
2.5	What is the total area irrigated in one year (ha)? - Same as Q 1.5	____	50	
2.6	Calculate the average phosphorus loading (kg/ha/year) = (Q 2.4 / Q 2.5)	____ / ____ = ____	3,750/25= 75	
2.7	Calculate your score: 1) Irrigation area is grazed and: • Q 2.6 is less than 100 Score = 10 • Q 2.6 = 100 to 200 Score = 5 • Q 2.6 is more than 200 Score = 0 2) Irrigation area is cropped and: • Q 2.6 is less than 150 Score = 10 • Q 2.6 = 150 to 250 Score = 5 • Q 2.6 is more than 250 Score = 0 **Note: Take land as grazed unless crop is harvested and removed from the land**		Grazed land, 75 kg/ha **Score = 10**	____
	TOTAL FORMS A-4.1 AND A-4.2		10 + 10 = 20	____

[1] *"Q" refers to question number in left hand column*
See Section A-4.2 for more details and worked example.

FORM A-4.3 NUTRIENT AND CHEMICAL MANAGEMENT (3) - BOD AND SALT

No	ISSUE AND SCORING	WORKING	EXAMPLE	YOUR SCORE
	Carried forward from Form A-4.2		Score = 20	____
3.0	**BOD**			
3.1	What is the average BOD content of the effluent irrigated onto the land expressed in mg/L? *(Actual measurements preferable. Otherwise use Table A-4.1)*	____	1,000 Units	
3.2	How many days per year does the abattoir operate? - Same as Q 1.2	____	250	
3.3	What is the average daily output of effluent (in kL/day)? - Same as Q 1.3 *(Use Table A-4.2 to convert imperial units to kL/day)*	____	500	
3.4	Calculate the yearly output of BOD (kg) = (Q 3.1 x Q 3.2 x Q 3.3) / 1,000	(____x____x____)/1000 = ____	(1,000 x 250 x 500)/1,000 = 125,000	
3.5	What is the total area irrigated in one year (ha)? - Same as Q 1.5	____	50	
3.6	Calculate the average BOD loading (kg/ha/year)=(Q 3.4/Q 3.5)	____ x ____ = ____	125,000/50 = 2,500	
3.7	Calculate your score: • Q 3.6 is less than 10,000 Score = 5 • Q 3.6 = 10,000 to 15,000 Score = 3 • Q 3.6 is more than 15,000 Score = 0		< 10,000 Score = 5	____
4.0	**Salt**			
4.1	Does your plant cure or salt hides, skins or casings? • Yes Score = 0 • No Score = 5		No Score = 5	____
4.2	If answer to Q 4.1 was *"Yes" and* gypsum (or similar) is used to boost calcium concentrations: Score = 2		Score = 0	____
	TOTAL FOR FORM A-4 (A-4.1 + A-4.2 + A-4.3)		20+5+5 = 30	____

[1] "Q" refers to question number in left hand column
See Section A-4.2 for more details and worked example.

Table A-4.1 *Typical abattoir effluent quality after different levels of treatment*

	Treatment	Total N[1] (mg/L)	Total P (mg/L)	BOD (mg/L)	Oil & Grease (mg/L)
Primary Treatment					
1.	***Fine screening (1 mm)***, with a well designed and operated saveall;	200	30	1500	300-750
2.	***Screening coarser than 5 mm***, over-loaded and poorly operated saveall;	250	40	3000	800-1500
3.	***Well designed and operated DAF*** (dissolved air flotation) unit.	200	30	1500	50-150
Secondary Treatment					
1.	***Anaerobic lagoons/ponds*** which receive effluent from:				
	(a) good primary treatment, 1 or 3;	180	30	250	10-150
	(b) poor primary treatment, 2;	200	40	350	10-1500
2.	***Aerobic/facultative (oxidation) pond*** following anaerobic lagoon(s), (with or without subsequent maturation ponds):				
	(a) well designed and operated pond(s) receiving good anaerobic effluent;	130	30	50	5-20
	(b) poorly designed and operated pond(s) receiving poor anaerobic effluent;	170	40	100	5-150
3.	***Aerated pond*** (with mechanical aerator(s)) following anaerobic lagoon(s), (with or without subsequent maturation ponds):				
	(a) well designed and operated pond(s) receiving good anaerobic effluent;	130	30	50	5-20
	(b) poorly designed and operated pond(s) receiving poor anaerobic effluent.	150	40	100	5-150

1 *If low temperature rendering unit is operated or abattoir has associated tannery or fellmongery, total N values shown in Table A-4.1 should be doubled.*

Table A-4.2 ***Common units and conversions***

To Obtain	From	Multiply by:
Volume		
Cubic metre (m^3)	Kilolitre (kL)	1
Litres (L)	Cubic metres (m^3)	1,000
Litres (L)	Gallons (imperial) (gal)	4.54
Flow		
Litres per second (L/s)	Gallons per minute (gpm)	0.076
Litres per second (L/s)	Gallons per hour (gph)	0.00127
Kilolitres per hour (kL/h)	Litres per second	3.6
Kilolitres per hour (kL/h)	Gallons per hour (gph)	0.00454
Litres per hour (L/h)	Gallons per minute (gpm)	272.4
Gallons per minute (gpm)	Kilolitres per hour (kL/h)	3.671
Area		
Hectares (ha)	Acres	0.405
Square metres (m^2)	Square yards	0.8361
Hectares (ha)	Square metres (m^2)	0.0001
Concentration		
Milligrams per litre (mg/L)	Parts per million (ppm)	1
Grams per cubic metre (g/m^3)	Milligrams per litre (mg/L)	1
Kilograms per megalitre (kg/ML)	Milligrams per litre (mg/L)	1
Other		
Depth of water (mm)	Megalitres of water per hectare (ML/ha)	100
Depth of water (mm)	Kilolitres of water per hectare (kL/ha)	0.1

A-4.1 Hydraulic Loading

Before you can calculate the nutrient and chemical loading, the total amount (volume) of effluent which is used for irrigation in one year needs to be calculated.

If you measure daily flow volume or instantaneous flow rate anywhere within the wastewater treatment plant, use those to calculate the annual volume of effluent.

If effluent flow is not measured or recorded, use the volume of water consumed by the abattoir over a typical year. If the water supply is metered use this data. If water is pumped from a well, the flow can be calculated by knowing the pump curve and the level over which the pump is raising the water. The assistance of the pump supplier may need to be sought.

> ***Example:***
>
> The flow of water is recorded entering the treatment plant only while the plant is operating. By looking at the records, a typical value of 80 gpm has been estimated. In a typical year the abattoir operates for 2,000 hours (200 days x 10 hours/day).
>
> 1. Convert units to m^3/h (which is the same as kL/h):
>
> $80 \text{ gpm} = 80/3.67 \text{ m}^3/\text{h} = 21.8 \text{ m}^3/\text{h}$
>
> 2. Calculate total volume per year:
>
> $\text{Volume/year} = 21.8 \text{ m}^3/\text{h} \times 2{,}000 \text{ h/year} = 43{,}600 \text{ m}^3/\text{year}$

In the event that no data is available for either effluent volumes or water supplied, then a very rough estimate can be made by using the following:

- *Modern efficient abattoir with minimum wastage of water - 4 m^3 per tonne live weight killed (LWK).*
- *Older plant with moderate amount of water wastage - 8 m^3 per tonne LWK.*
- *Very old plant with inefficient use of water - 20 m^3 per tonne LWK.*

A-4.2 Effluent Loading

All plants require a variety of nutrients for growth, the main ones being nitrogen (N), phosphorus (P) and potassium (K). Of these N and P are important constituents of abattoir effluent. There are three main ways in which these nutrients can be "captured" or "transformed" so that they cease to be a pollution threat:

- Taken up by plants,
- Transformed by chemical or microbiological processes in the soil,
- Adsorbed onto the soil particles.

Plant nutrients and chemicals obey the principle of conservation of mass:

Inputs = Outputs ± Storage

Apart from their use by plants, N and P behave quite differently within the soil. These differences need to be understood in order to be able to manage effluent irrigation correctly. If more nitrogen and/or phosphorus is applied than the crops or pasture can take up from the soil, then they may be washed off the surface or leached into the groundwater.

Biochemical Oxygen Demand (BOD) is a measure of how much oxygen is required by micro-organisms to break down the effluent. Most soils have the ability to absorb a high BOD effluent, but high application rates may cause anaerobic conditions which generate offensive odours and may create public health problems in spray irrigation systems. However, the anaerobic conditions can help to denitrify nitrate in the effluent and thereby lose return nitrogen to the atmosphere.

Soils which receive a lot of sodium salts can easily become waterlogged and collapse into a structureless mass. The soil is then said to be sodic. The risk of this occurring is much greater when an abattoir salts skins or casings. The addition of calcium (from, for example, gypsum) to the effluent improves most soils and reduces the risk of sodic conditions occurring.

A-4.3 Nitrogen

Nitrogen contained in effluent is subject to complex chemical and microbial activity in the soil which can transform it into plant available nitrogen, ammonia or nitrite. All forms of nitrogen remain capable of being transported in the flow of water through the soil. The main pollution threat occurs when high soil moisture levels are maintained and nitrogen compounds can be conveyed by water which percolates to the groundwater. Nitrogen may also be washed from the surface of the soil into the local creeks but this is not likely to be a problem if the irrigation is managed to prevent ponding on the surface and appropriate runoff capture facilities are in place (See Chapter A-8).

Although nitrogen can be transported in water, it can also be stored within the soil profile for several months. Therefore, it is not essential that all the nitrogen is used immediately by plants. In many agricultural crops it is common practice to fertilise the land just prior to planting with enough fertiliser to meet the needs of the crop over the growing season.

Example - calculation of nitrogen load

Final effluent samples taken at monthly intervals and analysed for total nitrogen gave the following results (concentrations in mg/L):

Jan	180	Jul	200
Feb	220	Aug	180
Mar	210	Sep	170
Apr	190	Oct	190
May	230	Nov	210
Jun	220	Dec	200

Average concentration = 200 mg/L (g/m^3)
Total volume of effluent = 12,500 m^3/year
Total amount of nitrogen = 200 g/m^{3}x12,500 m^3/year
= 2,500,000 g/year
= 2,500 kg/year

If analyses have not been carried out you will need to estimate the amounts. Data in Table A-4.1 is based on typical values from the meat processing industry, but it is important to appreciate that there is considerable variability depending upon waste management practices within the abattoir, and the effectiveness of the effluent treatment system. Choose the process listed in Table A-4.1 which best matches the final treatment process at your abattoir.

Some approximate values of the nitrogen required to grow typical crops are set out in the example below. In the second column the nitrogen required by the crop is expressed as kg/ha for the nominated yield (after making an allowance for loss of nitrogen during irrigation and within the soil). The third column shows the amount of effluent expressed as the depth of irrigation needed to supply the nitrogen requirements of the crop and the losses. (For this example the effluent is assumed to contain 200 mg/L of N). The final column shows how much plant available nitrogen would be applied with a total irrigation of 300 mm of water over the period of crop growth.

Example: Representative nitrogen requirements for selected crops			
Crop	Nitrogen Required (kg/ha)	Effluent Irrigation Required (mm)	Nitrogen (kg/ha) in 300 mm Irrigation
Wheat (2.7 t/ha of grain)	120	60	600
Lucerne (15 t/ha)	360	180	600
Pasture (7.5 t/ha)	300	150	600

The example shows that the nitrogen requirements of typical crops can be met by the application of 60 - 180 mm of water. This depth of water is much less than the irrigation demand (evapotranspiration - rainfall) in many locations in Australia where abattoirs are located. Typically, a crop may be expected to require a total of 700 - 900 mm of water to reach full potential. If 400 mm is supplied from rainfall, there is still a need for an additional 300 - 500 mm of water from irrigation to meet its full growth potential. If 300 mm of irrigation was to be applied for the examples above, then the nitrogen applied would be 2 - 5 times that required for crop growth and there would be a high risk of polluting the local creek or groundwater.

Unless the total nitrogen concentration in the final effluent can be reduced to about 50 mg/L by the treatment system, it is likely that insufficient irrigation water can be supplied to get full production of most crops without overloading the crop with nitrogen. This problem can be solved in two basic ways:

1. ***Add additional fresh water to meet the full evapotranspiration and nitrogen requirements for full production***
2. ***Use "deficit" irrigation management to maximise production (and nitrogen use) with the limited available water.***

Lucerne is usually considered a good crop for irrigation with effluent because of its deep roots, high yield and high water use. However, together with all other legumes (peas and beans) lucerne can manufacture some of the nitrogen compounds it needs for growth. While lucerne is a good crop for irrigating with low strength effluent (such as secondary treated municipal effluent), it is not an ideal plant for soaking up nitrogen rich effluent.

For most Australian abattoirs, the irrigation area required to take up the nitrogen in the effluent will be much larger than the area required to take up the irrigation water.

Because animals will return nitrogen to the land in dung and urine, about twice the area is needed to remove a given quantity of nitrogen with a grazing system compared to a cropping system.

To get most effective removal of nitrogen, the crop or pasture grown with effluent irrigation should be harvested and removed from the area.

Nitrogen can be safely managed by:

- ***Knowing how much is added and removed each year.***
- ***Ensuring that the nitrogen removed by the crops grown over a year is equal to the nitrogen added in effluent.***
- ***Avoiding saturated soil conditions which might cause the movement of nitrogen.***
- ***Monitoring residual nitrogen (in various forms)***

A-4.4 Phosphorus

Phosphorus is strongly adsorbed onto clay particles and this tends to prevent the further movement of phosphorus in any surface or groundwater drainage. In general, Australian soils have a very low level of phosphorus and have a large capacity to absorb it (of the order of 1 - 5 t/ha). While phosphorus is strongly bound to clay particles, it is not completely immobilised and the capacity of the soil to absorb phosphorus can eventually be exceeded.

The common way in which phosphorus is removed from the land is by being transported on soil particles which are eroded from the land surface. The release of phosphorus from the sediments in rivers and lakes is the prime cause of algal blooms which have become such a threat to Australian waterways in recent years.

Because of the high capacity of Australian soils to absorb phosphorus, most authorities permit some storage of phosphorus in the soil but phosphorus levels would need to be monitored regularly (every 1 - 3 years). The storage of phosphorus in the soil cannot go on indefinitely and the time will eventually come when a new irrigation area will be required.

Some examples of the phosphorus required to grow typical crops are set out in the example below. The third column shows the amount of effluent expressed as the depth of irrigation needed to supply the phosphorus requirements of the crop. (For this example the effluent is assumed to contain 30 mg/L of P). The final column shows how much phosphorus would be applied with a total irrigation of 300 mm of water over the period of crop growth.

Example: Representative phosphorus requirements for typical crops

Crop	Phosphorus Required (kg/ha)	Effluent Irrigation Required (mm)	Phosphorus (kg/ha) in 300 mm Irrigation
Wheat (2.7 t/ha grain)	19	63	90
Lucerne (15 t/ha)	36	120	90
Pasture (7.5 t/ha)	24	80	90

The example shows that to achieve a full phosphorus balance from one year to another, then the depth of effluent which can be applied is limited. However, even on a sandy soil without much clay, 300 mm/year of effluent (with 30 mg/L of P) could be applied for about 15 years before the top 1 m of soil would be saturated with phosphorus. With a clay soil it might take 75 years for this to occur.

It is highly desirable to have a system in which the amount of phosphorus added by the effluent is balanced by that removed in the crop.

If this balance cannot be achieved, then the irrigation area will have a limited useful life for irrigation with effluent.

Management of phosphorus involves:

- ***Knowing how much is added and removed each year***
- ***Controlling accumulation of phosphorus in the soil***
  (Excess phosphorus can be absorbed by the soil for a number years - depends on soil type).
- ***Monitoring the phosphorus content of the soil at least every three years, preferably annually.***
- ***Control of soil erosion from the irrigation area to prevent attached phosphorus polluting local water bodies.***

A-4.5 Salt

No discussion of irrigation management would be complete without some mention of the question of managing salt. The problem with salt (primarily common salt - sodium chloride) is that it is ubiquitous in the Australian environment and in some locations is a serious threat to sustainable land management. Salt tends to accumulate in irrigation soils simply because the irrigation water is lost by transpiration while the salt is left behind. Thus, salt brought onto the land by irrigation water tends to accumulate in the root zone. Unfortunately, unlike potassium, sodium is not used by plants, and can significantly reduce plant growth. Fortunately, most abattoirs do not contribute large amounts of salt to the effluent. The main danger comes from salt which is already in the water supplied to the abattoir. The exception to this will be abattoirs which use salt for treatment of hides on the premises.

Because there is not a significant take-up of salt by plants, the only way in which accumulation in the soil can be remedied is by washing the salts downwards through the soil profile. This practice of "leaching" salt from the soil profile is common in irrigation areas but is best achieved with the assistance of some form of sub-surface drainage to remove the leached salty water for discharge to some safe location. You will immediately recognise that the suggestion that water be deliberately allowed to drain through the soil is in conflict with the requirement to prevent pollution of groundwater. Leaching of salts from land which is irrigated with abattoir effluent should only be done under carefully controlled conditions. Details of how this may be achieved are explained in Section B-6.3.

CHAPTER A-5: IRRIGATION AREA AND WET WEATHER STORAGE

Previous sections of the manual have referred to the need to match the nutrient supply from effluent to the amount that can be taken up by the crop or transformed and stored in the soil. Similarly, the effluent irrigation system must be capable of achieving a balance between the water supply and the consumption by the crop. For most abattoirs in Australia, there will be no problem in achieving a water balance <u>over the whole year</u>. However, imbalance may occur during a year and needs to be considered on two different time scales:

- ***Season to season** - Because the difference between rainfall and evapotranspiration varies throughout the year, the irrigation system as a whole must be capable of accommodating this variation. In order to do this the system must have sufficient **capacity**, in terms of both irrigation area and effluent storage.*

- ***Day to day** - When you have just had heavy rain and the soil is saturated, trying to irrigate with effluent will only lead to runoff from the area or drainage to the groundwater. Irrigation must therefore be **scheduled** on a day to day basis.*

In this section we will examine the question of achieving an overall water balance for the whole system. Section A-6 will deal with the associated question of day to day management.

For most locations in Australia there will be some times in the year when irrigation is not possible because there is sufficient rainfall to meet the evapotranspiration demand of a crop and fill all available soil moisture storage. When this happens, the abattoir will need to temporarily store the effluent until the soil has dried out sufficiently to be able to absorb more water. The size of storage needed will depend upon:

- *Seasonal variation (ie the difference between rainfall and evapotranspiration in different seasons. Does the area have most rainfall in winter, when evapotranspiration is low, or does it have a tropical wet season when heavy rainfall exceeds evapotranspiration?)*

- *rainfall encountered in a particular year (ie how much different is the rainfall in a wet year compared to a dry year).*

- *area available for irrigation*

In most States the regulatory authorities now require any effluent disposal system to demonstrate that it can store sufficient effluent to be able to operate safely (ie without overflow) in a wetter than normal year. The size of the storage required is usually related to the strength of the treated effluent used for irrigation.

FORM A-5 IRRIGATION AREA AND WET WEATHER STORAGE

No	ISSUE AND SCORING	WORKING	EXAMPLE	YOUR SCORE
5.1	Where is the abattoir located?	______	Townsville	
5.2	What is the average annual pan evaporation (in mm)? *(from Figure A-5.1 or actual data if you have it)*	______	2,000 mm	
5.3	What is the median annual rainfall (mm)? *(from Figure A-5.2 or actual data if you have it)*	______	1,200 mm	
5.4	Deficit = evaporation - rainfall (mm) = Q 5.2 - Q 5.3 *(Note: if answer is less than 500 adopt 500 mm)*	____ - ____ = ____	2,000 - 1,200 = 800 mm	
5.5	Number of days per year of operation	______	235	
5.6	Average daily flow of effluent (kL)	______	1,250	
5.7	Total effluent flow per year (kL) = Q 5.5 x Q 5.6	____ x ____ = ____	1,250 x 235 = 293,750 kL	
5.8	Determine the "*Basic*"[1] irrigation area (ha) required for effluent disposal[2] = Q 5.7/(Q 5.4 x 10)	____ / (____ x 10) = ____	293,750/ (800 x 10) = 37 ha	
5.9	What area (ha) is used in one year for irrigation of effluent?	______	85 ha	
5.10	Ratio of actual area to "Basic" area = Q 5.9 / Q 5.8 Scoring: • Ratio less than 1.5 Score = 0 • Ratio 1.5 - 2.5 Score = 10 • Ratio greater than 2.5 Score = 15	____ / ____ = ____ ______	85 / 37 = 2.3 Score = 10	______
5.11	What is the total volume of wet weather storage[3] available (in kL)?	______	65,000 kL	
5.12	How many days storage of average flow does this represent? = Q 5.11 / Q 5.6	____ / ____ = ____	65,000/1250 = 52 days	
5.13	Look up Figure A-5.3 and find the nearest climate analysis site within the same climatic zone.	______	Townsville	
5.14	In Table A-5.1 read the required days[4] of storage at that location for the nearest multiple of the "basic" irrigation area (from Q 5.10): • Less than quoted range[5] Score = 0 • Within quoted range Score = 10 • Greater than range Score = 15	______ ______	For 2.3 times "basic" area, required days storage: 40 - 110 Score = 10	______
	TOTAL SCORE FOR FORM A-5		10 + 10 = 20	______

N.B. Important notes relating to this table are on the next page *"Q" refers to question no. in left column*

Notes for Form A-5:

1 "Basic" area is the theoretical irrigation area needed if the crop consumed water at a rate equal to the pan evaporation rate throughout the year, all rainfall could be used by the crop (there was no runoff or deep percolation) and the effluent could be applied at just the right time to meet the crop demand. The "basic" area is a simple yardstick which has been used to simplify and generalise the analysis from which the data in Table A-5.1 has been developed. The "basic" area defined here should not be used for any purpose other than in association with the calculations in Form A-5 and the data in Table A-5.1 to give an indication of the adequacy of the available irrigation area.

2 The factor of 10 used in this calculation is needed to obtain an answer in ha.

3 Only count the available storage capacity in your ponds which is not used for normal effluent treatment

4 Table A-5.1 contains **estimates** of the range of required storage size necessary to limit discharge to the wettest year in ten based on the historic rainfall record. The range quoted represents the differences which may occur because of variation in rainfall sequence in years which have a similar total rainfall. For the same total rainfall, a larger wet weather storage is likely to be needed if the rainfall occurs in the winter months, when evapotranspiration is low, than in the summer months.

5 The days of storage shown in Table A-5.1 are those needed to restrict discharge from the storage to the wettest year in ten. The NSW EPA Draft Guidelines, "The Utilisation of Treated Effluent by Irrigation" (1995) classifies wastes into "high", "intermediate" and "low" strength according to the average concentration of a number of constituents (N, P, BOD and total dissolved salts). The required storage (expressed in terms of the probability of occurrence of a wet year in which overflow can occur) are:

Strength	Total N (mg/L)	Total P (mg/L)	BOD (mg/L)	TDS (mg/L)	Storage Required for (wettest year in X)
Low	<50	<10	<40	<500	2
Intermediate	50-100	10-20	40-1500	500-1000	4
High	>100	>20	>1500	>1000	10

Unfortunately there is no simple relationship between the storage size required for different strength wastes. The ratio of the size of, say, the 1 in 10 year to 1 in 2 year storage is a function of the rainfall patterns at any particular locality.

Table A-5.1: ***Wet weather storage requirements (days) for various locations for the wettest year in ten.***

LOCATION	RAINFALL (mm/year)	MULTIPLES OF "BASIC" AREA				
		0.5	1.0	1.5	2.0	2.5
ADELAIDE (SA)	640	200 - 220	125 - 145	115 - 135	100 - 125	90 - 120
ALBURY (NSW)	1130	285 - 320	270 - 285	270 - 280	270 - 275	270 - 275
CARNARVON (WA)	350	155 - 165	90 - 105	55 - 75	40 - 65	30 - 50
DARWIN (NT)	2180	185 - 235	155 - 210	130 - 195	115 - 195	95 - 195
ECHUCA (VIC)	590	200 - 230	170 - 200	160 - 190	155 - 185	150 - 185
HOBART (TAS)	800	275 - 300	210 - 265	180 - 265	180 - 265	180 - 265
NOWRA (NSW)	1700	115 - 160	65 - 110	40 - 90	30 - 80	20 - 75
PERTH (WA)	940	140 - 160	130 - 145	115 - 135	110 - 130	110 - 130
SALE (VIC)	820	230 - 240	180 - 195	150 - 180	135 - 165	130 - 150
SCONE (NSW)	900	110 - 155	70 - 110	40 - 90	30 - 70	20 - 55
TOOWOOMBA (QLD)	770	190 - 200	90 - 135	35 - 110	20 - 90	15 - 80
TOWNSVILLE (QLD)	1680	80 - 185	60 - 150	45 - 125	40 - 110	40 - 110

NOTES: The data presented in this table is a simplified version of more detailed data in the "System Performance Diagrams" in Appendix C-2.

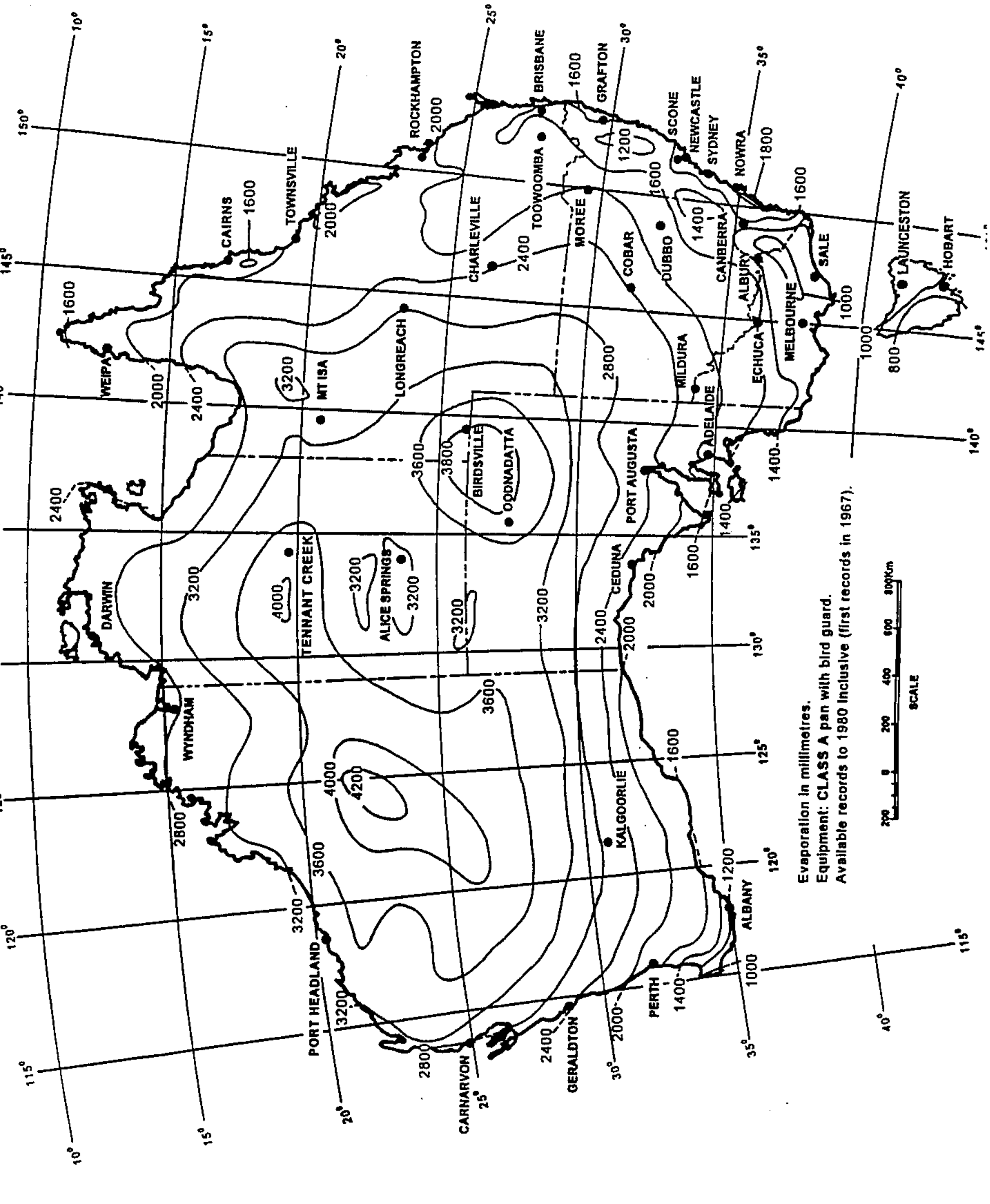
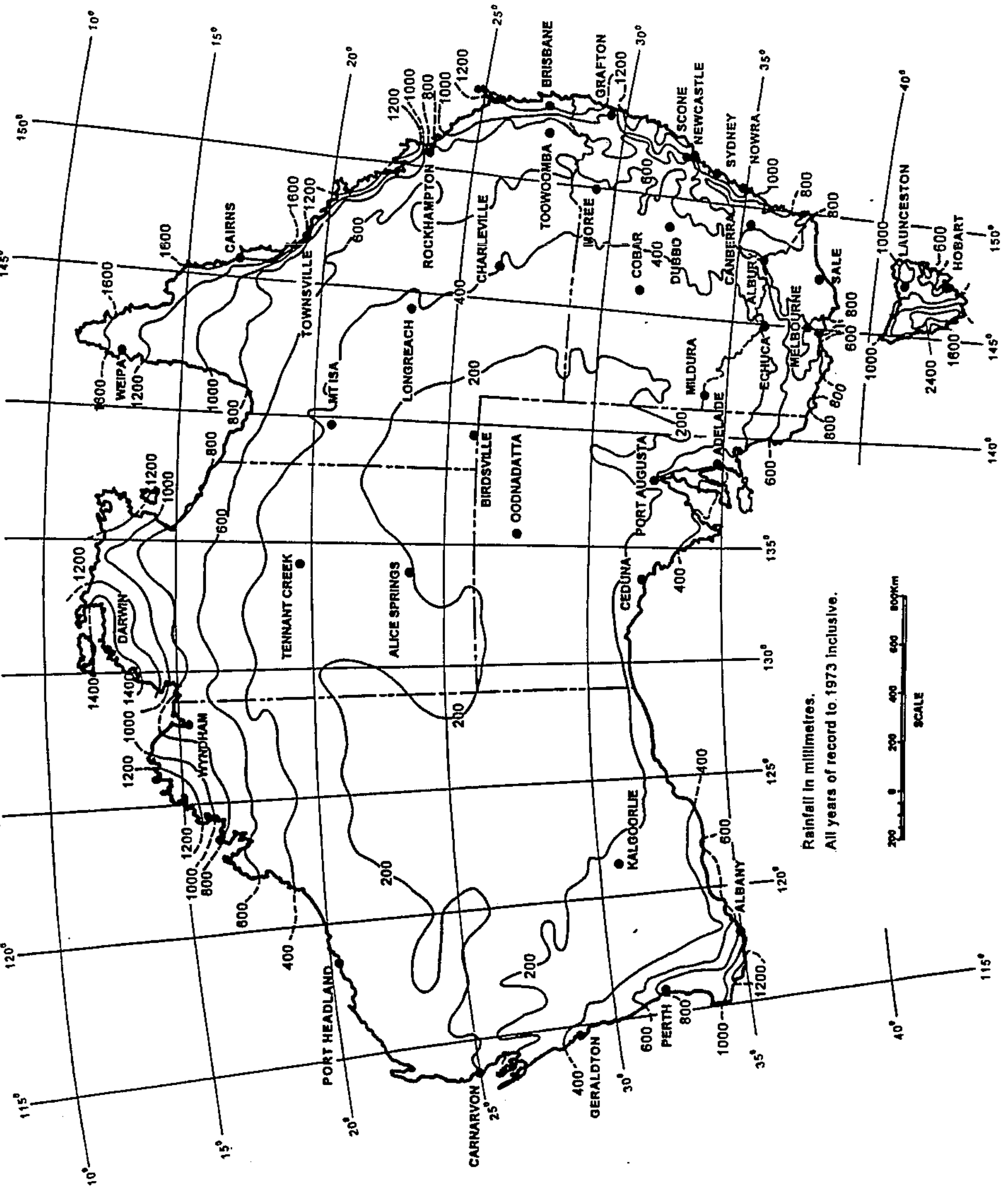


Figure A-5.1: ***Average Annual Pan Evaporation***



Rainfall in millimetres.
All years of record to 1973 inclusive.

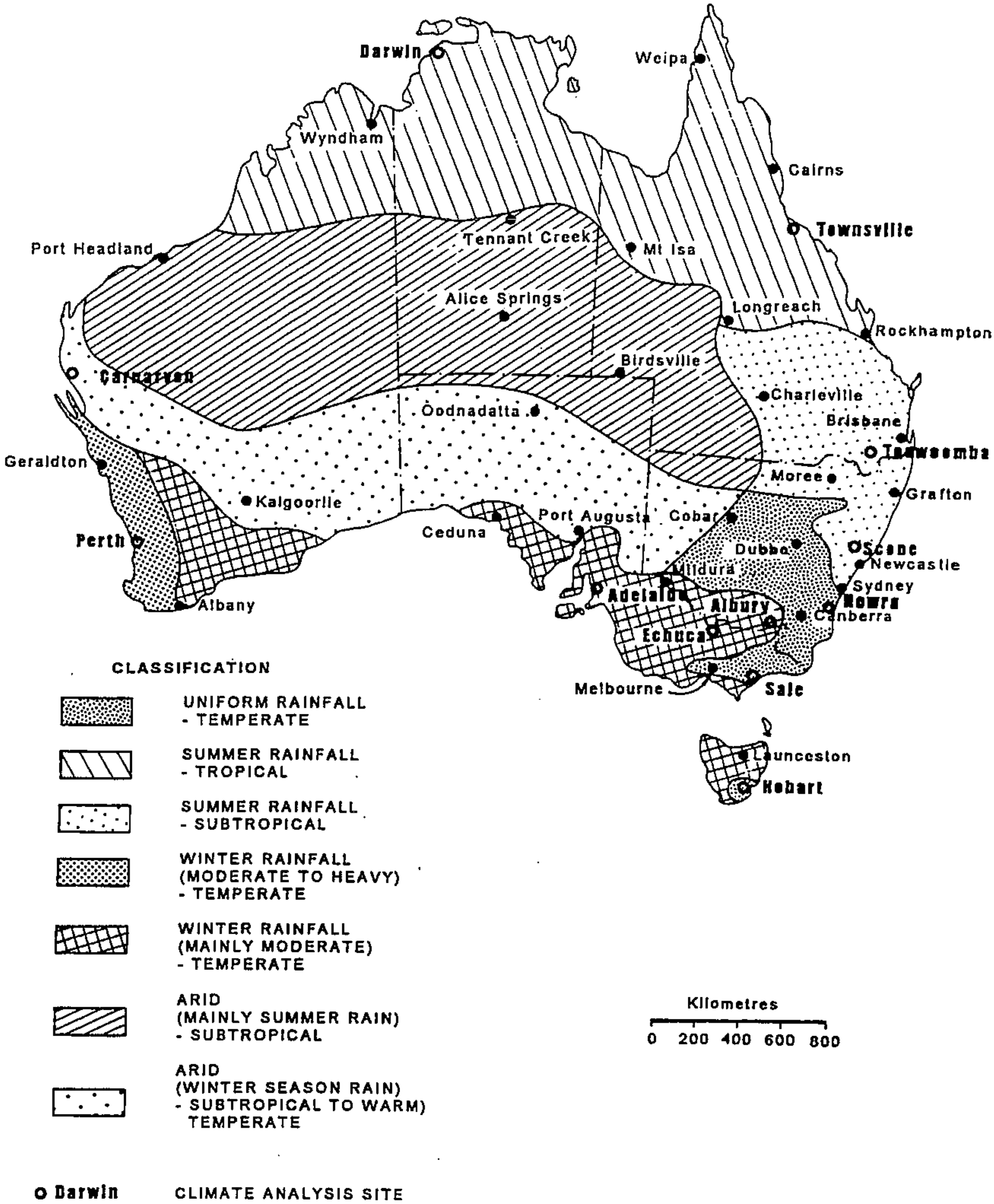


Figure A-5.3: ***Australian Climatic Zones and Climate Analysis Sites***

A-5.1 Water Balance

For all abattoir effluent irrigation systems, there must be a balance between inputs and outputs for each of the main components of the effluent:

- water
- plant nutrients (nitrogen and phosphorus)
- salt

The focus of this section is **water**, but as noted in Chapter A-4, inputs and outputs of plant nutrients (particularly nitrogen) must also be balanced and will usually govern how large the irrigation area must be.

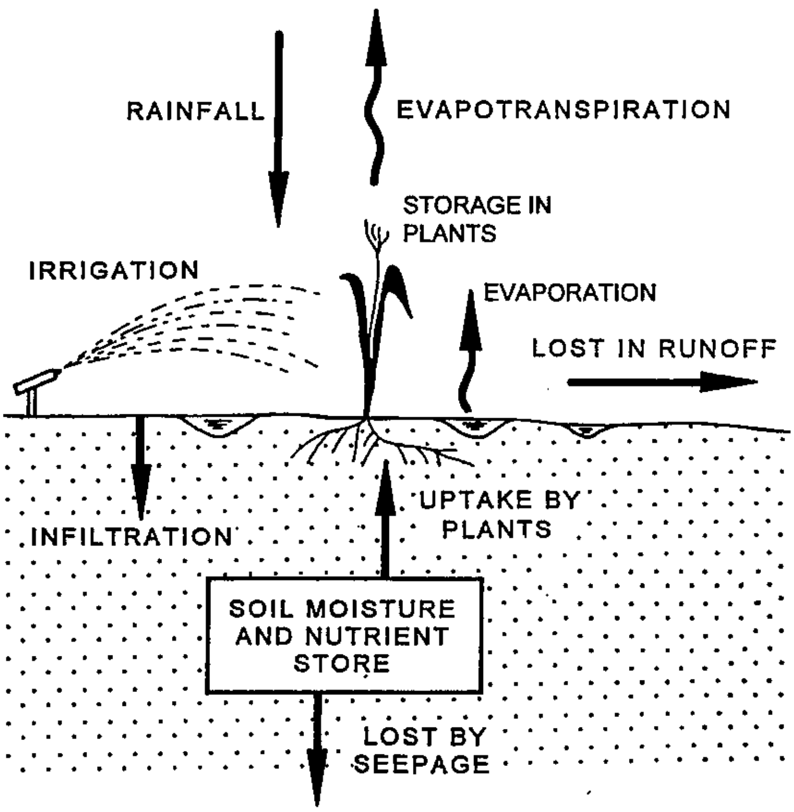


Figure A-5.4: ***Inputs and Losses from an Effluent Irrigation System***

Inputs	=	**Outputs**
• Irrigation		• Evapotranspiration by plants
• Rainfall		• Evaporation from ponds or bare soil
	+	**Losses**
		• Runoff to creeks
		• Seepage to groundwater

Note that in the water balance equation above, the **outputs** are controlled by the climate, the **losses** can be controlled, to a large degree, by managing the amount of effluent added.

In an ideal system, total effluent and rainfall added will equal losses from evaporation and evapotranspiration. In practice, this balance cannot be achieved every day and the overall balance must be **averaged** over time by making use of the storage capacity of the soil and a wet weather storage pond.

A-5.2 Soil Moisture Storage

The available soil moisture storage is governed by the:

- type of soil
- depth of soil which the plants can exploit

This topic is explored in more detail in Chapter A-6, but for now it is enough to know that the available moisture storage within the root zone of most plants is of the order of 100 - 300 mm depth of water. This is sufficient to hold enough water to sustain a plant for a few weeks, but must then be replenished with rainfall or irrigation before the plants wilt. On the other hand, continuous irrigation for a few days could fill the soil moisture storage to capacity and lead to ponding and runoff.

The soil moisture storage is invaluable as a balancing storage for day to day water management but is far too small to be significant for absorbing seasonal variations.

A-5.3 Achieving a Balance

In general, an irrigation system which is not allowed to discharge to the environment can only expect to be able to apply a depth of water equal to the difference between evaporation and rainfall over a full year. This is a function of the climate and, in theory, varies from over 3,000 mm per year in central Australia to almost zero in Tasmania. At most locations there will be some period in the year when the rainfall plus the effluent from the abattoir exceeds the volume which can be lost by evaporation from the irrigation area. The effluent will have to be stored during these periods and then used for irrigation during the drier months. The size of this wet weather storage will depend upon the length of time over which rainfall and effluent flow exceed the evaporation loss. This is largely a function of the climatic and seasonal characteristics of the locality.

A-5.4 Area and Storage Needs

In NSW, the EPA have prepared guidelines which recommend the wet weather storage capacity in terms of how often the system can be allowed to overflow. An outline of these requirements is set out in the notes attached to Form A-5 and these are explained in more detail in Section B-5.7. Similar requirements are likely to be developed in other States.

The complex interaction between the local climate and the operation of an irrigation system requires a day to day water balance analysis for any particular situation. A simplified analysis has been developed to produce the data contained in Table A-5.1 which allows any abattoir to rapidly determine whether it has a combination of adequate irrigation area and adequate wet weather storage.

If either of these are not adequate, **no amount of smart management** will enable the effluent disposal system to operate without severe risk of causing pollution.

It turns out that, for a given situation, there is a limited range of possible combinations of storage capacity and irrigation area which can be expected to perform in an acceptable manner. If the irrigation system were too small, then a huge pond would be required. On the other hand, no matter how large the irrigation area, there will always be a period of a few weeks when rainfall exceeds the evaporation rate and the available soil moisture storage capacity. Under these conditions irrigation cannot occur without the risk of polluting the surrounding environment.

- Any effluent disposal system must balance the inputs (rainfall and effluent) and outputs (evapotranspiration, nutrient uptake and controlled leaching).
- **If the inputs are greater than the outputs there will be discharge to creeks and/or groundwater with consequent serious risk of pollution.**
- The balance must be achieved on a day to day basis as well as over the whole year.
- To achieve the required balance the effluent disposal system must have adequate:
  - irrigation **area**
  - wet weather **storage**

FORM A-6 SOIL MOISTURE MANAGEMENT

ISSUE AND SCORING		EXAMPLE	YOUR SCORE
6.1	**How far from the irrigation area is the nearest rain gauge?** • less than 500 m Score = 4 • 500 m to 2 km Score = 2 • More than 2 km Score = 0	Gauge 1 km from area Score = 2	______
6.2	**How often is the rain gauge checked?** • Daily at a regular time Score = 3 • When it has rained Score = 1	When it rains Score = 1	______
6.3	**How often do you measure soil moisture in the irrigation area?** • Weekly Score = 15 • A few times per year Score = 5 • Never Score = 0	Never Score = 0	______
6.4	**Do you stop irrigating when it has rained significantly?** • Yes Score = 5 • Sometimes Score = 3 • No Score = 0	Sometimes Score = 3	______
6.5	**How do you measure/estimate effluent which has been irrigated?** • Measure at least weekly from an in line flow meter Score = 5 • Measure pump running time Score = 4 • Measure water level in the pond Score = 1 • Estimate from abattoir kill Score = 1 • Estimate from abattoir water use Score = 3	Estimate from water use Score = 3	______
6.6	**Do you keep a daily chart or table of rainfall and irrigation?** • Yes Score = 4 • No Score = 0	No Score = 0	______
6.7	**Do you check the uniformity of watering by measuring soil moisture at several places in the field or block, checking spray distribution with a row of buckets or checking advance and recession times for surface irrigation?** • Yes Score = 4 • No Score = 0	No Score = 0	______
	TOTAL SCORE FOR FORM A-6	2+1+3+3 = 9	______

CHAPTER A-6: SOIL MOISTURE MANAGEMENT

In Chapter A-5 of the manual we have referred to the need to maintain a balance of water and nutrients in:

- *The whole irrigation syste.n*
- *The soil*

In this section our focus is on the soil.

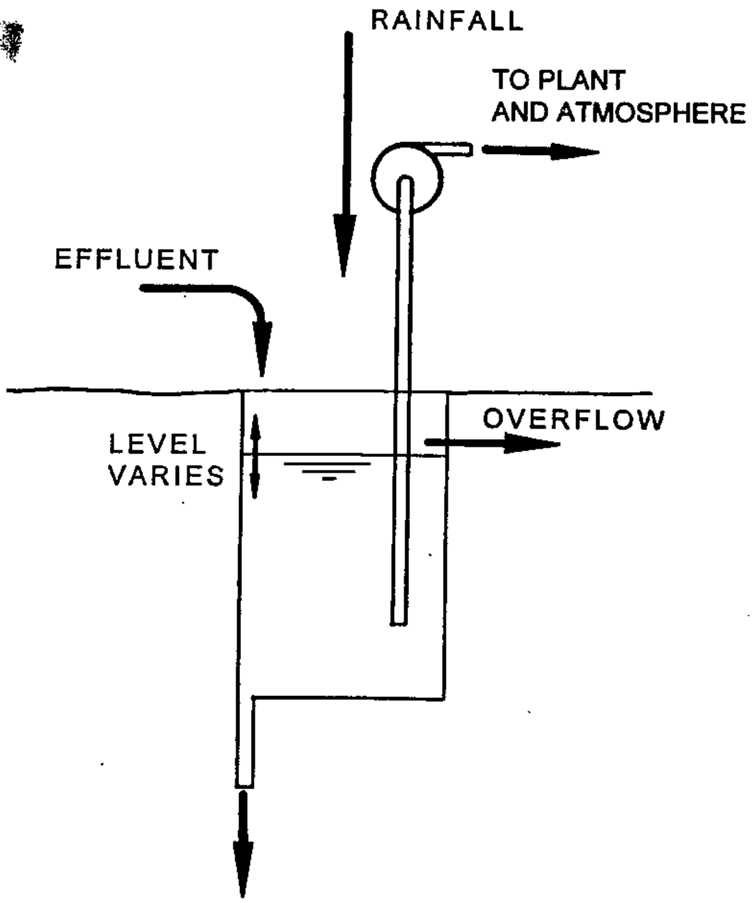


Figure A-6.1 ***The moisture stored within the soil is like a storage tank which must not be allowed to empty or overflow.***

A-6.1 Soil Moisture Storage

From the viewpoint of a growing crop, the soil not only provides a foundation which supports the plants but it also provides a reservoir from which the plant can take water and the nutrients it requires for its growth (mainly nitrogen, phosphorus and potassium). The total quantity of water and nutrients available to the plants will depend upon:

- ***The volume of the soil*** that a plant has access to. This is governed by the depth to which the plant roots penetrate and is a function of the type of plant being grown and its stage of growth. Table A-6.1 gives some typical maximum root depths for different plants.

Table A-6.1: ***Typical maximum root depths for plants useful for irrigation with effluent.***

PLANT	ROOT DEPTH (m)
Pasture Grass	0.6 - 1.2
Grain Crop	0.6 - 0.9
Maize	0.9 - 1.3
Lucerne	1.5 - 3.0
Trees	3.0 +

- ***The physical characteristics*** of the particular soil which are largely dependent on the soil texture. The texture of a soil influences two characteristics which govern how much water a plant can extract:

Field capacity - which is the maximum amount of water that a soil can hold once free drainage (due to gravity) has ceased.

Permanent wilting point - the moisture content of the soil where water is no longer available to the plant, causing it to permanently wilt.

The difference between the field capacity and permanent wilting point is referred to as the ***water holding capacity or available water*** of a soil.

All the terms relating to the moisture holding characteristics are usually expressed in terms of a depth of water (mm) per unit depth of soil (m). Some typical examples are given in the Table A-6.2 below.

Table A-6.2: ***Water holding capacity of some soils***

SOIL TYPE	FIELD CAPACITY (mm/m)	WILTING POINT (mm/m)	AVAILABLE WATER (mm/m)
Clay	330 - 500	170 - 250	160 - 250
Silty clay	250 - 330	130 - 180	130 - 160
Clay loam	250 - 330	120 - 170	130 - 160
Loam	250 - 300	100 - 150	130 - 160
Sandy loam	170 - 250	80 - 130	80 - 130
Sand	40 - 80	20	20 - 60

From the data in the Tables A-6.1 and A-6.2 it can be seen that, for example, the total water available to lucerne growing in a clay loam soil (3 m root depth x 160 mm/m = 480 mm) is significantly greater that the water available to a poorly developed grain crop growing on a sandy loam soil (0.5 m root depth x 80 mm/m = 40 mm).

A-6.2 Irrigation Scheduling

For good irrigation practice the moisture level in the soil should never be allowed to get down to the wilting point because the growth rate and vigour of the crop would have been affected long before that. A common "rule of thumb" is that the maximum moisture deficit in the soil should not be allowed to go below 50% of the plant available water.

A very useful way of envisaging what is happening to the soil moisture store is to draw a graph of soil moisture content against time. An example is shown in Figure A-6.2 below.

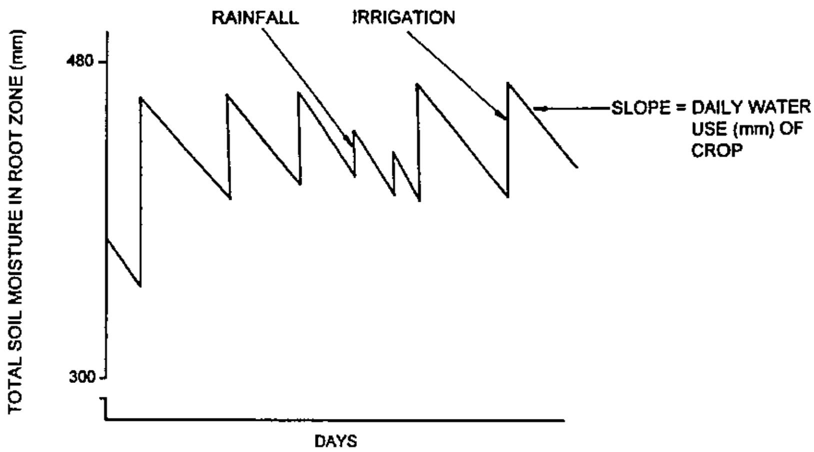


Figure A-6.2: ***Soil moisture history in an irrigated crop***

The basic "rule of thumb" for irrigated agriculture has been developed for circumstances in which the farmer wishes to make most effective use of his equipment and resources by irrigating as infrequently as possible without detracting from the production of the crop. In the case of effluent disposal, the priorities are usually different and more frequent smaller applications of irrigation water are used.

- The water requirement of a crop or pasture for evapotranspiration is met by removing moisture from the soil. This store is filled by both rainfall and irrigation. The amount of irrigation water which can be applied to the land on a given day will depend upon how much of the soil moisture store has already been supplied by rainfall. ***Only the difference between rainfall and evapotranspiration can be added as irrigation.***

- Because the soil moisture store is of limited capacity, it can easily be filled by rainfall alone. The application of irrigation effluent must therefore be ***scheduled on a day to day basis***. In order to do this you need to know:

  - The inputs (rainfall and effluent)
  - The outputs (evapotranspiration and runoff)
  - The soil moisture (by taking outputs from inputs - which should be checked regularly by measuring actual soil moisture)

- The general rules for irrigation with abattoir effluent are:

  - Do not irrigate any area more than one day in three.

  - Apply irrigation so that irrigation plus rainfall equals no more than 85% of the evapotranspiration.

There are a number of refinements to these rules which depend upon the nitrogen concentration in the effluent and the difference between rainfall and evapotranspiration for the locality. These refinements are explained in Chapter B-6.

CHAPTER A-7: GROUNDWATER POLLUTION

For a well designed effluent disposal system the water in the effluent disposed of onto land evaporates into the air, either directly from the ground, or by being taken up through the plant roots and transpired from their leaves.

Any excess water which cannot be used by the plants will eventually percolate to the groundwater. Whether water percolating to the groundwater is likely to cause a pollution problem will depend upon:

- *The amount of water percolating.*
- *The strength of the effluent being used for irrigation.*
- *How direct the connection is between the surface and the groundwater.*
- *The usefulness of the groundwater as a resource.*

The presence of groundwater below an effluent irrigation area needs to be carefully evaluated in terms of the risk associated with polluting of the groundwater. The score calculated in Form A-7 is a guide as to the importance and vulnerability of the groundwater beneath an effluent disposal area.

FORM A-7.1 GROUNDWATER POLLUTION (1)

No	ISSUE AND SCORING	WORKING	EXAMPLE	YOUR SCORE
7.1	**How important is the aquifer beneath your land disposal area?** (a) No aquifer known, or groundwater in negligible quantities, or aquifer grossly contaminated: Score = 4 (b) A minor aquifer which does not produce large quantities of water, but is important for local supplies and providing base flow to local rivers: Score = 3 (c) A major aquifer which is highly productive and used for a public water supply and/or other large users: Score = 0 (d) Don't know: Score = 0		No aquifer Score = 4	______
7.2	**What is the geology of the aquifer and its overlying strata?** (a) Fractured rock or low permeability clay/silt: Score = 3 (b) Moderately permeable alluvial material containing some silts and/or clays: Score = 2 (c) Highly permeable sand and gravel: Score = 0 (d) Don't know: Score = 0		Don't know Score = 0	______
7.3	**What is the depth to the water table below your land disposal area?** (a) Greater than 15 metres: Score = 3 (b) 5 to 15 metres: Score = 1 (c) Less than 5 metres : Score = 0 (d) Don't know: Score = 0		Greater than 15 m Score = 3	______
7.4	**How well are nutrients and water being managed?** Total scores from: End of Form A-4.3 + Form A-6: • > 60 Score = 4 • 40 - 60 Score = 2 • < 40 Score = 0		30 + 9 = 39 Score = 0	______
	TOTAL FOR FORM A-7.1		Total = 7	______

FORM A-7.2 GROUNDWATER POLLUTION (2)

No	ISSUE AND SCORING	WORKING	EXAMPLE	YOUR SCORE
	Carried forward from Form A-7.1		Score = 7	______
7.5	**Intensity of groundwater monitoring** (a) Number of groundwater monitoring wells (b) Total irrigation area (ha) (c) Wells per ha = (a)/(b) If wells/ha is: • >0.1 Score = 2 • 0.05 - 0.1 Score = 1 • <0.05 Score = 0	______ ______ ______ / ______ = ______	4 200 4/200 = 0.02 Score = 0	______
7.6	**How often is water taken from the wells for chemical analysis?** • 12 months or less Score = 2 • 12 to 24 months Score = 1 • more than 24 months Score = 0		12 months Score = 2	______
7.7	**Typical total nitrogen concentration in groundwater:** • < 5 mg/L Score = 2 • 5 - 10 mg/L Score = 1 • >10 mg/L Score = 0		< 10 mg/L Score = 2	______
	TOTAL FOR FORM A-7 (A-7.1 + A-7.2)		Total = 11	______

A-7.1 Depth to Watertable

The greater the depth to the watertable, the lower the risk of effluent polluting the groundwater. Shallow watertables are found in three common situations:

- River flat areas where a shallow aquifer is hydraulically linked to the river.
- Coastal sand plains where local wetlands and lagoons are connected to the groundwater.
- In the vicinity of major irrigation schemes particularly in the Murray Darling Basin.

The presence of a shallow watertable is, in itself, a threat to successful irrigation because once a watertable is less than about 2 m from the surface, it saturates the lower root zone and starts to adversely affect plant growth. In addition, deep drainage is inhibited and salt buildup can be expected to occur in the soil.

As a general rule:

- ***areas with watertables less than 2 m from the surface should be avoided because they will cause difficulty with the agricultural management of the area***
- ***areas with watertables less than 15 m from the surface should be assessed by experts to ensure that groundwater pollution is prevented.***

A-7.2 Groundwater Quality

The most important aspect of groundwater quality is its salinity. In many parts of Australia, the groundwater is naturally saline, even saltier than sea water in some places. The salinity of the groundwater is usually a good indication of whether the water can be used for domestic or agricultural purposes ant therefore its value as a resource.

In addition, highly saline shallow groundwater is likely to lead to a situation in which soil salinisation will occur and the productive capacity of the land will decline significantly unless the land is carefully managed.

Salinity of groundwater is usually measured by its electrical conductivity (EC), the unit being micro-siemens per centimetre (μS/cm) or deci-siemens per metre (dS/m).

(Note: 1 dS/m = 1,000 μS/cm) The units μS/cm are commonly abbreviated simply as EC units or even just EC. An approximate relationship exists between EC and the total dissolved salts (TDS):

$$\mathbf{EC\ (\mu S/cm) \cong TDS\ (mg/L) \times 1.56}$$

Table A-7.1 gives some values of the salinity of water suitable for different purposes.

Table A-7.1 ***Maximum Salinity for Selected Uses***

Use	Maximum Salinity (μS/cm)
Human consumption	1,000
Sheep	8,000
Cattle	6,000
Irrigation	5,000

The maximum values quoted in Table A-7.1 may be exceeded for short periods or may be used with fresher water to produce a "shandy" of suitable quality. It is unlikely that water which has salinity greater than about 10,000 μS/cm would be used for any significant productive purpose. The presence of groundwater of greater than 10,000 μS/cm is therefore an indication that contamination of the groundwater is unlikely to cause significant problems. That is not to say that an effluent irrigation system should deliberately allow uncontrolled deep seepage to occur because this will still carry the risk that the groundwater level would rise to cause future problems of productivity decline from waterlogging of the root zone and salinisation of the soil.

A-7.3 Monitoring

Any operation involving land disposal of effluent should include some kind of monitoring system to measure the effects on the groundwater. A well designed monitoring system will include a number of monitoring wells, and a regular sampling and analysis program. As a general rule:

- Groundwater levels and quality should be monitored at least every year.

- There should be a minimum of 1 monitoring bore per 100 ha. If the groundwater is shallow (< 5 m deep) and of low salinity (<2,000 μS/cm) up to 5 bores per 100 ha may be needed.

CHAPTER A-8: SURFACE RUNOFF

No matter how well an effluent irrigation area is managed, and even with no irrigation, there will always be some occasions on which rainfall will cause runoff to occur and therefore there is a risk of pollution of the nearby watercourse. The main factors which will increase the risk of pollution occurring are:

- *Maintaining very high moisture levels in the soil with frequent watering.*
- *Not having a formal drainage system to capture and store runoff.*
- *Allowing runoff from outside to flow onto the irrigation area*

FORM A-8.1 SURFACE RUNOFF (1)

No	ISSUE AND SCORING	WORKING	EXAMPLE	YOUR SCORE
8.1	How many days per year does irrigation take place?	________	150 days	
8.2	What area is irrigated each day? (ha)	________	5 ha	
8.3	Total effluent flow per year (kL) (from Q 5.7 in Form A-5)	________	293,750 kL	
8.4	Average daily irrigation depth (mm) = Ave daily volume /daily irrigated area = (Q 5.7 / Q 8.1)/(Q 8.2 x 10[1])	(______ / ______)/ (______ x10) = ______	(293750/150)/ (5 x 10) = 39	
8.5	Score for average daily irrigation: • If Q 8.4 > 40 Score = 0 • If Q 8.4 = 20 to 40 Score = 4 • If Q 8.4 < 20 Score = 7		Score = 4	
	TOTAL FOR FORM A-8.1		Score = 4	______

Notes: [1] Factor of 10 is necessary to get the units correct.
"Q" refers to question number in left hand column.

FORM A-8.2 SURFACE RUNOFF (2)

No	ISSUE AND SCORING	WORKING	EXAMPLE	YOUR SCORE
	Carried forward from Form A-8.1		Score = 4	____
8.6	Which of the following best describes the topography of the irrigation area? • < 1% slope and has been laser graded Score = 3 • Slopes 1% - 2% no depressions Score = 1 • Slopes 2% - 5% undulating Score = 0 • Slopes 5% - 10% rolling Score = 2 • Slopes >10% Score = 3	____	1% -2% Score = 1	____
8.7	What are the soils in the irrigation area? • Sands and Sandy loam Score = 0 • Clay loam and Loam Score = 1 • Silty clay and Clay Score = 2	____	Loam Score = 1	____
8.8	Does the irrigation area have drains to catch runoff? • Yes Score = 3 • No Score = 0	____	No Score = 0	____
8.9	Where does water which drains from the irrigation area go to? • Drain to a separate storage pond Score = 3 • Drain to a natural depression Score = 1 • Drain to a creek or gully Score = 0	____	Natural depression Score = 1	____
8.10	Is collected runoff pumped for irrigation re-use? • Yes Score = 2 • No Score = 0	____	No Score = 0	____
	TOTAL FOR FORM A-8		Score = 7	____

A-8.1 Stormwater Drainage and Storage

There will occasionally be times when a thunderstorm occurs soon after irrigation or the area is subject to continuous steady rain resulting in surface runoff. For abattoir effluent disposal systems, good management practice to minimise the impact of this runoff on the surrounding environment should include:

- A drainage system which allows excess rainfall to drain off the land within 24 hours. It is undesirable to allow excess water to lie on the ground for a long period because it causes waterlogging and promotes drainage of nitrogen and salts to the groundwater.

- A storage capable of holding the runoff from the area. There is no simple or general rule as to how large the storage should be and each abattoir should ***check with the local regulatory agency for their latest advice***.

The NSW EPA are moving to encourage all irrigators to provide storage facilities for 12 mm of runoff from land capable of being irrigated. The NSW EPA draft guidelines "*The Utilisation of Treated Effluent by Irrigation*" (1995) specify that the runoff terminal pond should be designed to collect the first flush runoff from a 24 hour storm which has a probability of occurrence of once in 20 years. The guidelines recognise, however, that where there is no nearby watercourse and the terrain is flat, runoff collection facilities may not be required.

The need for stormwater drainage and storage should not be viewed as yet another requirement which will cost money without any benefits. In Chapter A-4 it was noted that for many abattoirs the area required for effluent disposal will usually be limited by the nitrogen loading. Under these circumstances, when the crop has received enough effluent to supply its needs for nitrogen, it is unlikely to have received sufficient water for full growth. Runoff from the irrigation area can provide a useful supplementary source of water for the crop. The details of the procedures to assess just how much effluent and runoff can be used are dealt with in Chapter B-3.

A-8.2 Irrigation Management

The amount of runoff which occurs will be dependant on how much rainfall the soil can absorb. If the soil moisture content is maintained at very high levels with regular watering every few days, then more runoff can be expected to occur, which then has to be stored and pumped back onto the irrigation area. Close monitoring of soil moisture and control of irrigation can pay dividends in terms of:

- reducing the irrigation area required,
- reducing the amount of runoff storage needed.

CHAPTER A-9: EMERGENCY PREPAREDNESS

An estimated 80% of environmental "incidents" in which pollution is caused by industries are caused by some unforseen event or by someone's negligence. There is no reason to think that the meat industry is any different.

You might have the most sophisticated and well managed irrigation system imaginable, but if you are not prepared for an emergency, then you are still at risk.

What sort of emergencies can possibly arise with an effluent irrigation system?

- *Irrigation pump does not switch off when it should and too much effluent is discharged*
- *A pipeline breaks or hydrant blows off and water runs down to the creek*
- *The float level switch in the final pond is faulty and the pond overfills.*

FORM A-9 EMERGENCY PREPAREDNESS

No	QUESTION	EXAMPLE	YOUR SCORE
9.1	**How is the irrigation pump turned off?** • Automatic time clock Score = 2 • Manually Score = 1	Manually Score = 1	______
9.2	**Can the irrigation area be seen from the irrigation pump site?** • Yes Score = 2 • Partly Score = 1 • No Score = 0	Partly Score = 1	______
9.3	**How often does someone check the irrigation area?** • At least 4 times per day Score = 6 • Daily Score = 2 • Weekly Score = 0	Daily Score = 2	______
9.4	**If a spillage of effluent occurred, where would the effluent go to?** • Caught in pond within the irrigation area Score = 5 • Onto neighbours land Score = 2 • Into creek Score = 0 • Onto a public road Score = 0	Neighbours land Score = 2	______
9.5	**Does the irrigation system operate at night?** • No Score = 2 • Yes Score = 0	No Score = 2	______
9.6	**How many people know how to turn off the irrigation system?** • More than 3 Score = 2 • 2 or 3 Score = 1 • 1 Score = 0	2 People Score = 1	______
9.7	**Are emergency procedures written down?** • Yes Score = 2 • No Score = 0	Yes Score = 2	______
9.8	**Do plant security personnel (eg the gate attendant) have a copy of the emergency procedures and have they been instructed what to do?** • Yes Score = 2 • No Score = 0	No Score = 0	______
9.9	**Is a list of emergency contact names and phone numbers clearly displayed at:** *(Count half a point for each)* • Irrigation pump • Main office • Maintenance shed • Front gate	Main office and front gate Score = 1	______
	TOTAL SCORE FOR FORM A-9	Total = 12	______

A-9.1 Introduction

In any operation, no matter how well designed and operated, there will be occasions when something goes wrong. Irrigation systems are no exception. You need to be prepared for this to happen.

A-9.2 Monitoring and Checking

In most cases, unless active monitoring is being regularly carried out, you will not know there is a problem with the operation. Neighbours, the general public, and regulators should not be relied upon to monitor your operation. Unless the system is highly automated then a designated person needs to be responsible for checking the overall operation at least twice a day. Less frequent monitoring may be acceptable if the risks of failure are low and the consequences of failure have been allowed for by a good runoff capture system and adequate emergency storage.

A-9.3 Emergency Response and Remedial Action

All effluent disposal systems should be have an "Environmental Management System" which:

- Provides full operation details of the irrigation system including the location of the main valves and switches.
- Identifies abattoir staff responsible for various procedures and actions including staff available for emergency callout (eg plumber, electrician, fitter).
- A list of regulatory agencies which need to be informed in the event of a pollution incident.

A-9.4 Runoff and Storage

A runoff collection and storage system can be a valuable emergency collection system as well as collecting rainfall runoff (see Form A-8). If, for example, a travelling irrigator becomes stuck, a pipe break occurs, or some other failure happens in the system, then the effluent is likely to flow off the area. In the absence of a runoff collection system, there would be a serious threat of a pollution incident occurring.

SECTION B:

TECHNICAL MANUAL

CONTENTS

NOTE

This manual provides general guidelines for the ways in which abattoir effluent irrigation systems are planned, designed and managed. It attempts to identify those elements which constitute current "good management practice". Every abattoir will have its own particular set of circumstances. The guidelines in the manual must be interpreted and applied on the basis of the circumstances and needs of each individual abattoir.

There will always be exceptions to the general rule and individual abattoirs may find that experts may propose ways of operating an effluent irrigation system which do not conform strictly to the guidance presented in the manual. This is to be expected. The manual only seeks to provide guidance suitable for application by abattoir staff. Where outside professional help has been sought, more refined solutions may be available.

CHAPTER B-1: SITE CHARACTERISTICS

The effective management of an effluent irrigation system involves the combined management of:

- *the soil in which plants grow*
- *the plants growing in the soil*
- *the supply of water and nutrients to the soil*

You will notice that the soil is mentioned in all three dot points - so it is as good a place to start as any.

While this chapter will focus on the soil, we will first take a broader view and look at some of the other characteristics of the land which must be considered in the planning, design and management of the irrigation of abattoir effluent. The features of a site need to be considered in the basic planning and design of an effluent irrigation system. Some features of a site may render it completely unsuitable, while others may simply form constraints that require special care to be taken in the day to day management of irrigation systems.

This chapter provides an overview of the important characteristics of any site on which effluent is to be irrigated. It provides a basis for understanding some of the management aspects which are discussed in later chapters.

CONTENTS

B-1.1 Introduction

Before effluent can be applied to land for agricultural purposes, the suitability of the land to be irrigated must be assessed. We need to be sure that there will be minimal or no escape of effluent from the site and we need to assess the long term effects on the soil of the addition of nutrients and salt. In some situations the soil will be unable to accept the effluent and ponding will occur leading to runoff and potential contamination of the local watercourse. In addition the irrigated crop will become waterlogged and the anaerobic conditions will cause a reduction in plant growth and possible odour problems. Some soils drain so freely that the effluent will drain through the profile before plants can use it or the soil retain it. Soils may also be limited in the amount of nutrients that they can absorb or adsorb before they become overloaded. Salts in the effluent may accumulate in the soil, and risk leading to the eventual degradation of the soil.

To ensure that a site will be suitable for irrigation with abattoir effluent, a number of characteristics need to be considered:

- Climate
- Topography and slope of the land
- Underlying geology and groundwater
- Physical and chemical characteristics of the soils.

The question of the climatic characteristics of the area is a topic on its own and is dealt with in Chapter B-3. The topography, slope, geology and groundwater are characteristics inherent to the site which determine its suitability and may constrain how it is used. On the other hand, the way that the soil characteristics are managed and used are key factors in the success of any effluent irrigation system.

This chapter focuses on providing sufficient background to give an understanding of the ways in which the management of the soil must be integrated with management of the crops grown on the land and the supply of water and nutrients from the effluent.

B-1.2 Topography

The topography of the site will:

- Constrain the choice of method of irrigation suitable for the site.
- Dictate the location of supply points, drains and storage dams.
- Determine the susceptibility of the site to flooding or waterlogging.

You will need an accurate map of the site at a scale of 1:1,000 (at least) with contours at no more than 1 m intervals. If you are considering some form of surface irrigation method you will probably need contours at no more than 200 mm intervals.

B-1.2.1 Slope

It is not necessary to go into great detail at this point, but the data in Table B-1.1 can be used as a guide to the range of land slopes which can be used for different types of irrigation. (Other aspects of the suitability of different irrigation methods to different situations are presented in more detail in Chapter B-5).

Basically, spray and trickle systems can be made to work on a wide range of slopes. However, surface irrigation methods require very flat slopes in order to achieve the degree of control of water necessary to ensure that effluent does not contaminate the surrounding environment. Surface irrigation on steeper slopes demands a very high standard of water management which will require specialist advice and well trained staff.

Table B-1.1 ***Irrigation Methods for Use on Different Slopes***

Method	Slope (%)
Flood	0 - 0.1
Furrow	0.01 - 1.0
Spray	0.1 - 5.0
Trickle and Micro	0.1 - 10.0

In addition to the overall slope of the land, the topographic variation within the general slope is also important. Local ridges and furrows or hollows will provide points at which water can pond and cause difficulty in accurately controlling the application of effluent. The resulting lack of uniformity of watering can lead to excess water and nutrients at some locations with the consequent risk of harming the crop, degrading the soil or causing pollution from surface runoff or seepage to the groundwater. It is therefore desirable that any land used for effluent irrigation has a ***uniform*** slope.

B-1.2.2 Topographic Variation

Most regulatory authorities now require that effluent irrigation areas be protected against runoff from the area draining directly into a neighbouring watercourse. The usual requirement is that any runoff from the irrigated area (whether from rainfall or excess irrigation) be drained to a storage dam and be re-used for irrigation. The required size of the storage varies from State to State, but a ***minimum*** of 10 mm of runoff from the irrigation area can be taken as a guide. In order to minimise the cost of the drainage and storage system, it is desirable for the site to have sufficient topographic variation to allow the necessary drains and storage to be constructed with minimal volume of earthworks involved. A storage created by placing a dam across a gully will typically have a storage excavation ratio greater than 2. (ie the volume of water that can be stored is more than twice the volume of earth which must be excavated and placed to create the storage.). A storage which is created by digging a hole in the ground will have a storage excavation ratio less than 1 and will therefore be more expensive to construct.

B-1.2.3 Position on the Landscape

The location of an effluent irrigation area on the landscape can have an important bearing on how easy the area is to manage. The following factors should be considered:

☐ ***River flats*** - while the floodplain or "flats" adjacent to major rivers often contain the most fertile soils and are favoured for conventional irrigation, they can pose serious problems for effluent irrigation because:

- River flats tend to be flood prone and therefore special protective measures (eg a levee) may be necessary to protect the area in order to satisfy the pollution control authorities that the adjacent river is protected from pollution. Not only will this involve the expense of constructing a levee, but on many river systems State water authorities have placed controls on building of any levees which would decrease the natural flood storage volume on the floodplain and might redirect floodwaters onto neighbouring land.

- River flats are frequently underlain by a local groundwater system which is hydraulically linked to the river. These local aquifers often provide a source of water supply for farms and communities. Any proposed development of an effluent irrigation system on river flats will therefore have to demonstrate that the system can be managed in a way which will prevent pollution of the local groundwater. This is not easy to do.

☐ ***Steeper slopes*** - slopes greater than about 2% may require special erosion control practices if the area is to be cultivated rather than used for growing pasture for making hay.

☐ ***Mid-slope areas*** - in order to maintain full control of the water regime within an effluent irrigation area, it is desirable that runoff from up slope land into the irrigation area be prevented. Effluent irrigation areas should be selected so that this protection from up slope runoff can be achieved easily.

B-1.3 Geology and Groundwater

The underlying geology is of interest because it affects:

- The characteristics of the soil derived from the underlying rocks.
- The presence and depth of groundwater which might be polluted by seepage from the site;
- The presence of salt in the rocks or groundwater which might pose a threat to long term irrigation unless the irrigation is properly managed.

The question of the relationship between soils and the underlying rock is dealt with under Section B-1.4 below. The presence or absence of groundwater and the quality of the groundwater have an important bearing on what provision must be made for sub-surface drainage within the effluent irrigation area. The whole question of the management of sub-surface drainage is dealt with in detail in Chapter B-6.

B-1.3.1 Geology

It is obvious that the underlying geology of a site has an important bearing on the presence or absence of groundwater. In general, those sites which are underlain by alluvial (water borne) or aeolian (windblown) deposits are likely to be more porous and therefore store, and allow the movement of, groundwater. In addition, the groundwater in these areas is likely to be "unconfined" and water from the surface layers can drain direct to the water table. The depth to groundwater and the quality of the water need to be thoroughly assessed at such sites and is discussed in more detail below. In areas where the groundwater is "confined" by an impermeable or semipermeable barrier, there is poor hydraulic connection with the surface immediately above and any interaction with the irrigation area is unlikely to cause problems.

The other issue which should be considered is the presence of shale in the upper layers of the rocks. In many parts of Australia, these shale beds were laid down in a marine environment. They are often saline and the salts in them can cause land salinisation problems even in areas where there is no significant groundwater.

B-1.3.2 Groundwater

The presence of groundwater below an effluent irrigation needs to be carefully evaluated in terms of the risk associated with polluting of the groundwater. Several factors need to be considered:

- ***Depth to watertable***

The greater the depth to the watertable, the lower the risk of effluent polluting the groundwater. We have already noted (B-1.2.3 above) that river flat areas tend to have a local underlying aquifer which is hydraulically linked to the river. Typically such watertables are at depths of 4-10 m and are highly vulnerable to pollution from effluent.

Another common area where shallow groundwater occurs are on coastal sand plains. Typically the watertable below these areas is relatively shallow and there will be a series of local wetlands and lagoons which provide a "window" onto the groundwater.

A third area where shallow watertables are common is in some inland areas, particularly in the Murray Darling Basin where shallow watertables occur as a result of irrigated agriculture.

Shallow watertables are also found extensively in some areas of dryland agriculture. These shallow watertables show up as saline seeps or salt lakes. Although many of these are naturally occurring, their numbers and size have grown as a result of the clearing of native vegetation for cropping or pastures. The presence of deep rooted native vegetation allows deep subsoil moisture reserves to be exploited in drier times. Once this vegetation is replaced with shallow rooted crops or pasture, the amount of water seeping to the watertable has increased and groundwater levels will rise.

Shallow watertables may also be a threat to successful irrigation. As a general rule, once the watertable is less than about two metres from the surface, it will start to adversely affect plant growth because of saturation in the lower root zone. In addition, deep drainage is inhibited and salt buildup can be expected to occur in the soil.

As a general rule:

- o *areas with watertables less than 2 m from the surface should be avoided because they will cause difficulty with the agricultural management of the area*
- o *areas with watertables less than 20 m from the surface should be examined by a hydrogeologist to ensure that pollution of the groundwater can be prevented.*

☐ ***Groundwater Quality***

Groundwater quality is important fro two reasons:

- Good quality water suitable for use in irrigation or urban water supply will require a high level of protection from pollution.
- Saline groundwater, particularly if associated with a shallow watertable, can indicate that soil salinisation might be a problem.

In many parts of Australia, the groundwater is naturally saline, even saltier than sea water in some places. The salinity of the groundwater is usually a good indication of whether the water can be used for domestic or agricultural purposes.

Salinity of groundwater is usually measured in terms of its electrical conductivity (EC) which has units of micro siemens per centimetre (μS/cm) or deci-siemens per metre (dS/m). The units of μS/cm are commonly abbreviated simply as "EC units" or even just "EC". An approximate relationship exists between the total dissolved salts (TDS) and EC:

$$\textbf{TDS (mg/L)} \approx \textbf{EC } (\mu\textbf{S/cm}) \times \textbf{0.64}$$

or

$$\textbf{EC } (\mu\textbf{S/cm}) \approx \textbf{TDS (mg/L)} \times \textbf{1.56}$$

Note: 1 dS/m = 1,000 μS/cm

Table B-1.2 gives some approximate values of the salinity of water suitable for different purposes.

Table B-1.2 ***Maximum Salinity for Selected Uses***

Use	Maximum Salinity (μS/cm)
Human consumption	1,000
Sheep	8,000
Cattle	6,000
Irrigation	5,000

The maximum values quoted in Table B-1.2 may be exceeded for short periods or may be used with fresher water to produce a "shandy" of suitable quality. It is unlikely that water which has salinity greater than about 10,000 μS/cm would be used for any significant useful purpose. The presence of groundwater of greater than 10,000 μS/cm is therefore an indication that contamination of groundwater is not likely to be a major issue in terms of polluting a useable resource. That is not to say that an effluent irrigation system should deliberately allow uncontrolled deep seepage to occur because this will still carry the risk that the groundwater level would rise to cause future problems of productivity decline from waterlogging of the root zone and salinisation of the soil.

B-1.4 Introduction to Soils

A number of soil properties need to be investigated to assess the suitability of land for effluent irrigation schemes. The first stage of this is the soil survey which identifies the soils present and their distribution. This information is used to compile a soil map. Specific soil properties important in determining the suitability of land for effluent irrigation also need to be measured. The soil types, variability and limitations can be assessed and problem areas excluded or the irrigation design modified to suit the soil types present. For our purposes the main characteristics of interest are:

- physical
- hydraulic
- chemical
- biological.

Before we discuss each of these in detail, it is useful to digress a little to make some important points about soils which will aid our understanding of the important characteristics.

B-1.4.1 Soil Profile.

Soils are formed from rocks and sediments through the combined effects of climate, plants, animals, topography and time. Chemical, physical and biological processes act upon the parent material to produce a wide variety of soils. All soils are composed of a series of layers or "horizons" which go to make up the soil profile stretching from the surface to the underlying parent material. The character and arrangement of these layers provides the information which distinguishes one soil from another and is the basis of soil classification and mapping.

The features of the soil profile, particularly the depth and different characteristics of each horizon, gives a good guide to the properties of the soil and how it must be managed for effluent irrigation. The soil profile is generally composed of three major layers, designated A, B and C horizons which may be subdivided numerically (A_1, A_2 etc) if distinct differences are discernible. Some soils, in heavily vegetated areas, may also exhibit a surface layer of decaying organic material referred to as the O horizon.

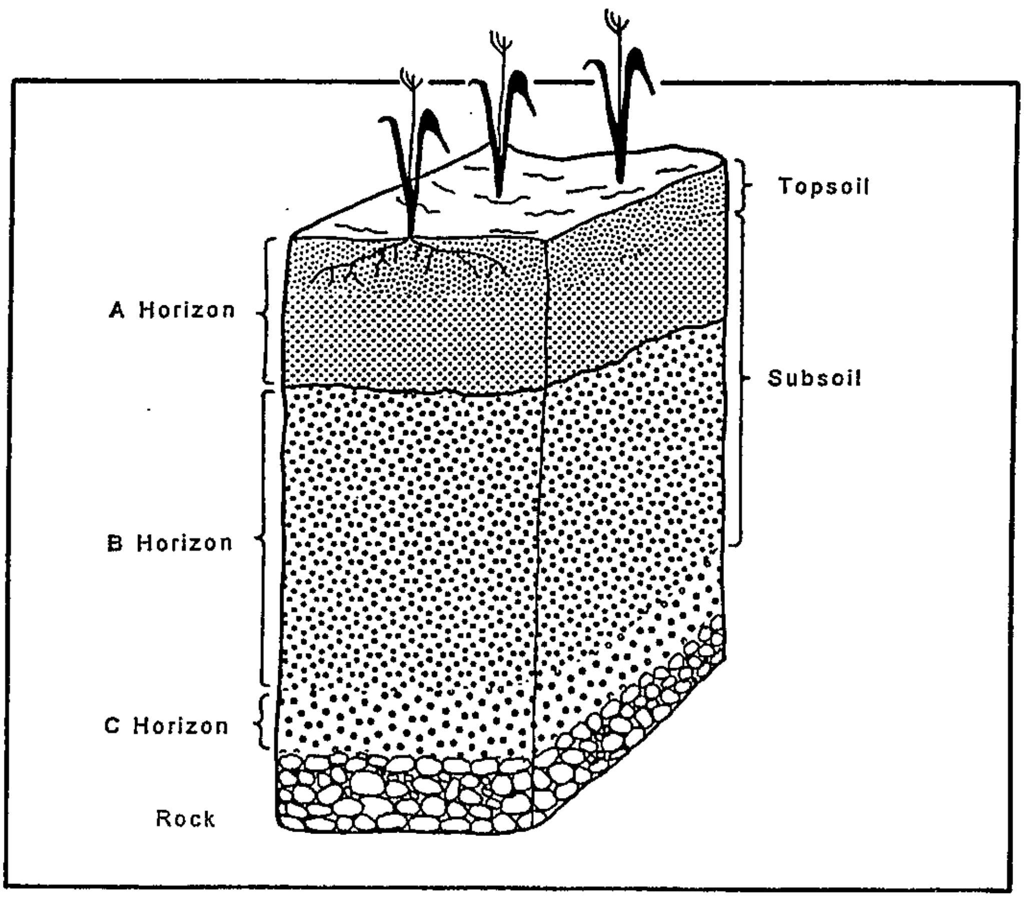


Figure B-1.1 *An idealised soil profile*

- ***A Horizon*** which is anywhere from 50 - 1,000 mm deep is characterised by being deeper in colour and having an accumulation of organic matter. The upper layer (sometimes referred to as the A_1 horizon or topsoil) is the most weathered portion and the most valuable for growing plants. In the lower portion of the A horizon, the soil will usually be paler in colour where clay minerals and organic matter have been leached out. This upper horizon is commonly referred to as the "topsoil".

- ***B Horizon*** ranges in thickness from 100 - 2,000 mm and usually has a finer texture with a higher content of clay than the above A horizon. The B horizon and any soil below it is often referred to as the "subsoil.

- ***C Horizon*** represents the bottom of the zone where decomposition of the parent material by weathering can be distinguished.

A number of features are used to distinguish between different soil horizons including texture, colour and structure. One of the main distinguishing features of any soil profile is the degree of differentiation shown between the soil horizons. The Factual Key classification method (see B-1.4.6) makes the distinction between:

- ***Uniform*** texture throughout the profile.
- ***Gradational*** change in texture down the profile.
- ***Duplex*** soils which have a marked contrast in texture between the A and B horizons.

B-1.4.2 Soil Texture

All soils are composed of a mixture of sand, silt, clay and organic matter. The texture of a soil is dictated by the proportions of sand, silt and clay, which determine many of the physical and chemical properties. These proportions may be plotted on a triangular graph, such as that shown in Figure B-1.2, to determine the textural class of a soil. (For example, a soil with 30% sand, 50% silt and 20% clay would be classed as a clay loam).

Although the process of determining the relative proportions of sand, silt and clay can be carried out precisely in a laboratory, there are also more subjective methods which can be used in the field. Such methods rely on the feel of the soil and how its consistency changes when it is wet.

Texture is very important in determining a number of soil characteristics vital in assessing the suitability of soils for effluent irrigation, including available water holding capacity, surface infiltration rates, permeability and cation exchange capacity (CEC). The CEC of a soil provides an index of the ability of a soil to form stable aggregates and to store nutrients and water. High CEC is usually associated with soils which have a high content of montmorillonite clay and high organic matter content. Low CEC is characteristic of sandy soils.

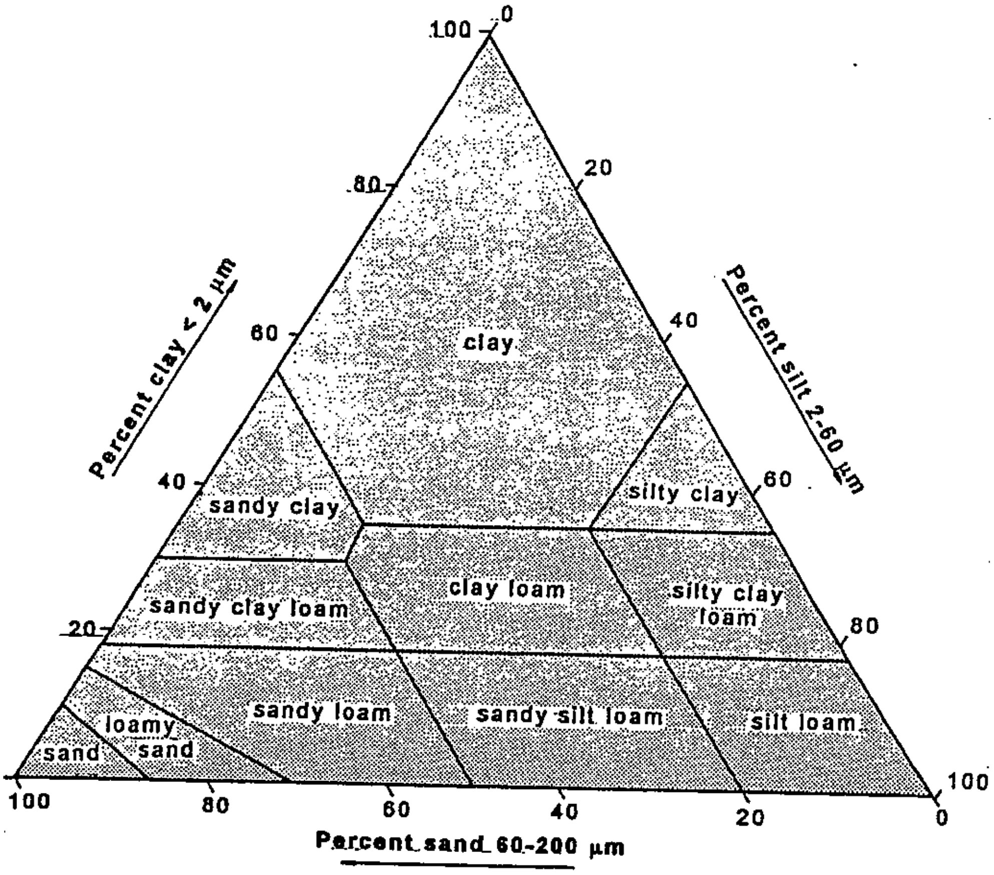


Figure B-1.2 ***Classification of soil on the basis of texture***

- ☐ ***Coarse textured soils*** like sands generally have a low water holding capacity. Infiltration rates and permeability are often high. Such soils are subject to through drainage and leaching of water and nutrients. Sands have a low CEC and this can be a problem if the effluent contains large amounts of dissolved nutrients.

- ☐ ***Medium textured soils*** like loams generally have good water holding capacity. Infiltration rates and permeability can vary but are usually good enough to allow irrigation without ponding with a minimal risk of through drainage. The CEC of these soils and their ability to hold nutrients are sufficient to reduce the risks of nutrient leaching.

- ***Fine textured soils*** like clay usually have a higher water holding capacity. However infiltration rates and permeability are low. There is little risk of through drainage, rather the risks are in ponding leading to runoff and waterlogging, both of which are big problems to irrigation schemes. The CEC of these soils is usually high and thus nutrient retention in the soil is generally high.

B-1.4.3 Soil Structure

Soil structure is the arrangement of the soil particles and the spaces between them to form compound units, called ***aggregates*** or ***peds***. Sand, silt and clay are organised into larger peds which are separated from neighbouring peds by lines of weakness or natural voids. If up to one third of the soil has aggregates it has weak pedality, up to two thirds aggregates - moderate pedality, and over two thirds aggregates - strong pedality.

The first indicator of structure is the variation in particle size or "grading" of a soil. Single grained soils such as sands have a relatively uniform grain size but exhibit no cohesion. Some clay soils may also have uniform grading but are very cohesive. These "massive" soils are cohesive but have no aggregates and look a little like a brick. The most useful agricultural soils are those which have a mixture of grain sizes and are classed as "loams". These soils usually contain aggregates of different sized grains which help provide some "structure" to the soil so that it does not break down into its constituent grains when wet.

Ped shapes are varied and peds themselves can be made up of smaller aggregates or peds. Ped size is also part of any description of structure. Generally soils with good structure will be better suited to effluent irrigation. Where structure is good, plant available water will be highest and plant growth will be at its optimum. Optimum plant growth will allow the maximum evapotranspiration of water to the atmosphere and the highest uptake of nutrients by the crop, both important in the success, or otherwise, of an effluent disposal scheme. Soil texture, organic matter, cropping and trafficking history are all important in soil structure. Poor soil structure can decrease infiltration rates (permeability), adversely affecting potential application rates.

A number of other features of soil structure may be important for determining the suitability of a site for irrigation:

Coarse fragments are particles larger than 2 mm. A high percentage of coarse fragments may limit rooting volume, thereby lowering the soils water holding capacity and nutrient availability. The ease of cultivation can also be affected if there is a high proportion of coarse fragments.

Pans tend to be relatively impermeable layers which inhibit drainage and increase the chances of waterlogging and restricted root growth.

B-1.4.4 Soil pH

Soil pH is a measure of the soil solution's acidity. It is measured, usually after mixing 1 part soil with 2.5 or 5 parts water, and it is the negative logarithm of the hydrogen ion activity. It has effects on chemical properties of soils and plant nutrition. For a pH less than 5, root growth and function are affected depending on plant species. Aluminium toxicity and, to lesser degrees, manganese toxicity occur at low pH. Calcium and magnesium deficiencies can also occur. For a pH between 5 and 8, growth is satisfactory. At high pH (>8) minerals such as phosphate and molybdate are adsorbed onto soil particles and become unavailable to plants.

B-1.4.5 Soil Variability

In addition to varying with depth, soils are quite variable across the landscape. In any area of only one hectare, the composition of the soil and the depths of the various horizons can be expected to vary significantly. While it is convenient to plan and manage an irrigation area on the basis of it having the same type of soil, we are really only dealing with characteristics which we think of as ***averaged*** over the landscape. It is important to recognise this variability because, if it is too great, then we may need to sub-divide the irrigation area so that we can manage the areas slightly differently to account for differences in the soils.

Much of the variability in soil across the landscape arises because of the weathering and geomorphological processes which have formed the soils. Differences in the depth and type of soil are likely to show up as a result of:

- ***Position on the slope.*** Soils at the top of the slope are likely to be shallower and more eroded than those at the bottom of the slope.

- ***Deposition processes.*** Soils on the floodplain of major rivers are likely to vary significantly depending upon the flow regime under which they were deposited. Thus soil may vary from a predominance of silt and clay in one location to a coarse sandy material within a few metres.

B-1.4.6 Soil Classification

Once the soil profile has been assessed and the soil type classified, the soil scientist produces a map showing the soil types present and their location. There a number of classification systems which have been developed in various countries for different purposes. Unfortunately the differences in terminology can be confusing to the layman but it is useful to have a basic understanding of soil classification so that informed judgements can be made on the basis of soils reports and maps. The basis of some common classification systems used in Australia and examples of the terms used are given in Table B-1.3.

The most simply understood system classifies soils on the basis of ***texture*** (see B-1.4.2 above). This system gives an indication of the important physical, chemical and engineering characteristics we can expect to find and is adequate for our needs in planning and managing an effluent irrigation area. The ***Factual Key*** system has been widely used for soil mapping throughout Australia but is difficult to interpret without specialist knowledge. The ***Unified Classification System*** is commonly used to describe the engineering properties of soils. The ***Great Soils Group*** system is commonly used internationally, and has been used in Australia since the 1930's. This system is largely based on the origins and soil formation processes. Unfortunately the names given to different soils do not give the layman any indication of their properties. Classification based simply on the ***parent material*** is commonly used by the farming community, but the terminology usually has specific meaning in a limited locality. Because all systems rely to some extent on a knowledge of the physical properties of the soil, further details are set out in Section B-1.5.

Table B-1.3 ***Examples of common soil classification systems used in Australia*** (adapted from SCS of NSW 1991)

CLASSIFICATION SYSTEM	BASIS OF CLASSIFICATION	EXAMPLES AND NOTES
Great Soil Group	Soil morphology and chemistry based on the origins of the soil	Podsols, kraznosems, yellow earths, black earths
Factual Key	Morphological and chemical properties, colour	Hard, pedal red duplex (Dr2) Black cracking clay (Ug5.15)
Unified Soil Classification	Particle size grading, plasticity and organic matter	Sandy silt (SM) Low plasticity silty clay (ML)
Parent Material	Soil parent material	Granite soil Basalt soil
Texture	Soil particle grading	Sandy loam Clay loam

B-1.4.7 Factual Key Soil Classification System

The Northcote Factual Key was developed in the 1960's as part of a program to prepare consistent soils mapping for Australia and has gained wide acceptance. Unfortunately the symbols associated with the system (eg Dr2.41, Ug5.1) are a bit like Egyptian hieroglyphics to most of us and the system is not widely understood outside the ranks of soil scientists. There are some very useful features of the system, however, which give a guide to the properties of a soil. It is therefore worth having a brief look at the basic features of the system.

The system recognises four primary divisions (designated by a capital letter) which have up to four subdivisions (designated by a lower case letter). The system also distinguishes further sections, classes and profiles (designated by a number which has one or two digits after the decimal point). For the purpose of understanding the important characteristics of a soil, it is sufficient to focus on the main divisions and subdivisions. The features of these are summarised in Table B-1.4.

Table B-1.4 ***Soil properties distinguished in the Northcote Factual Key***
(adapted from SCS of NSW 1991)

Division	Subdivision	
Organic (O) soils dominated by organic matter	Nil	
Uniform (U) soils which exhibit similar texture throughout the profile. This is usually characteristic of a soil which has been deposited at the site (by wind or water).	Coarse texture Medium texture Fine texture Seasonally cracking fine texture	Uc Um Uf Ug
Gradational (G) soils which show a gradual change in texture down the profile.	Calcium present in A and B horizons (nodules of lime) Calcium not present	Gc Gn
Duplex (D) soils which have a marked contrast in texture between the A and B horizons. Typically these soils have a relatively impervious B horizon which governs the water uptake and drainage characteristics of the soil.	Colour of upper 150 mm of B horizon= Red Brown Yellow Dark Gleyed (pale)	 Dr Db Dy Dd Dg

Throughout the key, accent is placed on the characteristics of the A_2 and B horizons, as it has been found that these are the most consistent and expressive features. However, other special features are used, such as hard setting nature of the surface and amount of calcium carbonate present in the profile.

B-1.4.8 Soil Survey

The objectives of a soil survey are to:

- Identify and characterise the soils of the area.
- Map the area covered by different soils.

Soil survey often starts with examining aerial photographs, geological maps and topographic maps to identify any major features on the landscape which might be indicative of a change in soil type. For instance, if the natural vegetation is still present, different types of vegetation are often a good indicator of different soils.

Soil survey procedure involves field sampling of soils across the area. The surveyor aims to investigate a representative range of soils within the area by choosing different positions on a slope and sampling locations in all the different soil types identified from mapping and aerial photography. To account for differences due to parent material, the sampling will cover all parent materials.

At each site, a core of soil is removed or a pit is dug so that changes in soil characteristics with depth can be observed. Each soil horizon (eg top soil - A horizon, sub-soil - B horizon) is examined and the characteristics such as colour, texture and other properties are recorded. Soil samples may also be taken for later chemical and physical analysis. Soil at each site is then classified according to the classification system being used (see Sections B-1.4.6 and B-1.4.7)

The characteristics of the soil types found at the sampling sites are extrapolated to sites at similar positions on the landscape and on similar parent material. A map is then prepared showing the boundaries of different soil types. Although the map will show distinct boundaries between soil types, in practice, soils will tend to blend from one soil type to another.

A completed soil survey will comprise a map delineating the soil types of the area and a description of each soil. The information contained in the description will depend on the original purpose of the mapping and may range from a simple visual classification of the soil to detailed results from testing the chemical and physical properties of the soil. For an area to be used for irrigation of abattoir effluent, the soils description should include texture, infiltration, permeability, nitrogen and phosphorus levels, organic matter, pH, SAR, ESP and salinity. (See Section B-1.6 for an explanation of these terms.)

B-1.5 Physical Characteristics of Soils

The main physical soil properties of relevance to irrigation are:

- **Strength** - this is of interest if we are trying to cultivate the soil or use it to build a dam or channel. The main strength characteristics are governed by the soil texture (see B-1.4.2). Further information relating to the use of soils in construction will be found in Chapter B-5.

- **Water transmission and holding characteristics** such as:

  - Infiltration at the surface,
  - Permeability,
  - Water holding capacity.

B-1.5.1 Surface Infiltration Rate

This is the rate at which water enters the soil surface. Initial water intake is influenced by soil porosity, texture, structure, moisture content, organic matter and permeability of the surface layer. These influences vary in importance in different soil types. Good infiltration rates are usually favoured by high soil porosity, low bulk density, low moisture content, good structure, good organic matter levels and high permeability.

Representative infiltration rates for different textured soils are set out in Table B-1.5. The data in the table should only be used as a guide, because a number of factors other than texture can have a marked effect on infiltration rate.

Table B-1.5 *Typical infiltration and irrigation application rates*

Soil Type	Infiltration Rate (mm/h)	Irrigation Application Rate (mm/h)		
		0-5% Slope (mm/h)	5-10% Slope (mm/h)	10% + Slope (mm/h)
Coarse textured sands, fine sands and loamy sands	12-25	10-20	8-16	5-10
Moderately coarse textured sandy loams, loam, sandy clay loams and silt loams	9-20	8-16	6-11	4-8
Medium textured very fine sandy loams, loam, sandy clay loams and silt loams	5-8	4-6	3-5	3-4
Fine textured sandy clays, silty clay and clay	1-4	<4	<3	<3

Note: Application rates are for bare ground. Rates can be increased with good plant cover. Air and surface evaporation in daylight hours may vary by 0.25-1.0 mm per hour.

As shown in Table B-1.5, application rates for spray irrigation systems should always be less than the infiltration rate to ensure that ponding and runoff does not occur.

One problem common in many parts of Australia is the occurrence of hard setting soils. These soils form a hard compact massive structure during wetting. This tends to be exacerbated by cultivation. Hard setting soils result from a combination of particle size distribution and clay mineral type. Generally these soils have a loam texture and the clay minerals are dominated by illites and/or kaolinites. The soils are characterised by a sandy matrix with small swell/shrink capacity, they have a low percentage of water stable aggregates, slake on wetting and have low organic matter content. These soils become very difficult to irrigate because their surface infiltration rates drop to very low values once the surface has set hard.

Soils that crack have very high infiltration rates as water flows down the cracks. As the soil becomes wet, the soil swells and cracks close. Eventually, infiltration rates are negligible. The right amount of water has to be applied to the soil and no more, otherwise ponding and surface runoff will occur.

For any serious analysis of effluent irrigation onto land, infiltration rate is one of the properties which must be measured during a thorough investigation of the site by a soil scientist. Surface infiltration rates can be measured by ring infiltrometers (or permeameters) and should be done in most irrigated areas. Infiltration measurement is, however, of limited use in cracking soils. For these soils it is necessary to know the moisture content at which the cracks close. The amount of irrigation water which can be applied will be that necessary to just close the cracks.

B-1.5.2 Soil Permeability

If the surface of the soil does not seal, continuing water intake rate is controlled by the permeability of the underlying soil layers, and is generally determined by the layer having the lowest permeability. The terms ***permeability*** and ***hydraulic conductivity*** are used interchangeably and refer to the rate of movement of water through the soil profile. Permeability is affected by soil structure, porosity, moisture content, texture and bulk density.

If permeability is high then water will move through the profile rapidly and through drainage of applied water may occur carrying nutrients into the groundwater. If permeability is low, then intake rates may be so low that even low application rates of irrigation water will cause waterlogging, ponding and surface runoff. Generally, some compromise between the two is reached and often permeability will determine the irrigation method, application rates and degree of management needed to meet the objectives of minimal runoff and through drainage.

B-1.5.3 Available Water Holding Capacity.

Water is held in the soil by capillary action and, in an unsaturated soil, will be held at a negative (suction) pressure. The moisture content of a soil at a particular suction is a characteristic of the soil type. The available water holding capacity refers to the capacity of a soil to hold water that is readily available to plants. Technically, it is the difference between soil water at about 10 kPa suction (***field capacity***) and 1,500 kPa suction (***permanent wilting point***). In practice, field capacity can be thought of as the soil moisture remaining after "free" water has drained out of the soil. Permanent wilting point is the point of soil moisture suction at which the plant is unable to extract water and expires. If irrigation is added after this point, the plant will not recover. In irrigated areas, the soil should never be allowed to reach permanent wilting point. The available water capacity (AWC) is generally expressed as the depth of available water (mm) per metre depth of soil. The total water available to a plant (W) will depend upon the depth to which the roots penetrate and can extract water (d). Thus the available water for a plant will be:

$$W = AWC \times d$$

Table B-1.6 gives some typical values of the available water capacity for a range of soils. There is a trend in Australia to use the difference between the "***full***" and "***refill***" points when describing the readily available water for an irrigated crop. The "full" point is the total depth of water available to the plant when the soil is at field capacity. The "refill" point is the depth of available water at the point where the crop starts to suffer moisture stress or a loss in potential production because of a lower soil water content. This concept is useful because it takes account of the way in which plants extract water from the soil profile. All crops have a root system which has a varying density of roots within the soil profile. This leads to the plant taking more water out of the soil at different depths. A typical example of this, which also illustrates the concept of "full" and "refill" points, is shown in Figure B-1.3.

In calculating the "full" and "refill" points, the depth of soil used is the depth from which the crop extracts water before it reaches refill point. This will not necessarily be the full rooting depth of the crop, but can be thought of as the "effective" rooting depth.

Table B-1.6 ***Typical values for water holding characteristics of soils***
(adapted from SCS of NSW 1991)

Textural Class	Field Capacity (% by weight)	Permanent Wilting Point (% by weight)	Available Water (mm/m)
Coarse sand	8	4	85
Sand	14	4	150
Fine sand	19	4	200
Very fine sand	20	4	225
Loamy coarse sand	13	7	110
Loamy Sand	18	7	160
Loamy fine sand	22	7	215
Coarse sandy loam	19	9	125
Sandy loam	26	9	175
Fine sandy loam	28	9	190
Loam	30	13	175
Silty loam	34	10	200
Silt loam	39	16	190
Sandy clay loam	26	15	150
Clay loam	34	18	185
Silty clay loam	43	20	190
Sandy clay	29	19	140
Silty clay	47	25	185
Clay	42	24	175

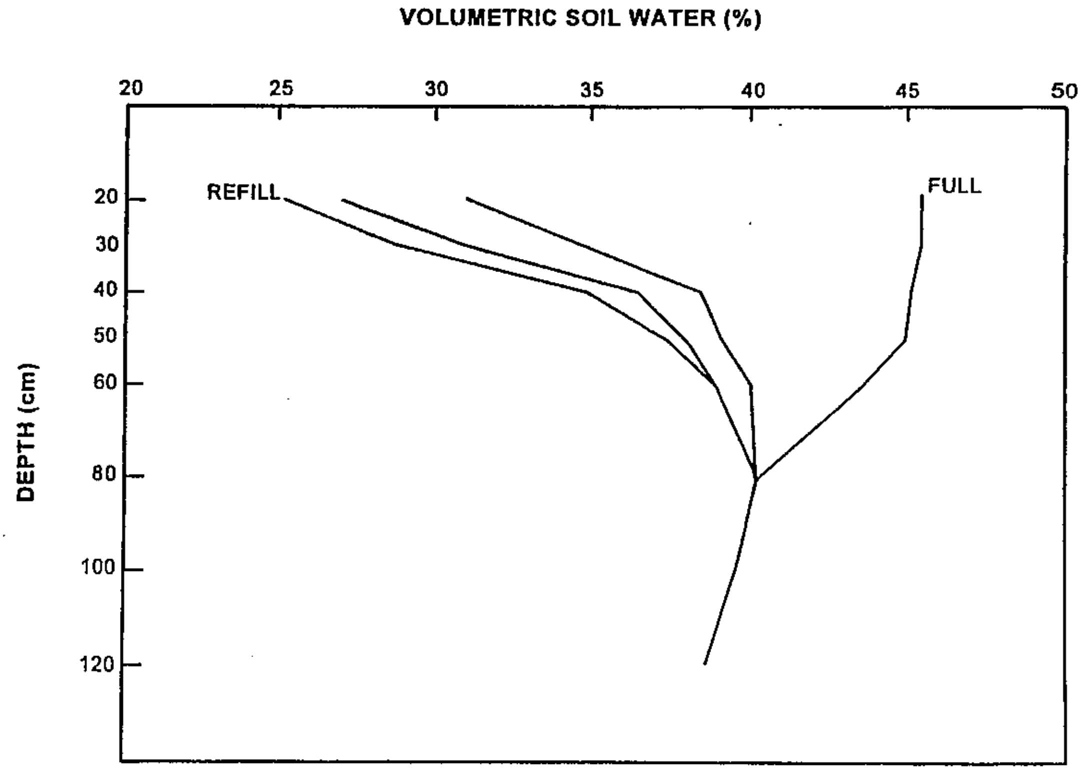


Figure B-1.3 ***Soil moisture profile at "full" and "refill" points under a cotton crop.***

IMPORTANT NOTE

There are two different ways in which soil moisture can be expressed:

- *As* ***volumetric*** *moisture content (W_v) expressed as:*
  - *% by volume*
  - *depth of water (mm) per unit depth of soil (m)*
- *As* ***gravimetric*** *moisture content (W_g) expressed as:*
  - *% by weight*
  - *mass of water (g) per unit mass of soil (g)*

Throughout this manual volumetric moisture content is used. However, if you get soils analysed by a laboratory the results will usually be given in terms of the gravimetric moisture content. To convert from one system to the other you need to know the in-situ density of the soil at the time. In practice, many soils used for growing crops will have an in-situ bulk density of about 1.5 t/m^3. (This may range from 1.2 t/m^3 in newly cultivated soil to 1.8 - 2.0 t/m^3 in a well compacted soil or a sand). The in-situ bulk density can be used to convert gravimetric moisture content (W_g) to volumetric moisture content (W_v):

$$W_v = W_g \times \rho$$

$$W_v = W_g \times 1.5$$

where ρ is the bulk density (typically $\rho = 1.5$ t/m^3)

eg Soil with a gravimetric moisture content of 20% and a bulk density of 1.5 t/m^3 will have a volumetric moisture content of about:

$W_v = 20\% \times 1.5 = 30\%$

Note that in Figure B-1.3, the pattern of moisture extraction by the cotton crop shows a typically *V* shape indicating that more water is removed from near the surface. Table B-1.7 shows the moisture extracted for different depths of soil illustrated in Figure B-1.3

Table B-1.7 ***Moisture extracted from different soil depths in Figure B-1.3***

Depth (cm)	Soil Moisture (mm)
0 - 20	45
20 - 40	30
40 - 60	15
60 - 80	5
Total	**95**

As a guide to the plant available water (W_p) within a soil, a common rule of thumb is that the "refill" point will represent about 50% of the total available water within the root zone.

$$W_p = W_v/2 = (AWC \times d)/2$$

Thus the example shown in Figure B-1.3, the total available water to a depth of 80 cm is about 200 mm of which 95 mm (about 50%) is available to the plants.

Soil porosity, organic matter, structure, texture and salinity can all affect readily available water. Good soil structure, good soil porosity and increasing organic matter will enhance readily available water. Salinity reduces the amount of water a plant can extract before stress occurs.

At any point in time, the actual soil moisture in a soil profile will be somewhere between "full" and the "refill" point. The amount by which the soil moisture within the effective root zone is less than full is termed the soil moisture "deficit" and, as with the other terms we have been using, is expressed as a depth of water (mm) which would just refill the soil moisture storage. The volume of effluent applied should never exceed the soil water deficit at the time of irrigation, otherwise ponding and runoff will occur. (The only exception to this rule is when leaching is being carried out to remove salts from the root zone. Details of this procedure are given in Chapter B-6)

Soils with a severe limitation of readily available water will have poor plant growth, and a low potential for retaining effluent. This in turn will lead to an increase in the potential for ground or surface water contamination. Low application rates may be necessary for these soils. Some sandy soils are also difficult to irrigate without water draining through the profile.

B-1.6 Chemical Properties of Soils

There are a variety of chemical properties of soils that have significant effects on the growth of plants and on the ability of the soil to accept irrigated effluent. The two main issues are:

- Plant nutrients - particularly nitrogen and phosphorus.
- Soil salinity and sodicity.

B-1.6.1 Nitrogen

Nitrogen is a critical element in any agricultural system, especially in an effluent reuse scheme. In Australian agriculture, shortage of nitrogen is often a major limitation in soils used for crop and pasture production. Fertiliser inputs or the use of nitrogen fixing legumes are necessary to obtain good yields. Effluent often contains large amounts of nitrogen which can be used by agriculture. However the addition of excessive amounts of nitrogen can lead to a high concentration of nitrates being available in the soil profile. The leaching of these nitrates into the groundwater poses one of the biggest environmental problems with land application of effluent because nitrogen in the form of nitrite can make groundwater unfit for human and stock use.

Nitrogen in the soil exists in a Nitrogen Cycle (Figure B-1.4) where nitrogen is transformed via a number of pathways into various forms. This system is not closed and there are various ways that nitrogen can be added to and lost from the system.

☐ ***Nitrification*** is a two stage bacterial process that converts ammonium to nitrate nitrogen

$$\text{Ammonium } (NH_4^+) \Rightarrow \text{Nitrate} (NO_3^-)$$

The rate of transformation varies depending on soil temperature, moisture, ammonium concentration and the number of bacteria present. Warm, wet (but not waterlogged) conditions favour the process. Nitrate is the preferred form taken up by plants.

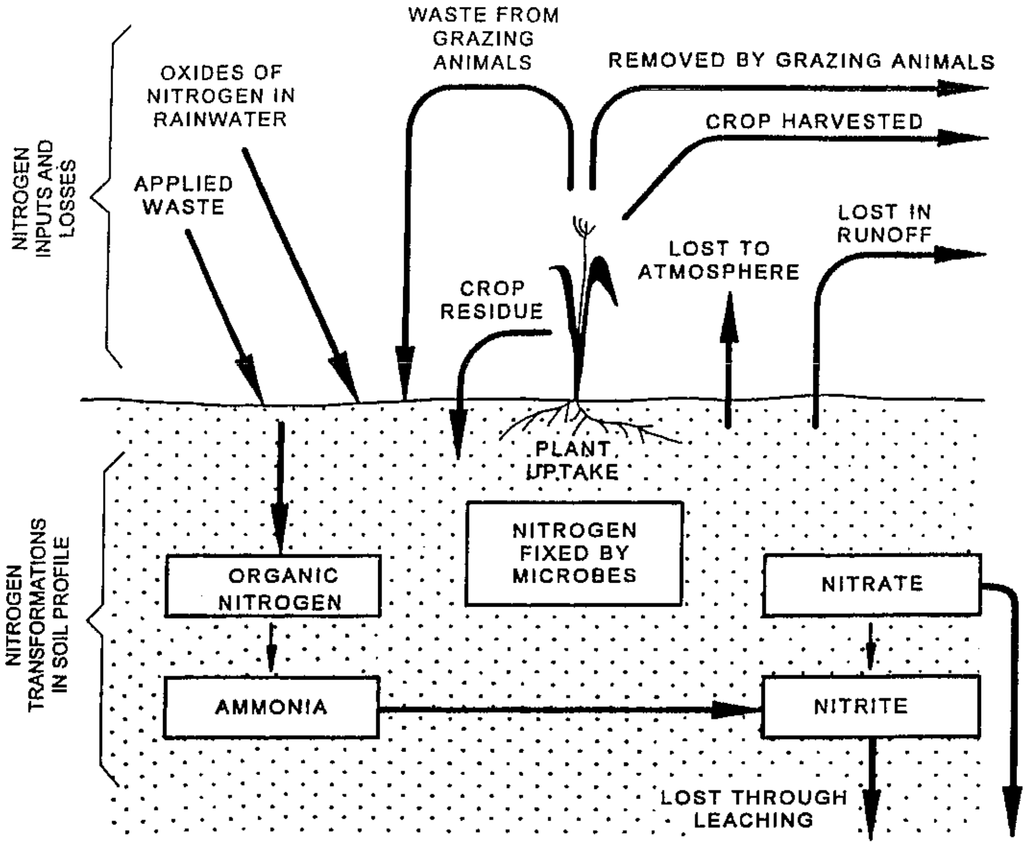


Figure B-1.4 ***The Nitrogen Cycle***

- ***Immobilisation / Mineralisation*** is the process where plant available nitrogen is immobilised by being taken up by the microbial population in the soil.

  Mineral Nitrogen (NH_4^+ and NO_3^-) ⇒ Organic Nitrogen

  The organic nitrogen is not lost from the system, but becomes available as the nitrogen is recycled by other organisms back into a plant available form - this is called mineralisation.

  Organic Nitrogen ⇒ Ammonium (NH_4^+)

  Normally, in excess of 95% of the soil nitrogen is in an organic form. A dynamic balance between plant available nitrogen and organic soil nitrogen is maintained. Carbon/nitrogen ratios in organic matter are important. If the ratio is below a critical value then net mineralisation will occur and there will be an excess of inorganic nitrogen. If the ratio is high then net immobilisation will occur and inorganic forms of nitrogen will fall.

  Nitrogen entering the cycle via the application of effluent is mainly in the form of organic nitrogen (eg blood proteins) or the inorganic ammonium (NH_4^+) and nitrate (NH_3). All these forms of nitrogen enter the nitrogen cycle and undergo various transformations, depending on a number of factors, including soil temperature, moisture, ammonium concentration and carbon - nitrogen ratios.

- **Denitrification** is a biological process encouraged by high soil temperature and occurs when the soil is waterlogged after irrigation and / or heavy rainfall. The process converts nitrate back to nitrogen gases.

  Nitrate (NO_3^-) ⇒ Nitrous Oxide (N_2O) ⇒ Di-nitrogen(N_2)

  Waterlogging causes anaerobic conditions and bacteria use nitrate as a source of oxygen for growth.

- **Volatilisation** is the loss of nitrogen to the atmosphere as ammonia, NH_3. It is a complex process involving chemical and biological reactions in the soil and physical transport of nitrogen out of the soil.

  Ammonium (NH_4^+) ⇒ Ammonia (NH_3)

  The rate of loss from effluent appears to depend on the effluent type, application methods, weather, CEC (see Section B-1.4.2) and soil pH. Higher concentrations of ammonium on the soil surface, high pH, dry conditions and a low CEC all increase volatilisation losses. Sprinkler irrigation will cause higher losses than surface or sub-surface irrigation.

- **Plant Uptake** In a system where large amounts of nitrogen are being added to the system, harvesting and removal of crops is necessary to remove some of the nitrogen. This topic is dealt with in Chapter B-2.

- **Leaching** is the transport of soluble nitrogen in soil water moving down through the profile. Organic nitrogen is immobile unless surface runoff carries away the organic matter. Ammonium nitrogen is relatively immobile as the positively charged ion tends to bind to the negatively charged clay particles. Nitrate is a highly soluble and mobile form of nitrogen. It is the form readily used by plants and readily leached from the soil profile.

The processes by which nitrogen is transformed in the soil and utilised by plants govern the rate at which abattoir effluent can be applied to the land. Further discussion of this topic is located in later sections of this manual:

Section B-2.6 considers nitrogen removal by crops and livestock.

Section B-4.5 looks at losses of nitrogen from irrigated effluent by volatilisation and denitrification.

Section B-6.1 looks at the overall management of nitrogen in the context of irrigation management.

B-1.6.2 Phosphorus

The phosphorus cycle (Figure B-1.5) in soil is less complex than the nitrogen cycle. Phosphorus exists in the soil in organic, soluble and bound forms.

- ***Organic Phosphorus*** is a part of all living things and is the principle form of phosphorus in waste.
- ***Soluble Phosphorus*** is the form used by plants and is subject to leaching. It generally accounts for less than 15% of phosphorus in the soil profile.
- ***Attached Phosphorus*** includes compounds formed when the anionic form of phosphorus become attached to cations such as iron, aluminium and calcium. Attached phosphorus includes loosely bound or "labile" forms and tightly adsorbed or fixed forms.

Labile phosphorus and soluble phosphorus forms are in equilibrium in the soil. Thus, if the concentration of soluble phosphorus is decreased, by leaching or plant uptake, some of the labile phosphorus will be converted to the soluble form to maintain equilibrium.

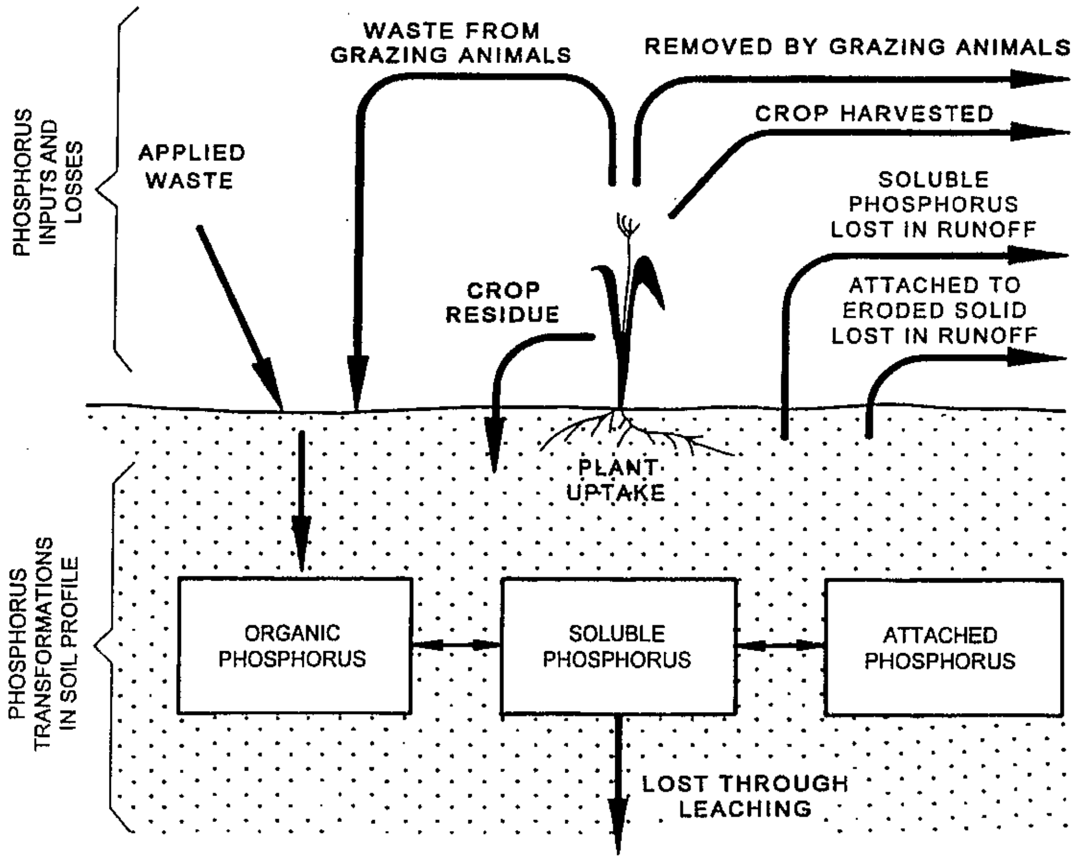


Figure B-1.5 ***The Phosphorus Cycle***

B-1.6.4 Soil Salinity

Salinity is the concentration of dissolved salts in the soil solution and is related to electrical conductivity, the standard measure of salinity. It is common practice to use units of dS/m for salinity of the soil solution and μS/cm for irrigation water or effluent. (See Section B-1.3 for further discussion on the units used to measure salinity and conversion between units.) The main conversions to remember are:

Total Dissolved Salts (TDS) (mg/L) ≅ EC (dS/m) x 640

Note: 1 dS/cm = 1,000 μS/cm

High soil salinity interferes with the plants ability to absorb water and nutrients from the soil. This reduces germination and plant growth potential. Crops with high salt tolerance will need to be grown if high salinity is present.

If the effluent itself is highly saline, the susceptibility of the soil to the accumulation of salts in profile will need to be assessed. Generally, it will be soils that have low or no drainage which retain any salts applied. Leaching of the soil profile may be needed to remove excess salts. Salinity is not a problem in areas which receive high rainfall and have soils that are naturally leached. Leaching or through drainage removes salts from the profile. Problems arise where rainfall is low or soils are not freely draining. Low rainfall problems can be overcome by the application of irrigation water. The amount applied would have to be enough to ensure that sufficient leaching of salts out of the profile occurred. In soils where little or no leaching occurs, salinity will inevitably arise with long term irrigation no matter what water is used as all irrigation water contains some salt. These soil types should be avoided in effluent disposal schemes.

If the effluent used is low in salinity and the soil is non - saline, then salinity will not be a serious problem. Where effluent is saline there will be a need to manage the system to minimise the build-up of salinity in the soil profile. If levels of salinity and nutrients are above high, there is a potential for conflict in the management strategies for nutrients and salinity. This aspect is considered in more detail in Section B-6.3.

B-1.6.5 Sodicity

Sodicity refers to the amount of exchangeable sodium cations (Na^+) in the soil and is usually expressed in terms of the exchangeable sodium percentage (ESP) where:

ESP = (Exchangeable sodium concentration/ Cation exchange capacity) x 100%

Clay particles are mainly negatively charged and tend to repel each other. This repelling action tends to disperse the clay particles to form suspension in water. The presence of chemicals to reverse the dispersion tendency will cause flocculation in which clay particles attract each other. Flocculation is necessary for stable structure, however, it alone does not guarantee stable structure.

Dispersion is highly undesirable because it leads to a structural instability of the soil aggregates and results in surface crusting, reduced permeability and loss of soil structure. In sodic soils, the monovalent sodium cation, Na^{+}, replaces the divalent calcium (Ca^{++}) and magnesium (Mg^{++}) cations at the exchange sites on clay particles. This results in a more negative charge and a greater tendency for dispersion of clay particles.

Dispersion and flocculation are dependent on both sodicity and salinity, and the critical level of ESP is highly dependent on the electrolyte concentration of the soil solution. In Australia the generally accepted definition of a sodic soil is one with an ESP exceeding 5. However, soils with an ESP less than this are not immune from dispersion.

B-1.7 Organic Content and Organisms in Soil

Soil organic matter derives from the debris of green plants, animal excreta and the organic matter in effluent. Topsoils in areas used for cropping commonly contain 1 - 5% of organic carbon. Grasslands and forest soils usually contain more than this. Organic matter in the soil is always in a state of flux (Figure B-1.6) and consists of a whole series of products ranging from un-decayed plant and animal tissues through temporary products of decomposition down to relatively stable brown to black material called humus which bears little resemblance to its original form. The soil organisms which live in the soil, many of which depend on this decaying organic matter for food, are also part of the organic matter in the soil.

The rate of breakdown of organic matter is important because the soil organisms need to be able to breakdown organic waste as fast as it is added. In general, factors that stimulate micro-organisms also stimulate residue breakdown. The rate of breakdown increases with an increase in the total residue. The rate of addition can also influence decomposition products. If oxygen demand exceeds supply, anaerobic respiration could occur and organic acids could be produced. Organic acids can be extremely toxic to young plants.

The carbon : nitrogen (C:N) ratio is important. High C:N ratios slow the rate of breakdown as the decomposers require a ready source of nitrogen. This also creates problems for plant growth as micro-organisms remove inorganic nitrogen and plants cannot obtain the amounts they need for optimum growth.

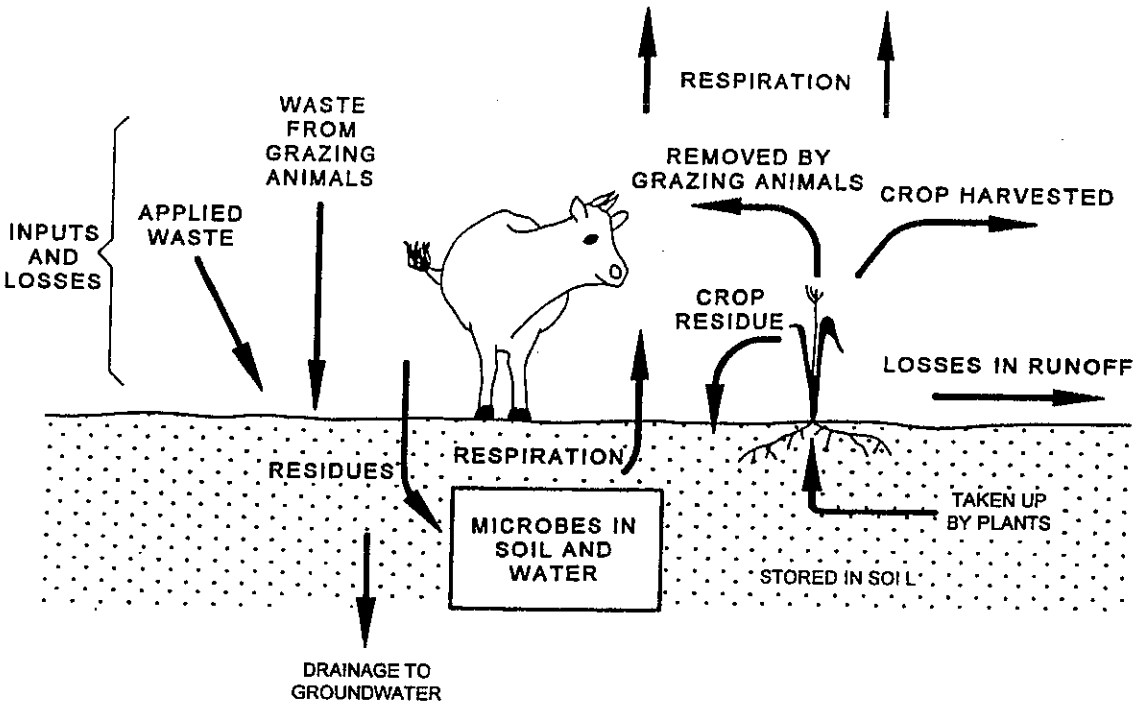


Figure B-1.6 ***The Carbon Cycle***

Organic matter is important because it plays a number of important roles which improve the soil as a medium for plant growth:

- Mulch effects - the surface layer of organic matter, leaf litter, etc reduces moisture loss and temperature fluctuations while protecting the soil surface from erosion.
- Physical separation of the soil fabric - the decaying organic matter swells and shrinks forming open channels between soil particles and allowing movement of air and water, thus providing planes of weakness for root penetration.
- Provision of cements and glues - these help to stabilise soil aggregates and are important in maintaining soil structure.
- Nutrient storage - organic matter plays an important role in storing essential nutrients, particularly organic nitrogen which is immobile and cannot be leached from the soil.
- Cation storage - organic matter can increase cation storage and cation exchange capacity.
- Absorption of organic compounds.

In an effluent disposal system, organic matter will improve soil porosity and structure, and thereby increase the amount of readily available water as well as improving the chemical and physical fertility. The organic matter load in effluent can also produce conditions in which, because of the high C:N ratio, denitrification processes will be enhanced. While such conditions are usually avoided in agriculture, it provides an opportunity to get rid of some of the excess nitrogen contained in a typical abattoir effluent. There is, however, a fine balance to be achieved between conditions in which denitrification is enhanced and anaerobic conditions which lead to the production of odours. The whole question of managing the nitrogen cycle so as to maximise nitrogen use but avoid other problems is a key issue associated with the irrigation of abattoir effluent and is dealt with in greater detail in Sections B-4.5 and B-6.1.

B-1.8 Maintenance of Soil Structure

As noted in Section B-1.4.3, good soil structure is important because it will provide conditions in which the soil has:

- Good moisture holding capacity
- Good infiltration
- High capacity to store and transform nutrients.

For an effluent irrigation system there are three main factors which affect the maintenance of soil structure:

- soil organic matter content,
- sodium absorption ratio (SAR) and
- trafficking of the field by farm machinery.

B-1.8.1 Soil Organic Matter

Soil organic matter is very important in the physical and chemical fertility of the soil. Most farming systems bring about a decline in organic matter in the long term as shown in Figure B-1.7. This happens in two ways: by decreasing the annual amount of organic matter added from plants and animals, and by changing the rate at which organic matter is broken down. The addition of organic matter in the effluent will change this situation and lead to higher organic matter levels than would otherwise have been, and possibly increase the residual organic matter levels. In Figure B-1.8, the addition of organic matter in the form of manure has increased organic matter.

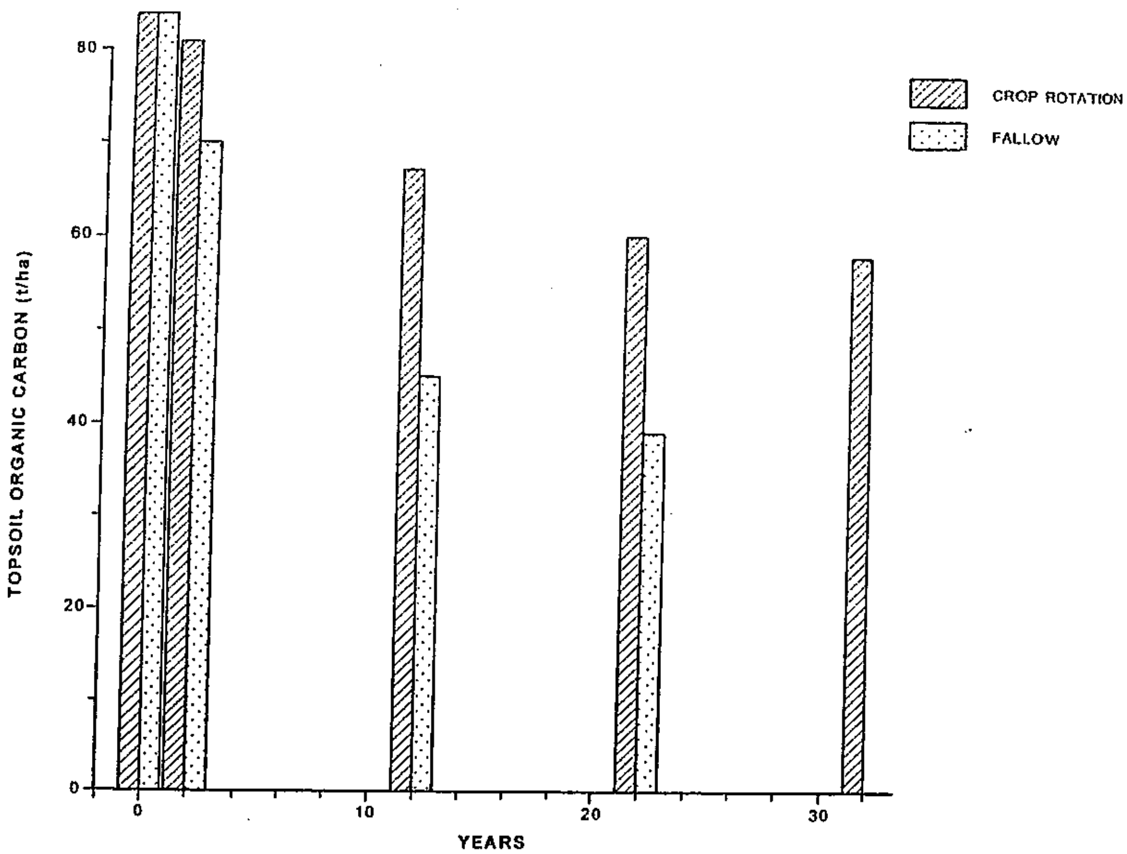


Figure B-1.7 *The effects of different farming systems on the carbon content of soils that started as pasture*

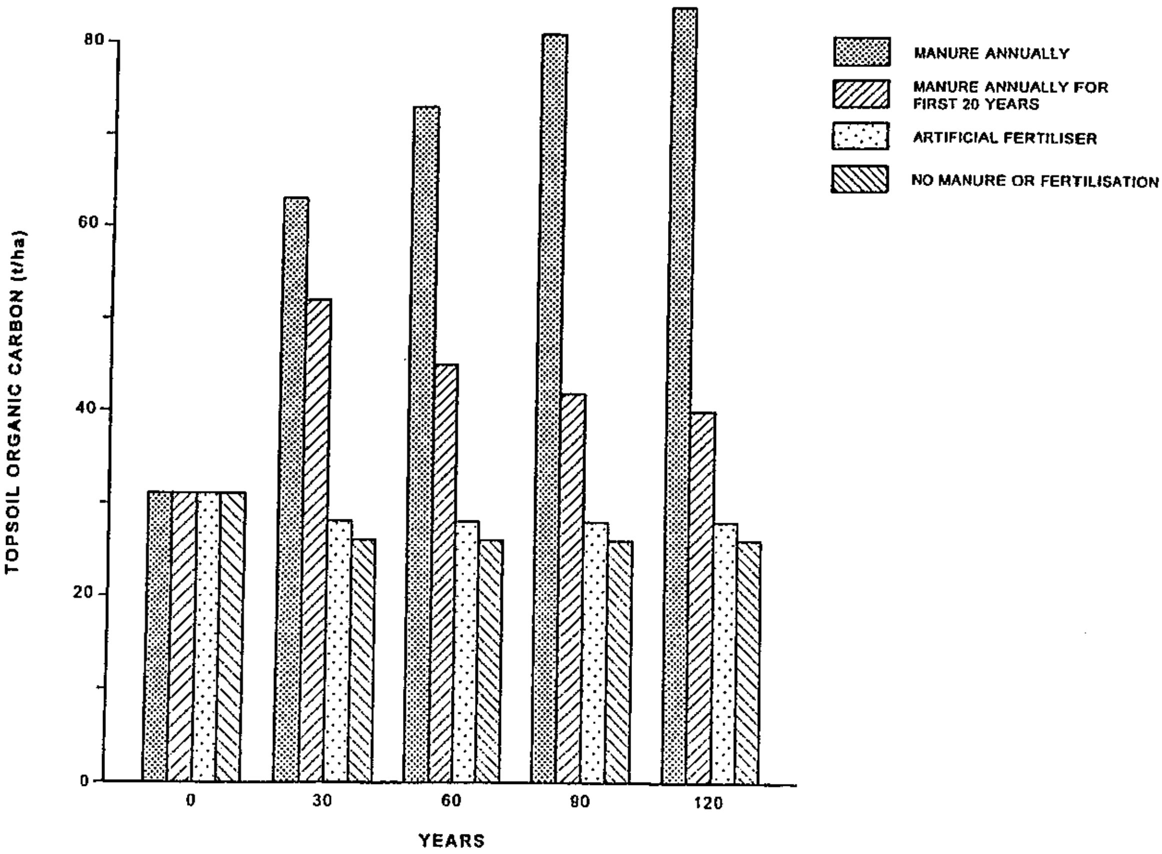


Figure B-1.8 *Effects of long term application of manure on the organic carbon content of soils*

B-1.8.2 Sodium Adsorption Ratio

High concentrations of sodium in the irrigation water may adversely affect soil structure by causing dispersion. The sodium hazard of water is expressed by its sodium adsorption ratio SAR.

$$SAR = \frac{[Na^+]}{\sqrt{\frac{[Ca^{++}]+[Mg^{++}]}{2}}}$$

where Na^+, Ca^{++} and Mg^{++} are the ion concentrations in milliequivalents per litre (meq/L).

The soil contains cation exchange sites (mostly clay minerals) which are occupied by the cations potassium, sodium, calcium and magnesium. If calcium dominates this group, the structure and permeability will be good. When sodium increases, and replaces calcium, soil structure deteriorates. Sodium causes clay in the soil to disperse when wet, lowering soil permeability which can lead to waterlogging problems. Problems with soil permeability arise when SAR approaches 6-10, depending on soil type. When a soil which is high in sodium dries, it tends to form a hard impermeable crust and surface infiltration rates decline. Soils may shed water rather than take it in. Salinity can effect SAR and increasing salinity inhibits clay dispersion and increases the acceptable SAR value. Water quality guidelines for controlling SAR in soils are given in Section B-4.4.3.

B-1.8.3 Soil Trafficking and Compaction

Australian soil types are generally prone to compaction which is partly due to trafficking, especially when wet. Due to the higher levels of trafficking associated with irrigation, this problem is exacerbated, especially if the soil is near its "full point". Compaction can affect water and air movement through a reduction in porosity and an increase in bulk density. Seedling emergence, root penetration, water and nutrient availability can all be reduced by compaction.

It is particularly important to minimise machinery usage for a day or two after irrigation has occurred. However, it is inevitable that compaction will build-up. At some point in time it is likely that compaction will start to have unacceptable effects on yield and or machinery operations. Some remedial action such as rotations or deep ripping will be needed to improve soil structure. It is best if this is done before the compaction gets to a serious level.

CHAPTER B-2: REQUIREMENTS FOR PLANT GROWTH

The ability of various plants to utilise water and nutrients are key considerations in choosing what crop to grow and how to manage the effluent irrigation system. This chapter describes the essential features of how plants grow and utilise a variety of inputs, particularly water and various nutrients which are essential to plant growth. The key management aims of any effluent irrigation area should be to:

- *Maintain balance between nutrient uptake by crops and the supply available from the soil store and effluent or fertiliser applied to the land. How much of a particular nutrient do different plants require?*
- *Fix or transform excess nutrients and non essential elements in harmless forms. What happens to nutrients and elements which are not used for growth?*
- *Minimise adverse effects, both on and off site, including changes in soil pH, toxicity and salinity. How can a crop be managed to minimise these possible side effects?*
- *Produce useful crops with no contamination or toxic levels of chemicals which preclude their use for a specific purpose. How can we maximise the benefit or value of the crop grown with effluent irrigation?*

Throughout this chapter reference is made to crops. This term is used in its broadest sense and includes any collection of plants which are deliberately grown on an area with the intention of achieving one or more of the aims listed above, including:

- *a crop such as maize grown to produce grain or fodder for animals,*
- *a pasture grown for making hay or for direct grazing by animals,*
- *unconventional crops such as trees or turf grass for sale.*

CONTENTS

B-2.1 Plant Growth

All plants need three things for healthy growth:

- ***energy*** to grow - which comes from sunlight and for practical purposes can be considered to be abundantly available.

- ***water and carbon dioxide*** (the basic building blocks for conversion by sunlight into carbohydrates which are then stored by the plant):

    - water - which is taken up from the soil by the roots.
    - carbon dioxide - which is obtained from the atmosphere through pores in the leaves.

- ***nutrients and minerals*** essential for healthy growth - which are taken up by the roots along with the water.

Of these requirements for plant growth, it is the supply of water and nutrients which are usually the limiting factors. The objective of effluent irrigation must be to harness this need for water and nutrients to use plant growth as a means to dispose of the effluent. Most of the water in the effluent will be returned to the atmosphere in the process of transpiration. Nutrients, on the other hand, are stored in the plant tissues and can most successfully be removed from the land by harvesting the crop.

Throughout this chapter we will use the word "crop" to denote any plants which are deliberately grown on an effluent irrigation area:

- maize which may be harvested for grain or fodder
- pasture for producing hay or grazed by stock,
- trees which are only harvested after a period of years,
- turf grass which is harvested along with some of the soil.

B-2.2 Water Use by Plants

Water is essential for plant growth and plays a role in a number of vital processes:

- It is an ***ingredient in the process of photosynthesis*** which uses energy from sunlight to produce carbohydrates which provide the plant with the energy to grow and are stored in the plant tissues.

- It provides a ***transport medium*** by which all substances are moved from the source to the region of use. The two main processes are:

    - Transport of nutrients and minerals from the soil to the growing tissues.

    - Transport of carbohydrates from the leaves to the regions of growth (stems and roots) or storage (fruit, seeds or tubers).

- Because of its high specific heat and high heat of vaporisation, water buffers the plant tissues against extremes of temperature. In particular, the process of ***transpiration*** (evaporation of water within the leaf structure) cools the leaves exposed to the heat of the sun.

- Water, under osmotic pressure within the plant cells, provides ***structural rigidity*** to sections of the plant.

Most of the water taken up by plants is transpired through the leaves. In the context of effluent irrigation, the important issue is the ***rate*** at which plants use water which is a function of:

- The ***energy supply*** to the plant - plants will use more water on a hot sunny day in summer than on a cool cloudy day in winter.

- The ***type of plant*** - some plants are more efficient at conserving water than others.

- The ***stage of plant growth*** - the maximum rate at which plants use water is usually when they are growing rapidly. Less water is used when plants are seedlings or have fully matured.

- The ***available water supply*** from the soil - if the soil is fairly dry then the plant will not be able to extract water at as high a rate as if the soil was moist.

In any irrigation system, the usual objective is to maintain the available water in the soil at a level which allows the plants to transpire freely. (This objective may have to be modified in some circumstances when irrigating with effluent - but that is a complication we will get to later). For now we can presume that any plants irrigated with effluent are not limited by the available supply. The rate at which water is used is therefore a function of: the weather, the type of plant and the stage of plant growth.

The essence of irrigation water management is to ensure that the available water supply to the particular crop (from irrigation and rainfall) matches the rate at which the crop uses water.

So how do we measure or estimate the rate at which plants use water? There are three basic methods of doing this:

- Direct measurement,
- Calculating evapotranspiration from a "reference crop",
- Relating evapotranspiration to water loss from an evaporation pan.

B-2.2.1 Direct Measurement

The moisture within the soil profile can be measured over successive days to calculate the total amount of water being taken up by the crop. This method is useful for monitoring an existing crop but requires a long sequence of records to enable predictions to be made. An example of records from direct measurement is shown in Figure B-1.3 in which the change in soil moisture with time corresponds to plant water use. Details of methods of measurement of soil moisture are set out in Section B-7.2.

B-2.2.2 Reference Crop Evapotranspiration

The evapotranspiration from a crop at a particular stage of growth can be related to a " reference crop" which is usually taken to be green grass of 80 - 150 mm height which is actively growing and is not short of water. The evapotranspiration from the reference crop (ET_o) takes account of climatic factors such as; latitude, altitude and season of the year. The evapotranspiration for our particular crop (ET_c) can then be calculated by multiplying ET_o by a "crop factor" or "crop coefficient" (K_c).

$$ET_c = ET_o \times K_c$$

where the value of K_c takes account of the resistance to transpiration of different types of plants and the stage of development of the plant. It should be noted that this approach permits an estimate of evapotranspiration to be made over a period of several days to a month. It will not provide an accurate estimate of the actual evapotranspiration on any particular day when cloud cover, temperature and wind can cause a wide variation in actual evapotranspiration.

Monitoring of crop water use has provided data on typical values of K_c, such as those quoted in Tables B-2.1 and B-2.2 below. The variation of K_c for a typical crop at different stages of growth is shown in Figures B-2.1 and B-2.2

Table B-2.1 ***Crop factors (K_c) for different crops at maturity and harvesting*** (adapted from Doorenbos & Pruitt, 1977)

CROP	INITIAL	MATURE	HARVEST	AVERAGE
Barley	0.30 - 0.50	1.05 - 1.20	0.20 - 0.25	0.85 - 0.95
Maize (corn)	0.30 - 0.50	1.05 - 1.20	0.55 - 0.60	0.75 - 0.90
Oats	0.30 - 0.50	1.05 - 1.20	0.20 - 0.25	0.75 - 0.85
Sorghum	0.30 - 0.40	1.00 - 1.15	0.50 - 0.55	0.75 - 0.85
Soybean	0.30 - 0.40	1.00 - 1.15	0.40 - 0.50	0.75 - 0.90
Wheat	0.30 - 0.40	1.05 - 1.20	0.20 - 0.25	0.75 - 0.85

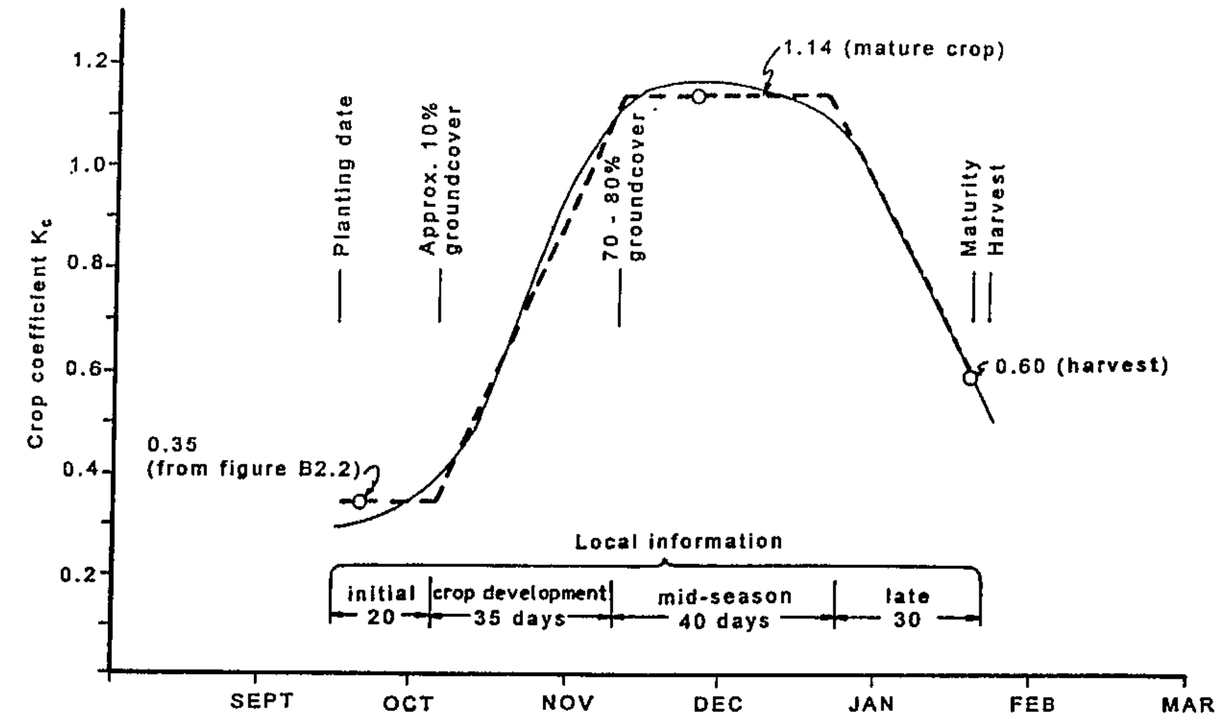


Figure B-2.1 *Example of a crop coefficient curve*

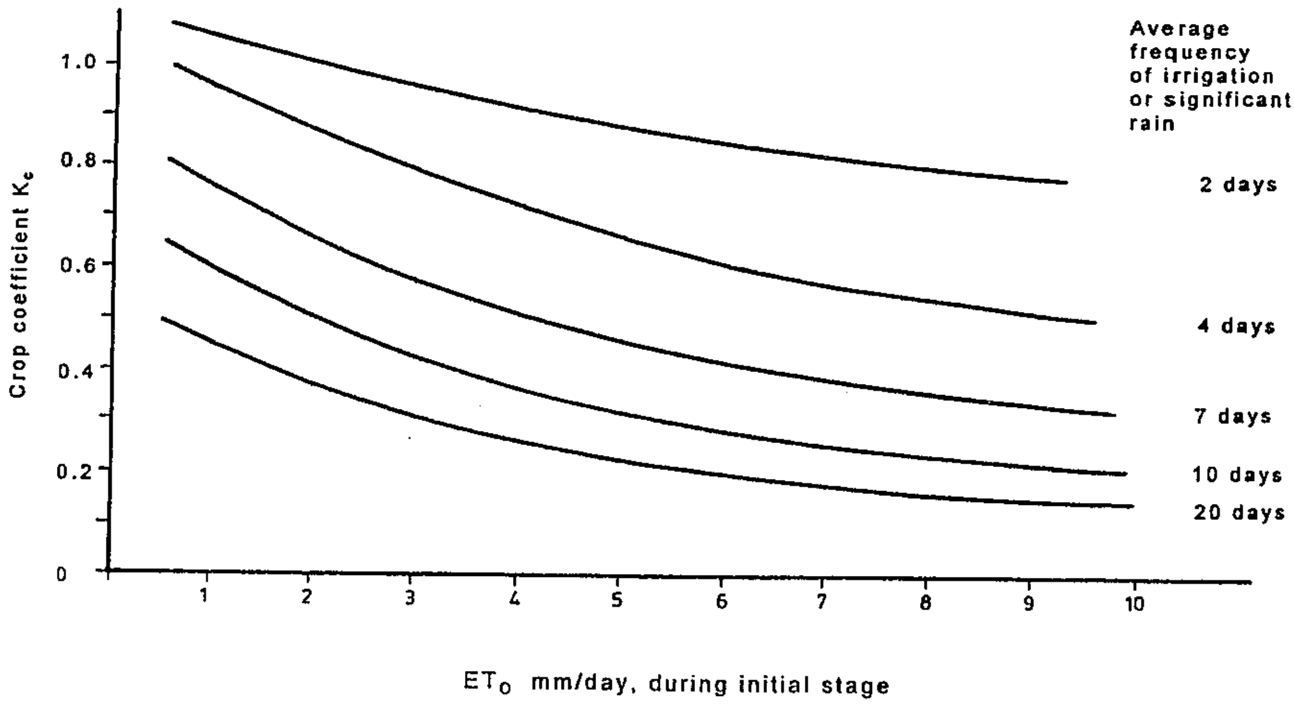


Figure B-2.2 *Graph of average K_c value for initial stage of crop growth*

Table B-2.2. ***Crop factors (K_c) for irrigated pasture, lucerne and eucalypts of various ages***

(adapted from Thomas 1992, NSW Agriculture, Doorenbos & Pruitt 1977)

CROP	SUMMER MAXIMUM			WINTER MINIMUM		
	Before cutting	After Cutting	Mean	Before Cutting	After Cutting	Mean
Lucerne	1.15	0.40	0.95	1.0	0.35	0.85
Pasture	1.10	0.50	0.90	1.0	0.45	0.90
Eucalypts						
- 1 year	0.7			0.55		
- 2-4 years	0.9			0.75		
- > 4 years	1.2			1.10		

The use of crop factors to estimate crop water use is best illustrated by means of some simple examples below.

Example B-2.1 - Estimation of monthly water use by a maize crop on the Darling Downs, Queensland.

Month	ET_o (mm)	K_c	ET_c (mm)
Oct	183	0.20	37
Nov	219	0.50	110
Dec	254	1.10	279
Jan	248	1.15	285
Feb	195	0.90	176
Total	**1,090**		**887**

Example B-2.2 Estimation of monthly water use by a lucerne pasture near Sale, Victoria.

Month	ET_o (mm)	K_c	ET_c (mm)
Jan	164	0.95	156
Feb	144	0.90	129
Mar	107	0.90	96
Apr	66	0.85	56
May	57	0.85	49
Jun	37	0.85	31
Jul	41	0.85	35
Aug	47	0.85	40
Sep	70	0.85	59
Oct	86	0.90	77
Nov	123	0.90	111
Dec	164	0.95	156
Total	**1,106**		**995**

There are a variety of ways in which ET_o, for a particular location, may be estimated. The most accurate methods use detailed climatic data including sunshine hours, average wind speed, air temperature, humidity and other data which are only collected at specialised centres. The methods of calculation are beyond the scope of this manual but are well set out in the publication "Crop Water Requirements" by Doorenbos & Pruitt (1977). There are a number of recording weather stations available in Australia which automatically carry out the daily calculation of ET_o.

B-2.2.3 Evaporation Pans

The simplest method of measuring evaporation is by means of an evaporation pan which consists of a small tank of water (typically 900 - 1,500 mm diameter x 250 - 1,000 mm deep) from which the daily rate of water loss by evaporation is measured (after accounting for rainfall). Details of evaporation pans and sources which can be used to obtain evaporation pan data are set out in Chapter B-3.

Any evaporation pan is an imperfect device for measuring evaporation and directly relating it to the evaporation from a larger body of water or transpiration from grass or a crop. This imperfection stems from the different factors which influence evaporation from a pan (E_{pan}) compared to a pond or green crop. Despite these sources of discrepancy, sufficient data from evaporation pans have been compared to measured losses from crops and open water to allow the derivation of a "pan factor" or "pan coefficient" (K_{pan}).

Thus: $\mathbf{ET_o = E_{pan} \times K_{pan}}$

and: $\mathbf{ET_c = ET_o \times K_c = E_{pan} \times K_{pan} \times K_c}$

There are many factors which affect the value of K_{pan} including the vegetation surrounding the pan. Most Class A pans used for measurement in Australia are surrounded by short green grass for at least 10 m and this standardisation of conditions helps to minimise the range of values of K_{pan} adopted in Australia to 0.7 - 0.85. In general the pan factor is higher when the pan is surrounded by a large area of short green grass, is exposed to light winds and high humidity. Conversely a pan in very exposed conditions with low humidity and high winds tends to have a lower value of K_{pan} (ie the pan tends to lose more water than would be lost from a reference crop).

For most purposes, a value of K_{pan} = 0.8 should be adopted unless there is local data to indicate differently.

NOTE: Take care when adopting a crop factors. Sometimes the "crop factor" is defined as K_{pan} x K_c (as defined above). Beware!

B-2.3 Essential Nutrients

All plants contain 80 - 90% water and 6 - 16% carbohydrates. The remaining 4% is various minerals and elements which are taken up by plants from the soil. Representative proportions of these elements which are essential for plant growth are shown in Table B-2.3. It is easy to see why some elements are referred to as "macro" nutrients and some "micro" nutrients from the amounts found in typical plants.

Table B-2.3 ***Composition of a range of elements in some crops***

ELEMENT	AVERAGE COMPOSITION OF ABOVE GROUND PORTION	LUCERNE (10 t/ha)	MAIZE (10 t/ha of stalks)	MAIZE (7.5 t/ha of grain)
Macro nutrients	(%)	(kg)	(kg)	(kg)
N	3.0 - 5.0	350	110	85
P	0.2 - 0.4	35	20	20
K	2.0 - 3.0	200	135	30
S	0.2 - 0.4	35	16	9
Ca	0.2 - 3.0	100	30	2
Mg	0.1 - 0.3	30	22	8
Micro nutrients	(mg/kg)	(g)	(g)	(g)
Mn	5 - 100	600	1,650	85
Fe	45 - 100	1,500	1,200	105
Zn	10 - 90	450	330	135
Cu	5 - 20	100	50	50

For optimum plant growth, nutrients must be available for plants in solution in the soil water, in appropriate and balanced amounts and at the right time. When deficiencies or gross imbalances occur, plant growth and development can suffer. An effluent irrigation management system needs to balance the ability of the plants and soil to transform the chemicals added against the rate at which they are added. Nutrient excesses or deficiencies can affect yields. Excesses may cause toxic levels of chemicals in plants and affect consumers or the environment. Excess or retained nutrients may eventually contaminate surface or groundwater.

For abattoir effluent the two nutrients of most concern are nitrogen (N) and phosphorus (P). Typical effluent contains 130 - 200 mg/L of N and 30 - 40 mg/L of P, and in most cases this is more than is required for crop growth. However, because the effluent does not contain high levels of other elements, it may be necessary to add fertiliser containing elements such as potassium and sulphur.

The quantities of the main nutrients of concern (N and P) in wheat and lucerne appear to be substantial. However, for most abattoirs which irrigate effluent to the land, the critical factor will be ***the ability***

Vegetable and fruit crops for direct consumption by humans cannot be recommended because of the risk of the transfer of disease pathogens to the crop.

It is usual practice with annual crops to have a rotation of crops and fallow periods with the land unused. Rotations represent good agricultural management practice because they:

- allow the land to be rested between crops,
- prevent the carry-over of pests and diseases between crops,
- allow crops to be grown in sequences which best utilise the soil and climate characteristics (eg planting a maize crop which requires nitrogen after a lucerne or clover rich pasture).

Under a rotation system, the land does not have a crop growing in it for part of the year. A consequence of this may be an increase in the area required for effluent irrigation.

The seasonal pattern of water use by annual crops is different from that of pasture. Generally when the crop has established full ground cover it will have water use rates as high as, and often higher than, pastures (see Table B-2.1). Total water use by summer crops (450 to 900 mm) can be comparable to the total water use by a perennial pasture but is concentrated in the growing period. Winter crops use less water than summer crops although they can still use significant amounts. For example winter wheat in south eastern Australia requires about 600 mm.

Nutrient removal by an annual crop is less than that for pasture. It is worth noting that the relative proportions of nutrients removed will differ. Potassium is the most noteworthy of these as its levels are high in leaf and stem material. Harvesting a pasture removes large amounts of potassium relative to that removed by harvesting grain crops. This may mean that continual harvesting and removal of pastures will lead to potassium deficiencies in a shorter time than with grain crops.

Generally, annual crops have higher requirements for management input and capital than pasture. Land preparation, sowing, irrigation, cultivation, harvesting and marketing are all increased in cropping as opposed to pasture. Input costs, machinery needs and management input are all likely to increase. Regulations are likely to impose constraints on the application of effluent on these crops if they are intended for human consumption.

B-2.4.3 Woodlots

The use of tree plantations or woodlots is another potential crop for effluent irrigation. The attraction of trees for effluent irrigation is that, once planted, they require minimal management inputs for a number of years. In the early years the rate of water use can be expected to be less than that in a pasture or field crop, but thereafter the demand

B-2.4.1 Pastures

Pastures are generally perennial crops (ie they keep growing from year to year without needing replanting). Their year round growth maintains some need for water and nutrients throughout the year. The main features of irrigated pastures are set out in Table B-2.4.

Table B-2.4 ***Features of pastures for irrigation with effluent***

ADVANTAGES	DISADVANTAGES
• Relatively low level of management effort • Minimal machinery requirements for hay production	• Nutrient and water uptake not as high as for planted crops • Nutrient removal reduced if area is grazed • Grazing should not occur less than 10 days after irrigation

Nutrient uptake is reasonable with pasture. For example, a lucerne crop producing 10 t/ha of hay would remove 350 kg of N and 35 kg of P per ha. However, lucerne, in common with all leguminous plants, fixes some nitrogen from the atmosphere. This characteristic is often used in agricultural production to increase the nitrogen level in the soil prior to planting a crop, such as maize, which needs nitrogen. Before lucerne is used in a pasture the overall nitrogen balance within the system will need careful evaluation. While all legumes have the ability to fix nitrogen, under high soil nitrogen conditions the use of nitrogen from the air is reduced so that large amounts of nitrogen added in effluent could still be removed.

Grazing of a pasture reduces nutrient removal significantly because as much as 90% of the nutrients are recycled by the animals. Pastures, once established, have reasonably predictable management requirements and do not usually require large amounts of capital input or management input and are therefore favoured for use in effluent irrigation areas.

2.4.2 Annual Crops

Annual crops are ones which must be planted each year although the growing period of any particular crop will be generally of the order of six months. A distinction is usually made between "summer" and "winter" crops depending on when the normal growing season occurs.

The list of crops which can be grown under irrigation is almost endless. In most situations in which abattoir effluent is being irrigated, however, annual crops like cereals, legumes, and oilseeds could be considered.

Example B-2.3 Nitrogen and phosphorus loading from effluent

For the maize crop grown on the Darling Downs (Example B-2.1 above), assume that:

- Effluent is applied in a year when median rainfall occurs
- 80% of rainfall is available to the crop
- Effluent contains 130 mg/L of N and 35 mg/L of P

If irrigation is applied to meet the full crop water demand, then the following amounts of irrigation water will be required:

Month	ET_c (mm)	Rain (mm)	Irrigation (mm)
Oct	37	63	0
Nov	110	80	30
Dec	279	105	174
Jan	285	122	163
Feb	176	90	86
Total	**887**		**453**

The application of 453 mm (or 4.53 ML) of water per ha would contain:

- 589 kg of N
- 158 kg of P

If the crop produced 10 t/ha of grain and 13.5 t/ha of stalks then (from the data in Table B-2.3 above multiplied by 1.33 to account for greater yield) the overall mass balance of N and P would be:

	N (kg/ha)	P (kg/ha)
Grain	115	27
Stubble	145	27
Total in crop	260	54
Total applied	589	158
Excess	**329**	**104**

If effluent is applied to meet only half the total requirement for irrigation then the total yield will be reduced (to say 7.5 t/ha), but we may get nearer to a balance for N:

	N (kg/ha)	P (kg/ha)
Grain	85	20
Stubble	110	20
Total in crop	195	40
Total applied	295	80
Excess	**100**	**40**

From this example it can be seen that the ***nutrient load is the factor which limits how much effluent can be applied***, not the water.

of a crop and soil to utilise, transform or immobilise nutrients rather than the rate at which water is used. This important point is illustrated in the Example 2.3 below. From the data in Example 2.3 it can be seen that, even if the irrigation water is reduced to half that needed to meet the full "requirements" of the crop, there will still be an excess of nitrogen and phosphorus added to the land. Also, unless the crop is removed from the area where it is grown, a lot of the nutrients in the crop will be recycled back to the soil. ***It is therefore good management practice to harvest the crop from the effluent irrigation area so that nutrients are removed.***

Further details of how to analyse the nutrient balance of an irrigation area are set out in Section B-2.6.

B-2.4 Crop Types

Choice of crop type to be grown in an effluent irrigation area will involve consideration of many factors including:

- The characteristics of the site, including consideration of soil type, topography and climate.
- The effort which will be required to manage the irrigation area, including consideration of:
  - level of management of irrigation application
  - cultivation, planting and harvesting operations
  - management of grazing stock
  - marketing of agricultural products
  - weed control
  - machinery requirements and costs.
- Possible need for tolerance to high levels of particular constituent such as salinity.
- Ability to accumulate nutrients - if nutrient loads are high then crops capable of using these nutrients will be preferred.
- Water requirements - crops with high water use may not necessarily be the best because water is often in short supply compared to the mass of nutrients to be got rid of.
- Financial considerations - capital costs, operating costs.

The five activities that should be considered for an effluent irrigation area are:

- pastures,
- annual crops,
- woodlots,
- special horticultural crops,
- turf farming.

The previous sections have provided some background concerning the water and nutrient requirements of a range of crops. This section focuses on some of the other considerations to be taken into account in considering the cropping system to be adopted for an effluent irrigation area.

for water can be expected to be high. Water use rates up to 1.5 times the amount used by permanent pasture (see Table B-2.2) have been claimed. In recent years there have been a number of trials of eucalypt woodlots for the disposal of municipal effluent. Spectacular rates of growth have been achieved in these trials.

Eucalypts use reasonable amounts of nitrogen in the first one or two years of rapid growth. However, once a full canopy has been established, the accumulation of nutrients in the plants declines and nutrient recycling from leaf drop becomes significant. Trees will only, therefore, be suitable where the nutrient load applied to the land is relatively low. This is not the case with abattoir effluent.

The perceived benefits of tree plantations are both aesthetic and practical and can be summarised as:

- aesthetically pleasing and high amenity value,
- promote a green image,
- help reduce greenhouse gases,
- use more water than crops,
- a product that can be harvested.

The local environment, eg soil and climate, will have a significant impact on the success of any plantation. However, this affects all crops in a similar way. The success of the plantation depends on its ability to make use of three variables contained in the effluent: water, nutrients and salt. If any one of these variables becomes unbalanced (ie, inputs greater than output or reverse) then there is potential for land degradation and pollution.

Nutrient Use

Tree growth is characterised by two stages: an initial rapid growth period followed by a self sustaining period of growth. In the initial stages of growth, trees have high nutrient demands. Typically in the first five years, uptake capacity is high as the tree size increases logarithmically.

However once "canopy closure" (leaf foliage from one tree touches the foliage of the adjacent tree) occurs, nutrient uptake declines sharply because foliage growth essentially ceases (nutrients are largely required for leaf growth). After maturation the majority of growth occurs in the stem, that has relatively few nutrient demands. If nutrients continue to be added to trees after canopy closure has occurred, and these levels exceed the nutrient requirements of the tree, there is a risk that the excesses will leach into the groundwater or runoff into local waterways.

In order to maintain high level of nutrient uptake, the foliage would need to be harvested and removed from the effluent site. If the main trunk is harvested and the foliage left to decompose on site, the nutrients will be recycled on the site.

Water Use

Trees typically require more water than field crops in the initial rapid growth period and, because of their large leaf mass at maturity, have a large evaporation potential. All species have a limited capacity to absorb water, and there is little evidence to support claims of very high water usage. A plant will absorb water to a point and thereafter any additional water will leach into the groundwater or runoff into the nearest waterway. Trees also have seasonal variations in water uptake, and therefore a constant water input may be inappropriate and detrimental to the health of the plant.

The maximum water absorption occurs when the plant has reached maximum foliage cover. At the point where nutrient uptake is declining, water loss is a maximum. If the plantation is harvested at this stage to maintain nutrient uptake, there will be a serious decline in the water usage.

Woodlots should only be considered seriously where there is expert advice available and where the proposed nutrient and water balances have been thoroughly checked.

Uses of Trees

Trees do offer potential benefits to effluent disposal if they are used in conjunction with a harvested crop. One suggestion is to plant trees along the periphery of the disposal area, minimising the risk of water escaping from it, while the majority of the site is occupied by a seasonal crop such as lucerne. The deep roots of the tree would capture any effluent that infiltrated below the shallow roots of the lucerne, and prevent effluent leaching into the groundwater. The lucerne would help remove nutrients and the majority of the water. Salt remains the most difficult issue to manage.

2.4.4 Horticultural Crops

Because of the threat of transfer of pathogens from the effluent to the harvestable portion of the crop, irrigation of horticultural crops should only be considered where:

- The harvestable portion of the crop is well away from the ground. (eg fruit or nut trees)

- Spray irrigation is **not used**. Surface irrigation or trickle irrigation could be considered.

Because of the problems of keeping the crop free of pathogens and the high level of management expertise which will be needed, horticultural crops should only be considered for irrigation with abattoir effluent when specialist advice has been sought.

2.4.5 Turf Farming

Turf farming provides opportunity for use of abattoir effluent which has a number of advantages:

- The varieties of grass used for turf are usually fast growing and require high nutrient levels for rapid growth to a stage where it can be cut.
- The turf taken from the field also carries a small depth of soil, effectively "mining" the soil resource and removing accumulated nutrients, particularly phosphorus.

While turf farming requires special expertise and equipment, the potential for high returns might warrant serious consideration of this enterprise for utilisation of abattoir effluent.

B-2.5 Rotation and Management of Land

Rotations are used in farming to address problems of sustainability, both financial and environmental. In a waste management system, rotations will have a number of roles:

1. **Efficient water use** - to make best use of water and nutrients, crops will need to be available all year round or while waste can be supplied. A mix of summer, winter and possibly perennial or tree crops may be needed to achieve this.

2. **Restore physical structure** - if intensive irrigated crops are grown, soil compaction may result. A rotation with a pasture phase may be used to restore structure.

3. **Excess nutrients** - excessive amounts of nutrients such as phosphorus or nitrogen may accumulate when effluent is supplied. A subsequent unirrigated crop may be needed, especially one which is hungry for these nutrients.

4. **Salinity and Sodicity** - a build-up of salts or sodium from the waste water supplied may limit the amount of effluent that can be added to the land. The monitoring of sodium and salt levels is needed to establish if problems are going to appear. The use of salt and sodium tolerant varieties may be useful. Adding gypsum or lime to the soil helps reduce sodicity problems.

   Soils with low permeability are not suitable for use in systems with high salinity / sodium levels. Soils with a medium level of permeability may have problems which can probably be overcome by good management. Highly permeable soils will have salts and sodium leached readily from the soil. This leaching of nutrients including phosphorus and nitrogen will also be a concern.

5. **Other considerations** - these include weed management, stubble management, erosion and market availability for crops grown.

The way in which the soil is treated and the rate of effluent application can have a significant impact on soil structure. Section B-1.8 outlines the important considerations for preserving soil structure which include:

- Controlling the SAR of the soil (by addition of gypsum if necessary) so that dispersion is minimised.
- Maintaining organic matter to assist in preserving good soil structure.
- Minimising the movement of tractors and machinery over irrigated soils, particularly for a few days after effluent has been applied, in order to minimise compaction and physical breakdown of soil structure by the wheels.

B-2.6 Nutrient Removal by Harvesting

If large amounts of nutrients are being added to a land, then eventually they have to be removed or excesses occur. The obvious way to do this is by harvesting crops. The nutrient content of a crop depends on the nutrient availability and the environmental growing conditions. Figure B-2.3 illustrates the relationship between nutrient supply and crop yield. It can be seen that yield increases as the amount of nutrient supplied increases until a point is reached where there is sufficient nutrient to meet the plant's requirements.

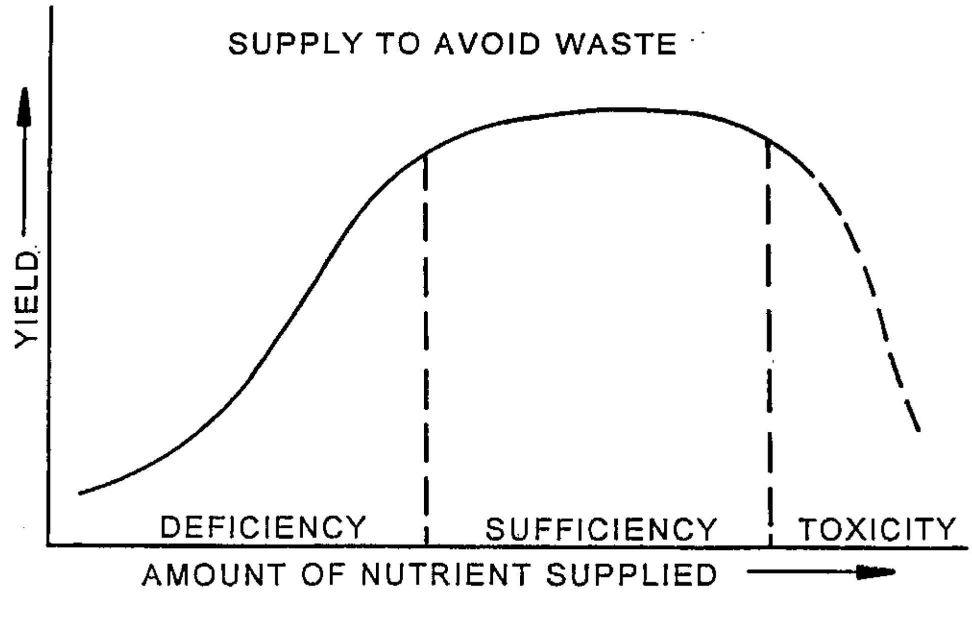


Figure B-2.3 ***Relationship Between Yield and Nutrient Supply***

Increasing nutrient supply further does not increase yield and eventually the point is reached where toxic concentrations are present. Figure B-2.4 shows that once the critical level of nutrient is reached, relative yield cannot be increased but the concentration of nutrients in the plant can be increased. Eventually yield will suffer through nutrient toxicity.

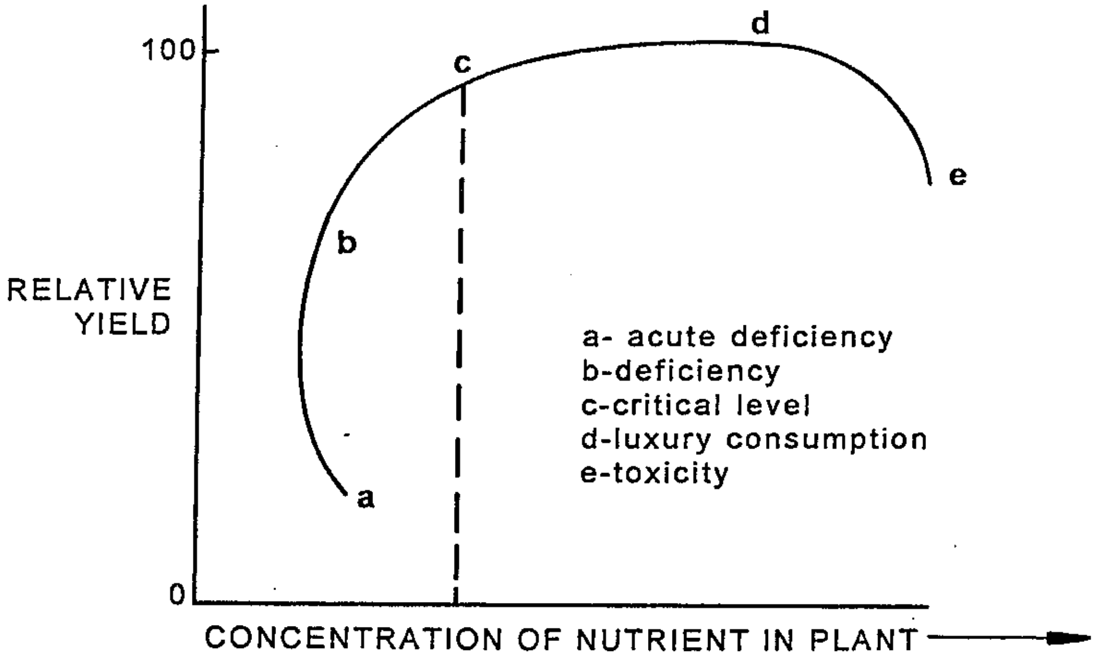


Figure B-2.4 ***Relationship Between Yield and Nutrient Content in the Plant***

In general, the total nutrient uptake increases as yield increases. These nutrients may be viewed as being temporarily stored in the crop in a form suitable for removal as a useful product. In order to successfully use irrigation as a method for disposal of abattoir effluent, the ***crop must be harvested and removed from the field.*** Nutrient concentrations are highest around flowering, therefore harvesting a fodder crop a number of times just after flowering would maximise nutrient removal.

Uptake by Plants

Table B-2.5 shows typical percentages of nutrients present in a range of crops. The mass of a particular nutrient removed from an irrigation area may be estimated from the appropriate percentage of the nutrient in Table B-2.5 multiplied by the expected yield of the crop. (The accuracy of the estimated mass of nutrient removed can be improved if actual crop yield and measured nutrient concentrations are used in the calculation.)

Table B-2.5 ***Plant nutrient removal in the harvested part of specific crops.***
(adapted from Lemunyon, Cropper and Geter, 1992)

CROP	TYPICAL DRY WEIGHT (t/ha)	AVERAGE CONCENTRATION OF NUTRIENTS (% of dry harvested material)								
		N	P	K	Ca	Mg	S	Cu	Mn	Zn
Grain Crops										
Barley	2.7 grain	1.82	0.34	0.43	0.05	0.10	0.16	0.0016	0.0016	0.0031
	2.2 straw	0.75	0.11	1.25	0.40	0.10	0.20	0.0005	0.0160	0.0020
Buckwheat	1.6 grain	1.65	0.31	0.45	0.09			0.0009	0.0034	
	1.1 straw	0.78	0.05	2.26	1.40		0.01			
Corn	7.5 grain	1.61	0.28	0.40	0.02	0.10	0.12	0.0007	0.0011	0.0018
	10.0 stover	1.11	0.20	1.34	0.29	0.22	0.16	0.0005	0.0166	0.0033
Oats	2.9 grain	1.95	0.34	0.49	0.08	0.12	0.20	0.0012	0.0047	0.0020
	4.5 straw	0.63	0.16	1.66	0.20	0.20	0.23	0.0008	0.0030	0.0072
Rice	6.2 grain	1.39	0.24	0.23	0.08	0.11	0.08	0.0030	0.0022	0.0019
	5.6 straw	0.60	0.09	1.16	0.18	0.10			0.0316	
Rye	1.9 grain	2.08	0.26	0.49	0.12	0.18	0.42	0.0012	0.0131	0.0018
	3.4 straw	0.50	0.12	0.69	0.27	0.07	0.10	0.0300	0.0047	0.0023
Sorghum	3.4 grain	1.67	0.36	0.42	0.13	0.17	0.17	0.0003	0.0013	0.0013
	6.7 stover	1.08	0.15	1.31	0.48	0.30	0.13		0.0116	
Wheat	2.7 grain	2.08	0.62	0.52	0.04	0.25	0.13	0.0013	0.0038	0.0058
	3.4 straw	0.67	0.07	0.97	0.20	0.10	0.17	0.0003	0.0053	0.0017
Oil Crops										
Peanuts	3.1 nuts	3.60	0.17	0.50	0.04	0.12	0.24	0.0008	0.0040	
	2.5 vines	2.33	0.24	1.75	1.00	0.38	0.36		0.0051	
Canola	2.0 grain	3.6	0.79	0.76		0.66				
	6.7 straw	4.48	0.43	3.37	1.47	0.06	0.68	0.0001	0.0008	
Soybeans	2.4 beans	6.25	0.64	1.90	0.29	0.29	0.17	0.0017	0.0021	0.0017
	4.5 stover	2.25	0.22	1.04	1.00	0.45	0.25	0.0010	0.0115	0.0038
Sunflower	1.2 seeds	3.57	1.71	1.11	0.18	0.34	0.17		0.0022	
	9.0 stover	1.50	0.18	2.92	1.73	0.09	0.04		0.0241	
Fibre Crops										
Cotton	0.7 lint	2.67	0.58	0.83	0.13	0.27	0.20	0.0040	0.0073	0.0213
	1.2 seeds	1.75	0.22	1.45	1.40	0.40	0.75			
Forage Crops										
Lucerne	9.0	2.25	0.22	1.87	1.40	0.26	0.24	0.0008	0.0055	0.0053
Bromegrass	11.0	1.87	0.21	2.55	0.47	0.19	0.19	0.0008	0.0052	
Bluegrass	4.5	2.91	0.43	1.95	0.53	0.23	0.66	0.0014	0.0075	0.0020
Guineagrass	22.0	1.25	0.44	1.89		0.43	0.20			
Paragrass	24.0	0.82	0.39	1.59	0.39	0.33	0.17			
Red Clover	5.6	2.00	0.22	1.66	1.38	0.34	0.14	0.0008	0.0108	0.0072
Ryegrass	11.0	1.67	0.27	1.42	0.65	0.35				
Tall fescue	4.0	1.97	0.20	2.00	0.30	0.19				
Silage Crops										
Lucerne	20 wet/10 dry	2.79	0.33	2.32	0.97	0.33	0.36	0.0009	0.0052	
Corn	40 wet/14 dry	1.10	0.25	1.09	0.36	0.18	0.15	0.0005	0.0070	
Forage	40 wet/12 dry	1.44	0.19	1.02	0.37	0.31	0.11	0.0032	0.0045	
Sorghum/ Oats	20 wet/8 dry	1.60	0.28	0.94	0.31	0.24	0.18			
Sorghum/ soudan	20 wet/10 dry	1.36	0.16	1.45	0.43	0.34	0.04		0.0091	

Uptake by Animals

If the effluent irrigation area is used for grazing livestock, then allowance must be made for the nutrients returned to the land by the animals. This is usually expressed in two ways:

- the net ***removal*** of nutrient per animal per year which may be estimated from the average removal per animal and the average number of animals on the land for the whole year. Representative values for the mass of nutrients in various types of livestock are given in Table B-2.6.
- the amount of nutrient ***returned*** to the land per animal per year. As there is no way of actually measuring the mass of crop eaten in the first place, this method appears less reliable.

Table B-2.6 ***Nutrient removal by livestock***

LIVESTOCK	PART	YIELD	NUTRIENTS REMOVED (kg/ha)		
			N	P	K
Beef	Live weight	1250 kg/ha	34	9	2.5
Dairy Cattle	Whole milk	3500 L	21	3.5	7
Lambs	Live weight	400 kg/ha	8	2	1
Sheep	Wool		4	0.25	3

Examples

Examples B-2.4 and B-2.5 below illustrate a number of significant points about managing effluent irrigation:

1. The amount of effluent which can be applied to the land is limited by the ability of the agricultural enterprise to absorb and remove the nutrients contained in the water.
2. A larger amount of effluent can be applied to the land if a crop is harvested and removed, than if domestic livestock are allowed to graze on the area.
3. The processes of nitrogen loss by volatilisation, during irrigation application, and denitrification in the soil remove more nitrogen than is removed by the crop in this example.

Although nutrient removal by crops and animals plays an important role in achieving a balance of nutrients, other processes (discussed in Chapter B-1) also play an important role:

- ***nitrogen loss during irrigation water application***
- ***denitrification within the soil***
- ***adsorption of phosphorus onto clays.***

Example B-2.4 Nitrogen and phosphorus balance: irrigated ryegrass pasture producing hay

Assumptions:

- Rainfall is 600 mm
- Net irrigation demand for the year is 900 mm
- Effluent contains 140 mg/L of N and 35 mg/L of P
- Full production with adequate water and nutrients - 11 t/ha
- Production declines by 5% for every 100 mm shortfall of water
- Nitrogen and phosphorus contents of ryegrass taken from Table B-2.5
- Nitrogen losses: 10% volatilisation in irrigation, 20% denitrification in soil

Note: in calculations below all values are <u>per ha</u>.

A) Irrigate to meet full water demand
- hay production is 11 t

Added by effluent	1260 kg (N), 441 kg (P)
Removed by crop	184 kg (N), 30 kg (P)
Losses in irrigation and soil	378 kg (N)
Excess nutrient	**698 kg (N), 411 kg (P)**

B) Irrigate to meet nitrogen demand
- apply 110 mm of irrigation
- hay production 6.7 t

Added by effluent	154 kg (N), 54 kg (P)
Removed by crop	111 kg (N), 18 kg (P)
Losses in irrigation and soil	43 kg (N)
Excess nutrient	**0 kg (N), 36 kg (P)**

Note:

1) Even when a balance in nitrogen usage is achieved, there is still an excess of phosphorus.

2) The calculation required to determine how much water will just meet the nitrogen requirement involves an iterative process - details of this are set out in Section B-6.2

Example B-2.5 : Nitrogen and phosphorus balance: irrigated ryegrass pasture grazed for beef production

Assumptions:

- Rainfall is 600 mm
- Net irrigation demand for the year is 900 mm
- Effluent contains 140 mg/L of N and 35 mg/L of P
- Full production with adequate water and nutrients - 11 t/ha of grass
- Beef cattle require 4 t of fodder/year
- Production declines by 5% for every 100 mm shortfall of water
- Nitrogen and phosphorus contents of cattle taken from Table B-2.5
- Nitrogen losses: 10% volatilisation in irrigation, 20% denitrification in soil

Note: in calculations below all values are per ha.

A) Irrigate to meet full water demand

- hay production is 11 t
- cattle fattened 2.75

Added by effluent	1260 kg (N), 441 kg (P)
Removed by cattle	94 kg (N), 25 kg (P)
Losses in irrigation and soil	378 kg (N)
Excess nutrient	**788 kg (N), 416 kg (P)**

B) Irrigate to meet nitrogen demand

- apply 55 mm of irrigation
- hay production 6.3 t
- cattle fattened 1.6

Added by effluent	77 kg (N), 27 kg (P)
Removed by cattle	54 kg (N), 14 kg (P)
Losses in irrigation and soil	378 kg (N),
Excess nutrient	**0 kg (N), 13 kg (P)**

Note:

1) *Even when a balance in nitrogen usage is achieved, there is still an excess of phosphorus.*

2) *The calculation required to determine how much water will just meet the nitrogen requirement involves an iterative process - details of this are set out in Section B-6.2.*

Because the ability of a crop to take up the nitrogen and phosphorus usually determines how much effluent can be applied, a variety of management strategies must be applied to ensure that an overall balance is achieved:

- reduce the nutrient load in the effluent by:
  - reducing the loading of nutrients captured by the effluent (source reduction),
  - increasing the level of treatment which might help reduce the nitrogen load (but will not reduce phosphorus unless chemical dosing is employed).
- dilute the effluent with water so that both the water demand and the crop nutrient requirement are met simultaneously.
- "rest" the land from irrigation and grow one or more crops using rainfall only. This will allow the subsequent crops to take up the excess nutrients remaining in the soil.

Further details of how to balance the amount of nitrogen and phosphorus which can be applied while also meeting the water needs of the crop are set out in Section B-6.1.

B-2.7 Nutrient Uptake and Cycling

Nutrients can undergo a number of transformations in the soil which are illustrated in Figure B-2.5. These include:

- Absorption of soluble forms and nutrient uptake by plants.
- Breakdown and incorporation into soil organic matter by soil organisms. Further breakdown into gases, which may enter the atmosphere, or soluble forms, which enter the soluble pool.
- Leaching of soluble forms below root zone, potentially into the groundwater.
- Removal by erosion
- Fixation to exchange sites
- Formation of insoluble compounds
- Release to atmosphere from plants.

Generally for annual crops such as barley, nutrient uptake follows an S shaped curve (Figure B-2.6). The usual pattern is for a low uptake in the early stages of growth as the plant establishes a root system while above-ground growth is slow. Then follows a period of rapid above-ground growth and high nutrient uptake. This rapid uptake and growth usually decrease after flowering as the plant matures. It can be seen that uptake is highest at times of rapid growth. Perennial pastures will follow a similar pattern with high rates of uptake at periods of rapid growth, tapering off as the pasture approaches maturity. During periods of dormancy or low growth, uptake is low.

The soil acts as a store or buffer for most elements during periods of low uptake but it is important to realise that the addition of high nutrient loads during periods of low uptake leads to a higher risk of leaching. If the elements are not leached, then they will be available to the crops when growth recommences.

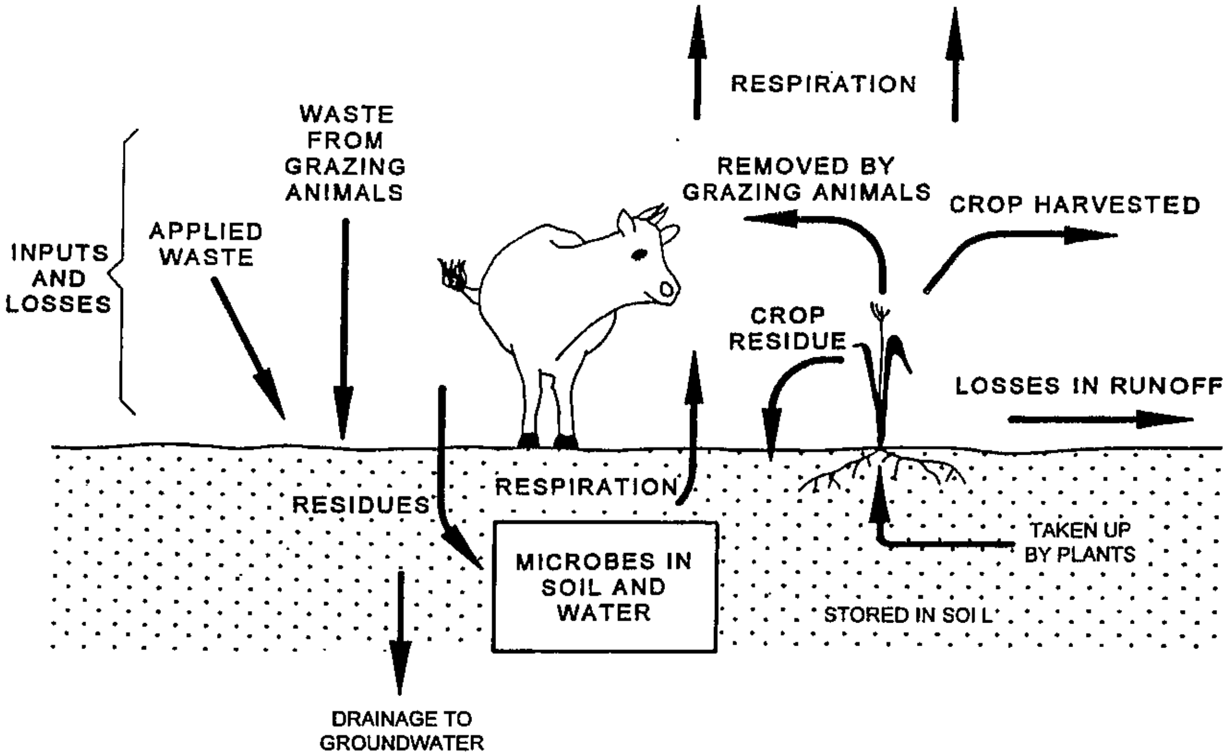


Figure B-2.5. ***General diagram of nutrient cycling in plant soil system.***

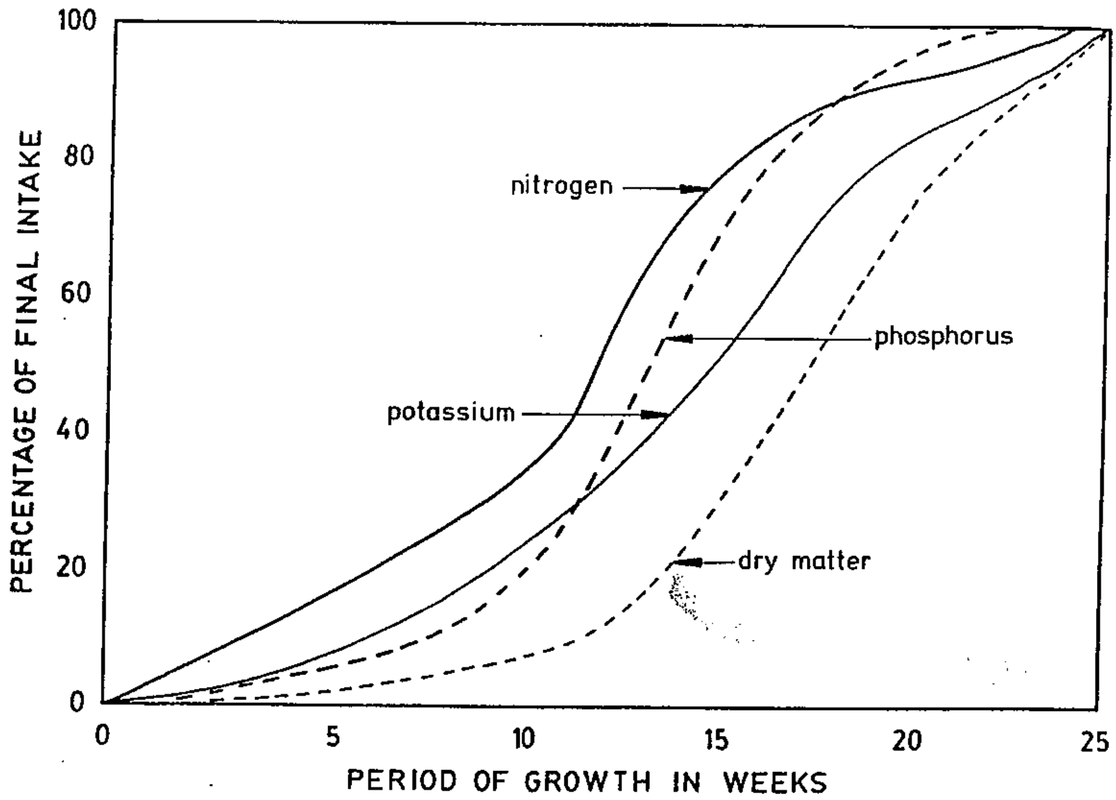


Figure B-2.6 ***Uptake of nutrients and production of dry matter in barley***

B-2.7.1 Essential Nutrients

Nitrogen

Nitrogen (N) is generally the key element in any cropping system and this will also be the case in waste re-use systems. It is the element that most often limits plant growth and yield. More nitrogen is removed by a crop than any other nutrient. This makes it a very valuable resource when it is available in waste. If the yield of a crop is to be maximised, it is essential that nitrogen levels are sufficient. Rates of nitrogen needed are dependant upon crop, yield, soil temperature, organic matter levels and crop fixation.

Excess levels of N are also a key factor in waste disposal. If high levels of N are applied, in excess of plant needs, then there will be high levels of soluble nitrates present in the soil. The potential for pollution of surface and groundwaters will increase due to high solubility and mobility of nitrates.

Phosphorus

Phosphorus is an important element for plant growth. Many Australian soils are phosphorus deficient. Phosphorus is relatively immobile in the soil due to its low solubility characteristics. Soils can absorb large quantities of phosphorus, however, there will be a point reached where soluble phosphorus levels and the potential for leaching of phosphorus will be of concern. One advantage may be that one large application of phosphorus can be made with low risk to ground and surface waters.

Potassium, Calcium and Magnesium

All three elements have very similar behaviour. They all are positive cations of similar size and uptake characteristics. A nutrient imbalance caused by the over or under application of one of these elements could cause problems. When mineralised, each forms cations that are strongly bound to negatively charged clay and organic matter. All can be leached but appear to present few, if any, problems in groundwater. Excess addition increases total dissolved salts in the soil profile.

Large quantities of potassium are present in leaves and stems and large amounts are removed if these parts are harvested. In some soil, potassium is limited. It is more mobile than phosphorous but much less mobile than nitrogen.

Calcium and magnesium are present in smaller quantities and the ratio of the two is important. In nearly all soils which are neutral or only slightly acidic, there should be no problems. When acidity rises, magnesium replaces calcium at the cation exchange sites and the ratio of calcium to magnesium may fall below 1. In these conditions, crops with a high calcium requirement may be sensitive to the relatively high concentration of magnesium found in acidic soils.

Sulphur

Sulphur exists in soil in either organic matter or, in the inorganic form, as sulphate. When a nitrogen: sulphur ratio is greater than 17:1, a soil may be regarded as being sulphur deficient. Sulphur deficiencies usually arise as a result of the following situations:

- Soils where parent material is low in sulphur, highly weathered or highly leached, are naturally deficient.
- The organic source of sulphur can be depleted through intense cultivation history and product removal.

- Sulphate is readily leached below root depth, especially in sandy soil or in areas of high rainfall.

- Crops such as lucerne, sorghum and cotton have high sulphur requirements. If the sulphur removed in the crop is not replaced with fertiliser, deficiencies may occur.

In most agricultural areas of Australia, the natural sulphur deficiency of many soils has been overcome with the widespread use of superphosphate fertiliser which contains sulphur.

B-2.7.2 Deficiencies of Essential Nutrients

This can occur through a shortage of nutrients supplied by the soil or through interference in the uptake of essential nutrients because of an excess of another element. A soil analysis and local knowledge will establish base levels of nutrients. This will indicate whether soils are deficient in certain elements and help ensure that all the essential nutrients are available in sufficient quantity for the crops grown. If soils are being sampled for analysis of nutrient levels, it is desirable that multiple samples be taken from different locations in the field in order to account for the natural variability which occurs across a field.

B-2.7.3 Excesses of Nutrients

The presence of high levels of nitrates can lead to nitrate toxicity in pastures. High NH_3 and NH_4^+ around the seeds can cause germination problems. A high level of NH_4^+ can replace cations on soil particles releasing calcium, potassium, and magnesium and increasing soluble salt levels and acidity.

B-2.7.4 Trace Element Toxicity

If wastes that have high levels of trace elements are applied over a long period of time, trace element toxicity to plants, animals and humans can occur. Some crops such as wheat, barley and bean crops are sensitive to boron concentration. Levels of boron which might reduce growth are usually associated with groundwater sources with high levels of boron. Because of the wide variety of possible influences of trace elements on crop growth, an agronomist should be consulted if the leaves of the crop show abnormal colour.

B-2.8 Salt Tolerance

Applied effluent will contain some level of soluble salts. If these salt levels are high and the salts are not leached from the root zone, then the salt levels in the soil will eventually reduce plant growth. If the irrigation area receives low rainfall or irrigation water is used which contains salts, then salt build-up is likely. Soil salinity is most likely to occur if there is a significant amount of salt in the water supply (say, more than 200 μS/cm) or if salt is used in abattoir processes (such as salting skins). If salts begin to build-up, then some action will need to be taken to leach salts out of the root zone. (This topic is discussed in detail in Section B-6.3.) Alternatively, a rotation of the effluent onto a new area will halt the build-up of salts and rainfall may eventually leach salts from the profile. Soils with low permeability and, therefore, low leaching should be avoided as salts will be difficult to remove from the profile once they are applied.

Table B-2.7 shows how salinity can affect plant growth and yield. Salt tolerance of a range of pasture/fodder species is expressed in terms of the soil salinity threshold causing yield reduction and the percentage yield decrease per dS/m increase in soil salinity.

Table B-2.7 ***Salinity tolerance of some pasture species.***

(adapted from Shaw et al, 1987)

TOLERANCE	CROP	SOIL SALINITY (dS/m)	PRODUCTION DECREASE (% per dS/m)
Low	White Clover	1.5	12.1
	Forage Corn	1.8	7.4
	Sertaria	2.4	12.2
	Paspalum	1.8	9.0
	Townsville Stylo	2.4	20.4
Medium	Lovegrass	2.0	8.5
	Lucerne	2.0	7.3
	Green Panic	3.0	6.9
	Pangola	2.0	4.0
	Sudangrass	2.8	4.3
	Oats	5.0	20.0
	Fescue	3.9	5.3
High	Wheatgrass	7.5	6.9
	Kikuyu	3.0	3.0
	Barley	6.0	7.0
	Buffel	6.9	6.8
	Couch	6.9	6.3
	Rhodes	7.0	3.2
	Sorghum	8.3	11.2

CHAPTER B-3: CLIMATE

Climate is one of the key factors which governs how an effluent irrigation system should be designed and operated. There are many different aspects to climate which have an important bearing on how an effluent irrigation system should be operated:

- *Average annual rainfall and evaporation*
- *Seasonal rainfall pattern*
- *Occurrence of high intensity storm rainfall*
- *Variation in rainfall between wet and dry years*
- *Temperature variation throughout the year*
- *Peak summer rate of evaporation*

Because this manual is designed for use by abattoirs throughout Australia, there is not sufficient space to deal with the details of all the different climatic zones. This chapter provides an overview of the important aspects of climate and provides some guidance on where to obtain the data which is essential to the successful design and operation of an effluent irrigation system

CONTENTS

B-3.1 Australian Climatic Zones

A very useful classification of the general climate which affects effluent irrigation is the classification developed by the Bureau of Meteorology, a simplified version of which is shown in Figure B-3.1. The basis for the classification is summarised in Table B-3.1.

Table B-3.1 ***Climatic Zone Characteristics***
(adapted from Climatic Atlas of Australia, 1988)

	Climate Type	Season of Main Rainfall	Seasonal Ratio[1]	Median Annual Rainfall (mm)
1	Temperate	Winter	>3.0	500-800
2	Temperate	Winter	1.3-3.0	250-800
3	Temperate	Uniform	<1.3	250-800
4	Sub-tropical	Summer	>1.3	350-1200+
5	Tropical	Summer	>3.0	350-1200+
6	Arid	Summer	>3.0	<350
7	Arid	Winter	>3.0	<250

[1] Ratio of greater seasonal rainfall : lesser seasonal rainfall
(**Summer** = November - April, **Winter** = May - October)

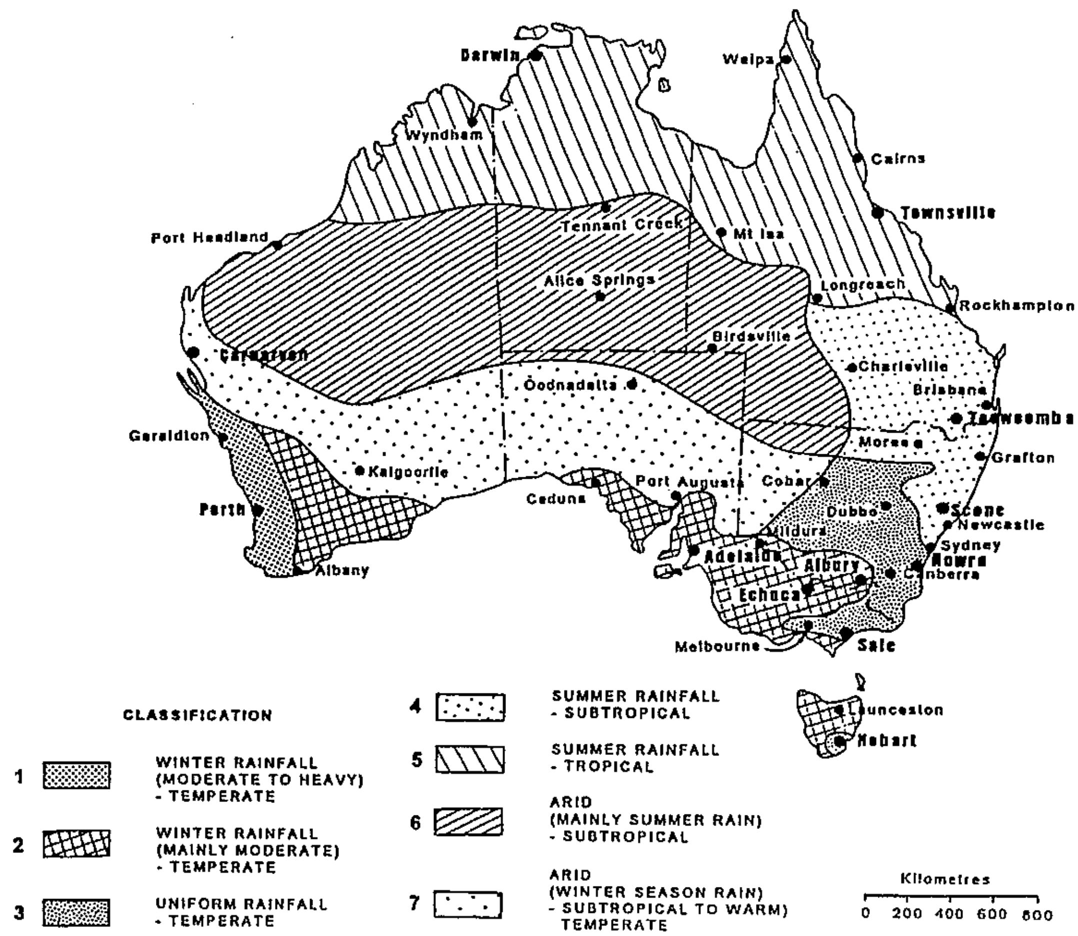


Figure B-3.1: ***Australian Climatic Zones***

B-3.2 Rainfall

B-3.2.1 Average Annual Rainfall

Average annual rainfall is clearly one consideration which has to be taken into account in designing and managing an effluent irrigation system. It appears obvious that the higher the rainfall in a particular area, the less opportunity there will be to irrigate with effluent without the risk of polluting the surrounding environment. In fact, from a climatic viewpoint, there is nowhere in Australia where an effluent irrigation system cannot be designed to work. The problems are usually those of finding enough land area and providing enough storage for effluent which cannot be irrigated at times of rainfall. The main considerations are not so much the annual rainfall as the seasonal distribution and the variation from year to year.

Figure B-3.2 shows the median annual rainfall for Australia. The main use that is made of this information in this manual is in calculating an index for the irrigation area and storage requirements.

It is often said that Australia is the driest continent, but most abattoirs are located in the pastoral zones of Australia which have an annual rainfall in the range of 300 to 1,000 mm.

B-3.2.2 Variation in Annual Rainfall

As well as being the driest continent (after Antarctica), one of the things which characterises the Australian climate is the variability of annual rainfall. Figure B-3.3 shows the mean deviation of annual rainfall expressed as a percentage of the average annual rainfall. It can be seen that, in areas where abattoirs are located, the range is 15-30% of the mean. This means that in an area with 600 mm of rainfall with , say, 20% variability, the average range from year to year will be 480 - 720 mm.

This variability becomes important because it will be reflected in the wet weather storage requirements for an abattoir. Each State is developing its own regulations for how much wet weather storage is required and no general guidelines have been developed. Draft guidelines published by the EPA of NSW "*The Utilisation of Treated Effluent by Irrigation*" (1995) set performance standards for wet weather storage in terms of the frequency with which the main effluent storage pond will need to overflow. (See Section B-5.7 for further details). The performance requirements are set in terms of the probability of occurrence of a year which has enough rainfall to just cause the holding pond to overflow (eg the wettest year in ten). The rainfall associated with a particular probability of occurrence of a wet year is calculated from the long term historical records for the area using the procedure outlined below. The example given is for calculating the wettest year in ten (90th percentile wet year) but the procedure is applicable to any other probability.

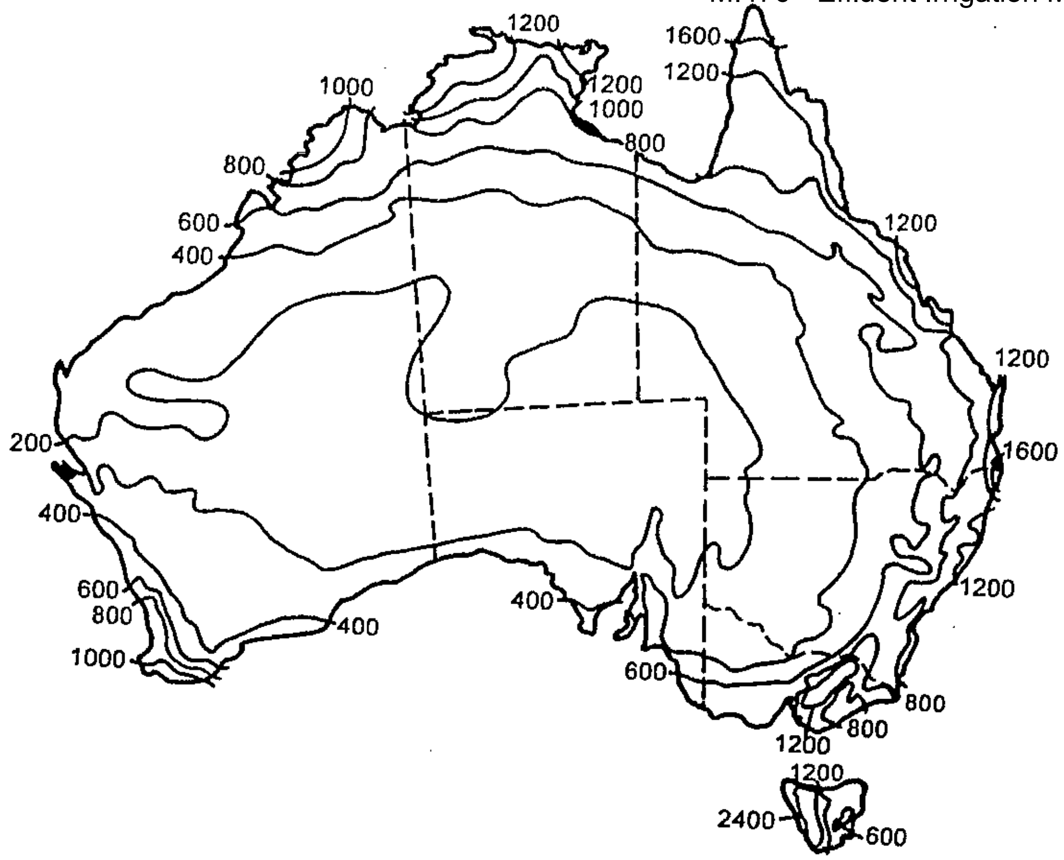


Figure B-3.2: *Median Annual Rainfall (mm)*

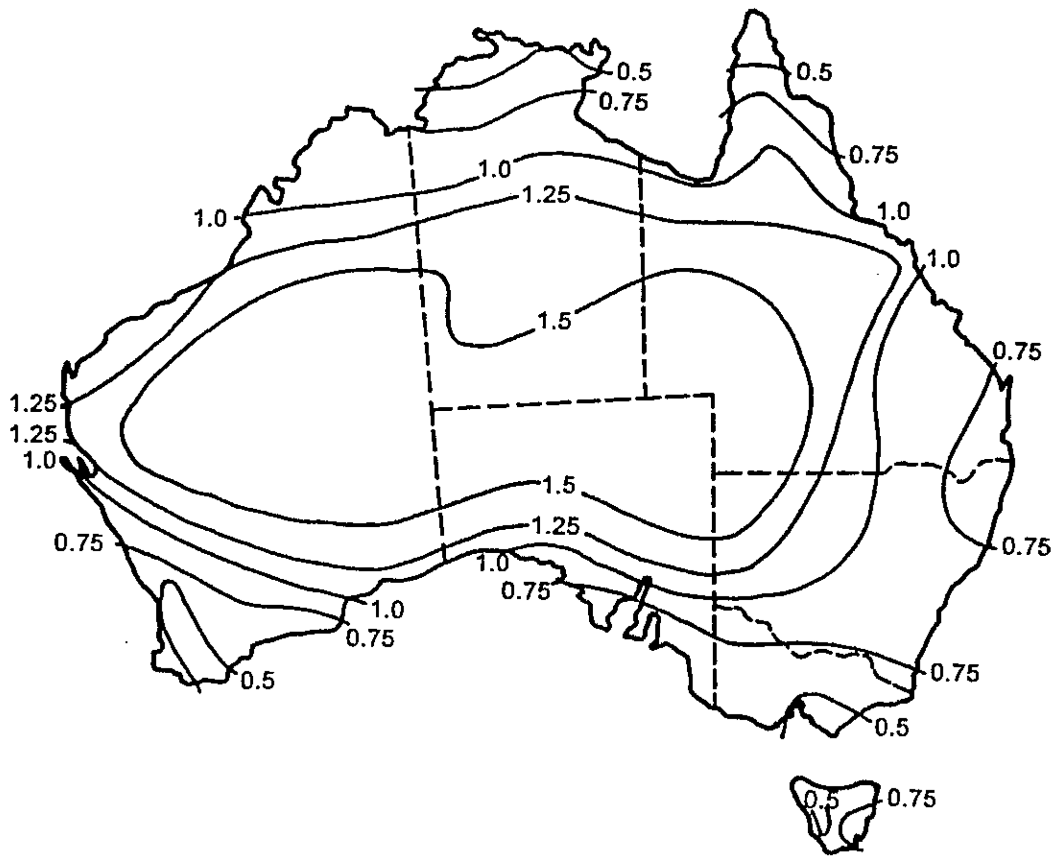


Figure B-3.3: ***Variability Index of Annual Rainfall - Based on Percentiles of Annual Rainfall [Variability index = (90% - 10%)/50%]***

Two terms are commonly used to describe the probability of occurrence of a wet year:

- Its ***percentile*** rank (P)
- Its chance of occurrence (1 in N years)

The correspondence between these two is:

N = 100/(100 - P)	eg	N	= 100/(100-75) = 4
P = 100 - (100/N)	eg	P	= 100-(100/4) = 75%

From the example it can be seen that the wettest year in 4 has a percentile rank of 75%. Note that, for clarity, any description of the probability of occurrence should also state whether the ranking starts from the wettest year or from the driest year. The 1 in 10 wet year is very different from the 1 in 10 dry year!

The correspondence between these two ways of expressing probability for other commonly used numbers are set out in Table B-3.2.

Table B-3.2 ***Correspondence between percentile probability and one in N chance of occurrence***

Percentile probability	One in N years
90	10
80	5
75	4
50	2

The 90th percentile wet year is calculated by the following procedure:

- Rank the yearly rainfall for the locality in order from the lowest to the highest, and give each a rank number (R) (1=lowest, 2, 3, etc)

- Calculate the probability (P) of that rainfall being exceeded:

  $$P = R/(Y+1) \times 100\%$$

  where Y = the number of years of record.

- Find the rainfall for the year corresponding to the a probability of 90%. (Note: unless you are very lucky, there will not be a year with a probability of exactly 90% and you will need to interpolate between values.)

- Calculate the rainfall corresponding to the 50% (median) and 80% probabilities.

The 90th, 75th or 50th percentile wet year rainfall is often needed to calculate the water balance of the effluent irrigation system in representative wet years. It is a good idea to do the analysis for a number of years with rainfall close to the percentile required. This is because the wet weather storage requirements are not just affected by the year being wet, but also by the rainfall pattern during the year. These different rainfall patterns can lead to quite different results when the wet weather storage requirement is calculated.

B-3.2.3 Seasonal Distribution of Rainfall

Seasonal variation of rainfall is almost more important in determining how an effluent irrigation system should operate than is the total amount of rainfall in a year. Any consideration of seasonal variation of rainfall really needs to take account of variability of evaporation which is dealt with in Section B-3.3.3. It is enough for now to point out the differences in how an irrigation system must perform in Darwin, Dubbo and Adelaide. The seasonal variation in rainfall and evaporation for these three locations is shown in Figure B-3.4. The figure is based on the evapotranspiration which would occur from a short green grass which had sufficient available water to prevent stress occurring (the objective of irrigation). The distinction between evaporation and evapotranspiration is explained in more detail in Section B-3.3, but for now it is sufficient to know that short green grass can be expected to loose slightly less water per unit area by evapotranspiration than would evaporate from an open water surface of the same area.

It can be seen from the data in Figure B-3.4 that:

- In Darwin, the evapotranspiration rate remains high all year round with a minimum of 105 mm in February. However the tropical monsoonal rainfall from November to March is sufficiently heavy that it is greater than the evapotranspiration so that there will be limited opportunities for irrigation.
- In Dubbo, an effluent irrigation system would also have difficulty in getting rid of much effluent over the period May to August. Also, because of the higher summer rainfall, the difference between rainfall and evapotranspiration is less than in Adelaide.
- In Adelaide, the rainfall tends to occur in winter which is also the time of minimum evaporation. An effluent irrigation system in this area would have difficulty getting rid of much effluent from May to August without the risk of polluting the environment through runoff or drainage to the groundwater. Effluent irrigation systems in this area can expect to require relatively large wet weather storage.

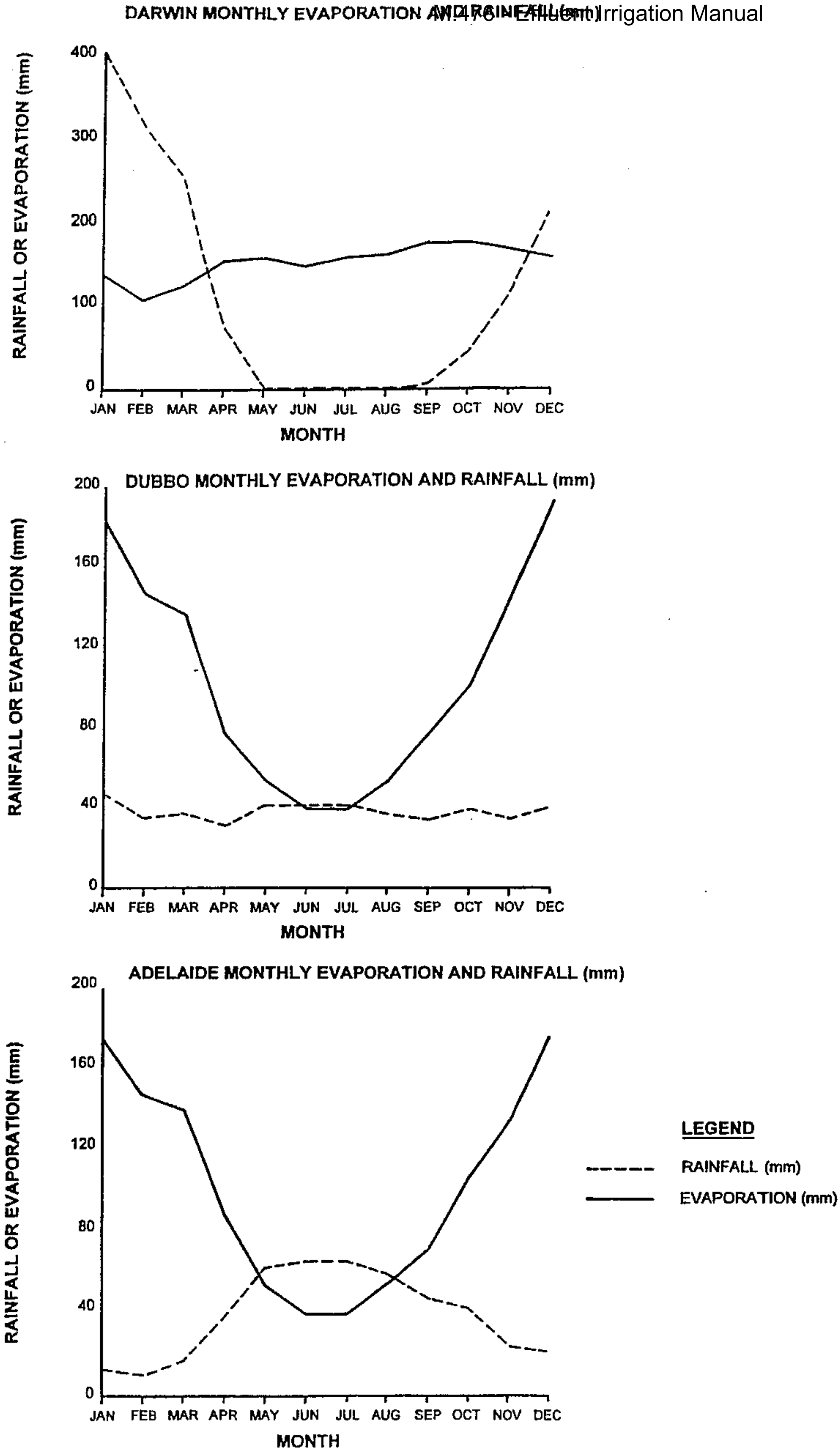


Figure B-3.4: *Seasonal Variation of Rainfall and Evapotranspiration*

> **Note:** *Although the rainfall may exceed the evapotranspiration rate in a particular month, it does not imply that no irrigation of effluent could take place. For instance the rainfall might occur as isolated thunderstorms which give intense short duration rainfall, a large proportion of which runs off. In that case, it might be possible to irrigate some effluent during the month. In order to analyse the opportunities more accurately it is necessary to carry out a water balance analysis on a day to day basis. This analysis will reflect more closely the way in which the irrigation system should be managed and identify opportunities for some irrigation even in months where the evapotranspiration is less than the rainfall.*
>
> *Despite a daily analysis being more accurate, the monthly difference between evapotranspiration and rainfall gives a useful guide to the amount of irrigation which could be applied.*

B-3.2.4 Storm Rainfall

Storm rainfall needs to be considered in terms of the volume and rate of runoff which would occur from the irrigation area:

- The rate of runoff will determine the required capacity of drainage channels.
- The volume of runoff will determine the size of storage required to store the runoff.

> *Section A-8.1 introduced this topic and Section B-5.5 deals with the whole question of collection of runoff from the irrigation area. The important point to note at this stage is that for high and intermediate[1] strength waste which is typical of abattoirs, a smaller irrigation area is likely to be required if the runoff is captured and used to dilute the effluent being applied. (Section B-6.2 explains the basis of this.)*

Note [1] Classification of strength of effluent as defined by the EPA of NSW (see Table B-3.3 below) is a useful guide to the pollutant loading, but should not be considered as setting fixed requirements for the way that the effluent disposal system is managed. (See Section B-5.7 for further discussion on this topic).

Table B-3.3 ***Classification of Effluent***
(EPA of NSW, 1995)

Constituent	Average Concentration (mg/L)		
	Low	Intermediate	High
Total nitrogen	<50	50-100	>100
Total phosphorus	<10	10-20	>20
BOD	<40	40-1500	>1500
Total dissolved salts	<500	500-1000	>1000

For the purposes of calculating the runoff volume from an effluent irrigation area, it is often the long duration rainfall which leads to the maximum volume of runoff being generated. In many cases the duration of rainfall which leads to the maximum volume may be a long wet spell of the order of a week or two, rather than the immediate effects of a single weather system over a period of 2 - 5 days.

The design of drainage channel size and the volume of runoff storage needed requires the services of someone with expertise in hydrology and data on the rainfall intensity characteristics of the locality. Whilst this data can be obtained from the Bureau of Meteorology (see Section B-3.4), its use for the design of drains and culverts is beyond the scope of this manual.

B-3.3 Evaporation and Evapotranspiration

B-3.3.1 Terminology

Brief mention was made about this topic in Chapter B-2. The main point to bear in mind is that there are a number of similar terms which are related but are not the same:

- **Evaporation** : This term is often used rather loosely to mean either open water evaporation or pan evaporation (see below for definitions). Be careful to correctly interpret any data which does not specify exactly what is meant.

- **Pan Evaporation (E_{pan})** : This term refers to the evaporation measured in a standard evaporation pan (see B-3.3.2). It is usually expressed as a depth (mm) of water per day or per month. Because an evaporation pan does not react to sunshine, wind, temperature and humidity in the same way as a lake or reservoir, the evaporation measured by a pan must be multiplied by a factor (usually about 0.8) to obtain an estimate of the evaporation from a lake or reservoir.

- **Open Water Evaporation (E_o)** : This refers to evaporation from a lake or pond and represents the evaporation loss which could be expected to occur from an exposed effluent treatment or storage pond. As noted above, it is usually estimated by multiplying the pan evaporation by a factor.

- **Reference Crop Evapotranspiration (ET_o)** : This refers to the evapotranspiration which would occur from short green grass which is adequately supplied with water so that no stress occurs. This may be calculated from meteorological data (temperature, solar radiation, wind, humidity, day length) or by reference to an evaporation pan measurement. Details of these methods are set out in Section B-3.3.2.

- **Potential Crop Evapotranspiration (ET_c)** : This refers to the potential evapotranspiration from a crop assuming that it has water freely available. It is usually calculated by means of a "crop factor", K_c, which relates the evapotranspiration characteristics of the particular crop to that of the "reference" crop.

- **Actual Crop Evapotranspiration (ET_a)** : This refers to the actual evapotranspiration occurring from a crop taking account of any moisture stress which might occur. In most irrigation systems this is not considered because the objective is always to have sufficient water available for the crop. For effluent irrigation, however, we do need to take it into account in trying to achieve a balance of both water and nitrogen.

B-3.3.2 Evaporation Pans

A variety of different standard pan sizes are in use throughout the world but in the last 30 years the Australian Bureau of Meteorology has standardised the US Class A pan, which is about 1,200 mm diameter x 250 mm deep. The pan is placed on a wooden platform at a height of 150 mm above the ground. All evaporation data published by the Bureau now relates specifically to the Class A pan unless otherwise specified. The other type of evaporation pan which has been used in Australia in the past is the Australian sunken pan which is 900 mm diameter x 900 mm deep and which, as its name suggests, is placed in the ground rather than on a platform above the ground.

Any evaporation pan is an imperfect device for measuring evaporation and various coefficients and factors must be applied to obtain an estimate of open water evaporation or potential crop evapotranspiration from observations of pan evaporation. Details of these procedures are set out in Section B-2.2.

There are only a limited number of sites at which the Bureau of Meteorology maintains evaporation pans. Maps showing monthly average pan evaporation throughout Australia can be found in the "Climatic Atlas of Australia" (1988). These maps provide a useful general guide to the variation of evaporation from month to month but are based on only 14 years of data. A number of research stations (operated by State Departments of Agriculture, Land Management or CSIRO) also collect evaporation data and should be consulted to obtain more accurate and up to date data if this is required.

B-3.3.3 Estimation From Climatic Data

There are a variety of methods by which evaporation and evapotranspiration may be estimated from climatic data. The details of these methods is beyond the scope of this manual. There are a variety of small automatic weather stations manufactured in Australia which, in addition to collecting and recording wind speed, humidity, temperature and rainfall, also automatically calculate reference crop evapotranspiration (ET_o).

One point to note is that for calculations based on climatic data, it is reasonable to obtain monthly average values. However on a day to day basis, the process of evaporation and evapotranspiration is so variable that the variation in climatic data is not sufficiently sensitive to be adequately described by day to day variation in wind speed, humidity etc.

B-3.3.4 Seasonal Patterns and Variability

In Section B-3.2.3, an example was given to illustrate the seasonal variability of evaporation. This is an important factor which must be taken into account in designing and managing an effluent irrigation system.

A factor which is often overlooked is the variability of evaporation between years. Many methods of calculating the performance of an irrigation system simply adopt the monthly average values of evaporation (or potential evapotranspiration). It is commonly assumed that evaporation does not vary as much as rainfall and that it is sufficient to adopt a monthly average value. This practice is acceptable if there is no other data available. However, evaporation for any given month of the year (eg January) does vary according to whether it is a particularly hot, dry month or a cool and cloudy month. The coefficient of variation of monthly evaporation at Scone, in the Hunter Valley of NSW, has been found to be of the order of 10 - 20% of the mean. There are no detailed studies around Australia of this variability of evaporation. It appears that variability may be highest in the mid latitudes and lesser variability may be experienced in the cool temperate climates to the south of the continent and the semi-arid tropics to the north.

It is usual practice to assume that the average monthly evaporation occurs uniformly throughout the month. This assumption is acceptable for undertaking water balance analyses because an over-estimate on one day is likely to be compensated for by an under-estimation a few days later. These minor discrepancies in the resulting estimate of the soil moisture tend to balance out.

B-3.3.5 Maximum Daily Evapotranspiration

Average monthly evaporation data are <u>not</u> a sufficient basis for estimating the maximum rate of evaporation. This figure is needed to design the irrigation system to ensure that the capacity of the pipes, pumps and irrigation equipment is capable of supplying sufficient water to match the peak summer rate of water demand. The usual criterion for selecting and designing the irrigation hardware is that it must be capable of supplying the full water demand of the crop or pasture, assuming a hot dry spell in which no rain occurs.

The maximum daily evapotranspiration rates in summer can be expected to be of the order of 10 - 12 mm per day in most parts of Australia. To determine a local value, an analysis will be required of the evaporation data from the nearest station, but this analysis will need to examine the maximum pan evaporation readings over periods from 5 to 25 days.

B-3.4 Data Sources

Whether you are simply wanting to manage the irrigation better or are considering improvements to the whole irrigation system, one of the things you will often need is a ready source of rainfall data which can be used to fully characterise all the attributes of the rainfall previously described in Section B-3.2.

The following suggestions are in order from the most general to the most specific. Which one you use will depend upon how detailed you need to make your analysis. If you are serious about analysing the behaviour of your effluent irrigation system in detail, then you will eventually need to obtain daily rainfall data from the Bureau of Meteorology and daily pan evaporation data for the region.

1. ***Climatic Atlas of Australia***, Bureau of Meteorology, Melbourne, 1988.

   Contains maps showing:
   - Average maximum and minimum temperatures.
   - Monthly pan evaporation
   - Sunshine hours
   - Rainfall
   - Seasonal rainfall zones
   - Relative humidity
   - Cloud cover
   - Wind.

2. ***Climatic Averages, Australia***, Published for Bureau of Meteorology by AGPS, Canberra, 1988.

   This book of about 500 pages gives monthly statistics for hundreds of places throughout Australia. The statistics include:

   - Temperature and relative humidity at 9 am and 3 pm.
   - Daily maximum and minimum temperatures.
   - Mean and median monthly rainfall
   - Mean number of rain days per month

   Unfortunately this publication does not contain any evaporation data.

3. ***District Rainfall Deciles - Australia***, D M Lee and D O Gaffney, Published for Bureau of Meteorology by AGPS, Canberra, 1986.

   This book provides a useful reference to the variability of monthly rainfall. **Note *the sum of the monthly rainfall values for a given probability (eg 10%) does not equal the annual total for the same probability. This is because the 10% dry year does not contain months in which every month is also the 10% dry month.***

4. ***Australian Rainfall and Runoff - Volume 2***, Published by Institution of Engineers, Australia, Canberra, 1987.

   This volume contains detailed maps and a method of interpolation which allows the calculation of storm rainfall anywhere in Australia for durations from 5 minutes to 3 days for probabilities of occurrence from once in 2 years to once in 100 years.

   Alternatively the storm rainfall characteristics for the locality can be obtained from the Bureau of Meteorology for a fee of $110 (as of 1995). The address for this is:

   Hydrometeorological Advisory Service
   Bureau of Meteorology
   GPO Box 1289K
   Melbourne VIC 3001

5. ***Detailed data*** for any location at which the Bureau of Meteorology has a station, can be obtained from the office of the Bureau in each State Capital. The most useful data is likely to be the long term daily rainfall from a nearby station. This data is available on computer disk and costs of the order of $100 (in 1995). Evaporation data is also available from stations monitored by the Bureau but there are only 50 or so sites around Australia compared to many hundred rainfall stations. Also evaporation data generally has only been collected since the 1960's or 70's. The length of the record is therefore much shorter than rainfall which has been collected in most districts for 100 years and in some places for nearly 150 years.

6. ***State Departments*** of Agriculture and other land or water management agencies (eg forestry, soil conservation and water resources) also collect rainfall and evaporation data. Enquiries should be directed to the local office.

   Take care that any data you acquire from these agencies has been collected using standard instruments. This is usually not a problem with rainfall. However, in NSW for example, many soil conservation research stations collected evaporation data from the 1950's to mid 1970's using an Australian Standard Pan rather than the Class A Pan, which is now the standard. Because the two types of pans respond differently to the climate, data cannot be converted from one to the other.

CHAPTER B-4: WATER QUALITY

The quality and amount of water applied to an irrigation area are critical for the health and growth of the plants and for the ability of the soil to act as a temporary store.

This chapter presents some general requirements for irrigation water and then looks at the major water quality issues which must be thought about when planning or managing an effluent irrigation system:

- ☐ *Phosphorus*
- ☐ *Nitrogen*
- ☐ *Salts*
- ☐ *Biological Oxygen Demand*

The first three sections of this chapter deal with recommended guidelines prepared by the Australian & New Zealand Environment and Conservation Council (ANZECC). These guidelines are a useful reference for assessing the suitability of water for general irrigation.

The last four sections of this chapter deal with the aspects of water quality of particular relevance to irrigation of abattoir effluent.

CONTENTS

B-4.1 Factors Influencing Irrigation Water Quality Guidelines

The quality of the water which can be applied to the land depends upon three important factors:

- ☐ ***Soil***: Soil texture, structure and organic matter determine percolation of water, holding capacity and exchange capacity. Therefore, the degree to which the irrigation water and its components will be leached out, remain available to plants or become fixed and unavailable to plants, depends largely on the soil characteristics. Nevertheless, insufficient rationale has been published in the scientific literature to establish soil categories as a standard part of water quality guidelines.

- ☐ ***Crops***: Crops vary widely in their sensitivity to toxic substances. The guidelines contained in Tables B-4.1 and B-4.2 are those required to protect the most sensitive crops. If the effluent has significantly higher concentrations of any constituent, the advice of an agronomist should be sought.

- ☐ ***Climate and management***: Evapotranspiration and rainfall determine the frequency of irrigation required. In general, the potential toxicity of the substances in the irrigation water increases as more frequent irrigation is required. Nevertheless, application of water in excess of crop needs may provide protection to the crop through leaching of salts from the plant root zone when drainage is unrestricted. However, to prevent contamination of any underlying aquifer, losses by leaching to the groundwater should be minimised. (The whole question of balancing the needs of protecting groundwater against the need to leach salts from the soil profile is an important topic for management of effluent irrigation and is dealt with in Chapter B-6).

The type of irrigation method used is also important (eg. flood, furrow or sprinkler methods) for the sensitivity of crops to toxic substances in the irrigation water.

B-4.2 Guidelines for Irrigation Waters

The recommended Australian water quality guidelines for irrigation (ANZECC, 1992), shown in Tables B-4.1 and B-4.2, assume an annual application rate of irrigation water of 1,000 mm and retention of trace ions in the top 15 cm of the soil. Under these conditions, the recommended concentration of ions in the irrigation water is based on allowing irrigation for a minimum of 100 years before levels in the soil become toxic to plants. In many parts of Australia where abattoir effluent is to be irrigated, application rates are likely to be significantly lower than 1,000 mm. For abattoir effluent irrigation areas it is the nitrogen loading rate which will govern the ammount of irrigation which can be applied. The values shown in Tables B-4.1 and B-4.2 must be adjusted to account for differences in irrigation application rates and the leaching conditions present in a particular soil.

Table B-4.1 ***Summary of Guidelines for Irrigation Water Quality***
(ANZECC, 1992)

Parameter	Recommended Limit (mg/L unless stated)	Comment
Biological parameters		
Plant pathogens	-	
Human and animal pathogens	1,000 faecal coliforms/100 mL	Tentative value. Geometric mean of not less than 5 water samples taken per month; no more than 20% should exceed 4,000 organisms/100 mL
Algae	Should not be visible	
BOD_5	-	No guideline recommended
Major ions		
Bicarbonate	-	No guideline recommended due to interaction with other factors
Chloride	30-700 Table B-4.3	Maximum concentration should be set according to sensitivity of crop.
Sodium	Soils: Figure B-4.1 Crops: Table B-4.4	
Total dissolved solids	Table B-4.5	

Table B-4.2 ***Summary of Guidelines for Irrigation Water Quality - Heavy Metals, Trace Elements and Pesticides***

(ANZECC, 1992)

Parameter	Recommended Limit (mg/L unless stated)	Comment
Heavy metals and trace ions**		
Aluminium	5.0	High toxicity in acid soils
Arsenic	0.1	
Beryllium	0.1	
Boron	0.5-6.0	
Cadmium	0.01	
Chromium	1.0	High toxicity in acid soils Limit chromium (VI) concentration to 0.1 mg/L
Cobalt	0.05	
Copper	0.2	
Fluoride	1.0	
Iron	1.0	
Lead	0.2	
Lithium	2.5	Citrus: 0.075 mg/L
Manganese	2.0	If acid soils, limit to 0.2 mg/L
Mercury	0.002	
Molybdenum	0.01	
Nickel	0.2	
pH	4.5-9.0	
Selenium	0.02	
Uranium	0.01	
Vanadium	0.1	
Zinc	2.0	1 mg/L is recommended for sandy soil below pH 6
Pesticides		
Insecticides	-	No guideline recommended
Herbicides		
Radioactivity	Gross Alpha 0.1 Bq/L Gross Beta 0.1 Bq/L	

** Higher maximum concentrations may be recommended in neutral to alkaline soils.

B-4.3 Biological Parameters

B-4.3.1 Plant Pathogens

A variety of pathogens can be distributed through irrigation water, including nematodes, fungi, viruses and bacteria. The risk of infection is lower if the irrigation water is not recycled from fields and reused on other crops or if wastewater is used for irrigation, with the exception of *Phytophthora* in surface waters that are used in Western Australia for irrigation of susceptible horticultural crops. However, insufficient data is available to allow the formulation of guidelines for plant pathogens.

B-4.3.2 Human and Animal Pathogens

A tentative guideline has been set at a geometric mean (log) of no more than 1,000 faecal coliforms/100 mL based on not less than five water samples taken per month. No more than 20% of these samples should exceed 4,000 organisms/100 mL.

The above criterion is described as tentative because there is ongoing discussion concerning whether alternative indicator organisms should be used.

Many micro-organisms that are pathogenic to animals and humans can be carried in irrigation water and may contaminate field crops which are subsequently eaten by humans. For this reason, irrigation of abattoir effluent should generally be confined to pastures and forage crops to be used for animal feed. Die-off rates of bacteria in irrigated pastures are reported to be a minimum of 99% in 12 days with the highest rates occurring in spring. The majority (90%) of bacteria in pastures are reported to be in the 30 mm immediately above the ground surface. Precautions against disease transmission through grazed pastures which have been irrigated with effluent include:

- Excluding stock for 7 days after irrigation,
- Light grazing to encourage grazing no closer than 50 mm to the ground,

B-4.3.3 Algae

No quantitative objectives have been recommended for algae. Nevertheless, to protect the irrigation equipment form clogging and to avoid soil oxygen depletion, algae should not be visible. This aspect has the potential to be a problem in abattoir effluent spray irrigation systems because of the high levels of nitrogen and phosphorus in the effluent, even after treatment. These conditions are likely to be ideal for algal growth in holding ponds. The problem of algal growth is most likely to occur in the warmer months. Fortunately the irrigation demand is highest at this time of year and therefore any holding ponds are likely to be drawn down or empty. If there are single celled algae in suspension, then they are unlikely to cause problems of blockage of spray irrigation nozzles. Filamentous algae will, however, need to be filtered out.

B-4.3.4 Biochemical Oxygen Demand (BOD)

Soil aeration and oxygen availability present no problem in well-structured soils with good water quality. High BOD loadings from effluent may cause anaerobic conditions to occur in the soil and this can lead to odours. This problem is of most concern in soils which have impeded drainage and which are easily saturated. No national guideline has been recommended for BOD loading. The EPA of NSW (1995) suggest 40 kg/ha/day as a maximum loading rate. However, the management of BOD loading can influence denitrification in the soil and is discussed in more detail in Section B-4.7.

B-4.4 Major Ions and Salinity

B-4.4.1 Bicarbonate

No quantitative guideline for bicarbonate is recommended because the potential hazard of bicarbonates is influenced by other soil and water characteristics. The bicarbonate hazard is high in low-salinity waters applied to sandy and silty loams soils.

B-4.4.2 Chloride

The maximum chloride concentration should be set according to the sensitivity of a crop (Table B-4.3). Irrigation water containing more than 100 mg of chloride per litre should not be used for sensitive crops.

Chloride is essential to the growth of plants. However, in excess it can have a toxic effect depending on the sensitivity of the crop and the irrigation method chosen. In general, most woody plant species (stone-fruit, citrus, avocados) are sensitive to low concentrations of chloride, whereas most vegetable, grain, forage and fibre crops are less sensitive. Much of the information available on the sensitivity of crops to chloride relates to crops consumed directly by humans (fruit and vegetables) which should not be irrigated with abattoir effluent.

There are two ways in which chloride damage may be caused. First, the chloride ion can be taken up by the roots and moved upwards to accumulate in the leaves. Excessive accumulation may cause burning of leaf tips or margins, bronzing and premature yellowing of leaves. Second, direct foliar absorption of chloride from sprinkler irrigation can cause damage especially on fruit trees, which are most sensitive. Generally these effects are minimised with night-time sprinkling and water applied at a rapid continuous rate, providing that care is taken to prevent soil erosion.

Table B-4.3 *Chloride Concentrations in Irrigation Water Causing Foliar Damage*
(ANZECC, 1992)

Sensitivity	Chloride (mg/L)	Affected crop
Sensitive	<178	Almond, apricot, plum
Moderately sensitive	178-355	Grape, pepper, potato, tomato
Moderately tolerant	355-710	Alfalfa, barley, corn, cucumber
Tolerant	>710	Cotton, safflower, sesame, sorghum, sugar-beet, sunflower

B-4.4.3 Sodium

Excessive sodium in irrigation water can adversely affect soil structure (see Section B-1.8) and reduce the rate at which water moves into and through the soil, as well as reduce soil aeration. The effect of sodium is dependant on the ratio of sodium to calcium and magnesium. This ratio, which is known as the sodium adsorption ratio (SAR), has been defined in Section B-1.8.2 which also contains an outline of the effects of sodium on the soil. Basically, if calcium is the predominant adsorbed cation, the soil tends to have a granular structure, which is easily cultivated and readily permeable. However, when adsorbed sodium exceeds 10-15% of the total exchange capacity of the soil, the clay becomes dispersed and puddled when wet, lowering permeability and forming a hard impermeable crust when dry.

Figure B-4.1 shows the chemical composition of four recognised classes of water for irrigation which can be used applying the following guidelines:

S1 Low sodium water can be used on almost any soil.

S2 Medium sodium water can be used on coarse textured or organic soils that take water well. It may present a moderate sodium problem in fine textured clay soils.

S3 High sodium water may produce problems in most soils and will require special management, good drainage, high leaching and the addition of organic matter. The addition of gypsum or lime material will help overcome problems.

S4 Very high sodium water is generally unsatisfactory unless low or medium salinity water is used and where gypsum or some other additive makes its use possible.

Sodium is required in limited amounts for most plant growth. However, some plants are sodium-sensitive and can be affected by low concentrations of exchangeable sodium. The direct toxic effects of sodium concentrations in irrigation water (expressed as SAR) on different plants are shown in Table B-4.4.

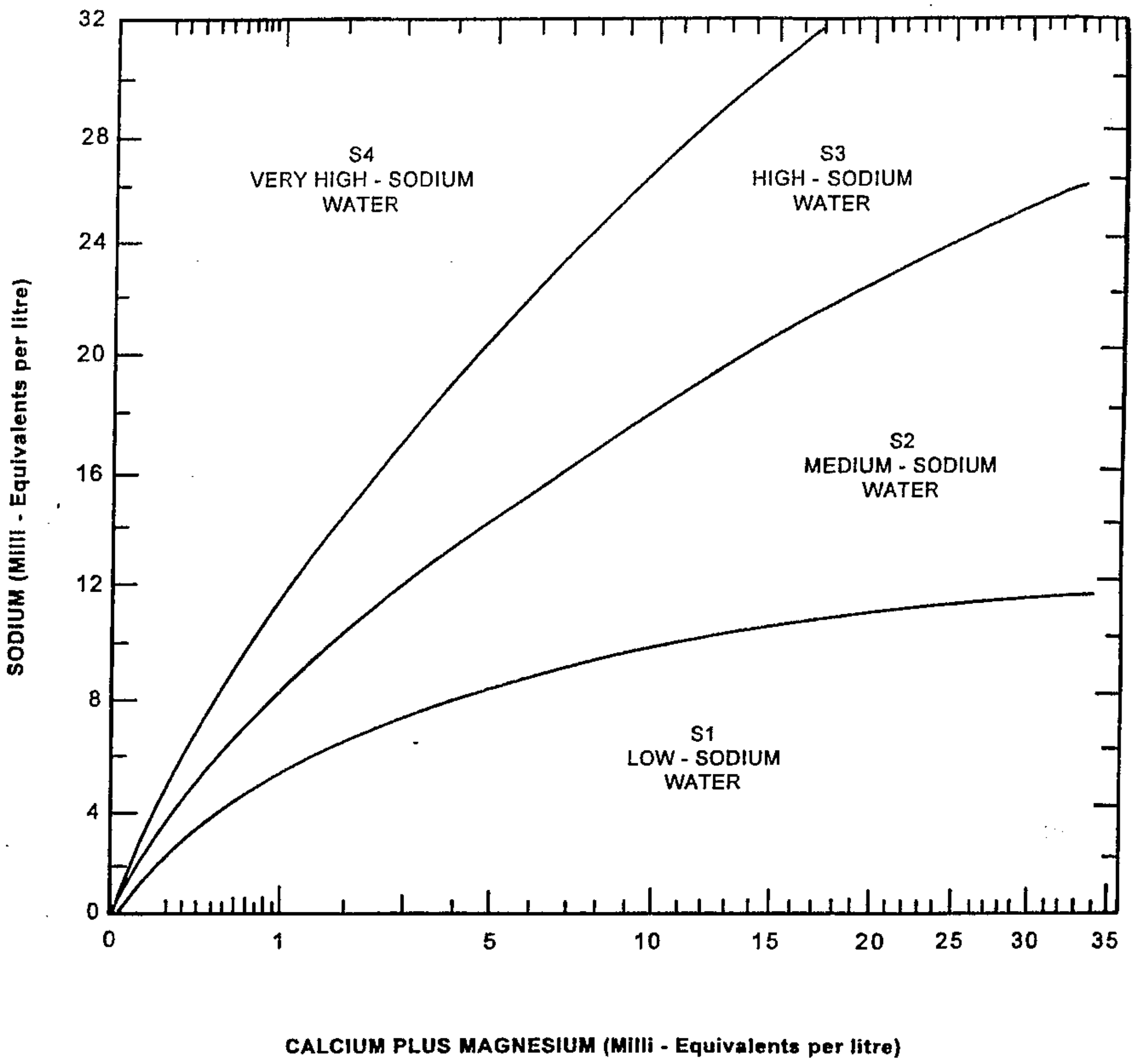


Figure B-4.1: ***Water Quality Classification for Sodium in Water***

Table B-4.4 ***Tolerance of Crops to Sodium***
(ANZECC, 1992)

Tolerance	SAR of irrigation water	Crop	Condition
Very sensitive	2-8	Deciduous fruits, nuts citrus, avocado	Leaf tip burn, leaf scorch
Sensitive	8-18	Beans	Stunted, soil structure unfavourable
Moderately tolerant	18-46	Clover, oats, tall fescue, rice	Stunted due to nutrition and soil structure
Tolerant	46-102	Wheat, lucerne, barley, tomatoes, beets, tall wheat grass, crested grass, fairway grass	Stunted due to poor soil structure

B-4.4.4 Salinity

The salinity or total dissolved salts (TDS) concentration of irrigation water is an extremely important water quality consideration. High salinity causes high osmotic pressure of the soil solution which results in reduced availability of water for plant consumption and possible retardation of plant growth. Table B-4.5 contains guidelines for salinity in irrigation water.

The main threat of saline irrigation water is that the salts will tend to accumulate in the root zone from where the crop will remove water but not salts. With adequate drainage, salt accumulation in the soil can be controlled by the rate of application of water. If the sum of applied irrigation water and rainfall is lower than evaporation and plant consumption, an accumulation of salts in the main root zone will result. Proper irrigation management will allow application of sufficient excess water to leach some of the salts out of the root zone, while not causing excessive increases in the ground watertable. The difficulty in doing this for effluent irrigation areas is that the water used to leach salts may also carry nitrates with it. Chapter B-6 provides further details of the management of leaching from an effluent irrigation area.

Table B-4.5 ***General Guidelines for Salinity of Irrigation Water***
(ANZECC, 1992)

	Comment	Electrical conductivity (µS/cm)	TDS (mg/L)[1]
1	Low-salinity water can be used with most crops on most soils and with all methods of water application with little likelihood that a salinity problem will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability	0-280	0-175
2	Medium-salinity water can be used if moderate leaching occurs. Plants with medium salt tolerance can be grown, usually without special measures for salinity control. Sprinkler irrigation with the more-saline waters in this group may cause leaf scorch on salt-sensitive crops, especially at high temperatures in the daytime and with low application rates.	280-800	175-500
3	High-salinity water cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required, and the salt tolerance of the plants to be irrigated must be considered	800-2,300	500-1,500
4	Very high-salinity water is not suitable for irrigation water under ordinary conditions. For use, soils must be permeable, drainage adequate, water must be applied in excess to provide considerable leaching, and salt-tolerant crops should be selected	2,300-5,500	1,500-3,500
5	Extremely high-salinity water may be used only on permeable, well-drained soils under good management, especially in relation to leaching and for salt-tolerant crops, or for occasional emergency use	>5,500	>3,500

[1] TDS (mg/L) ≃ 0.64 x EC (µS/cm)

Plants vary in their tolerance to soil salinity. An outline of the main considerations regarding the sensitivity of plants to salinity is given in Section B-2.8. In general, fruit crops are most sensitive, followed by vegetable, field and forage crops. For an effluent irrigation area, only pasture or fodder crops should be considered.

B-4.5 Nitrogen

Nitrogen and its management is a key aspect of successful irrigation of effluent, and is a topic which recurs in a number of places in this manual:

- Section B-1.6 considers the processes affecting nitrogen in the soil.
- Section B-2.6 considers nitrogen removal by crops and livestock.
- This section considers nitrogen losses and transformations occuring in the process of irrigation
- Section 6.1 considers the overall management of nitrogen in a field.

Nitrogen is essential for plant growth and in moderate quantities (50 - 300 kg/ha/year) can enhance crop growth significantly. The problem with abattoir effluent is that it contains up to 250 mg/L of total nitrogen. At a strength of 100 mg/L, the amount of nitrogen applied in 200 mm of irrigation water would be about 300 kg/ha which is about as much as would be taken up on a high yielding crop of maize which had a full supply of water and nutrients. In addition to its use by plants, some nitrogen is adsorbed onto the soil and metabolised into nitrogen gas. However, any excess nitrogen has the potential to pollute the surrounding environment.

Because of the complex processes involving nitrogen in the soil (outlined in Section B-1.6), it is not possible to specify a simple maximum concentration for nitrogen in effluent. As outlined in Section B-1.6, the main factors which govern the fate of nitrogen in effluent are:

- The form in which nitrogen occurs in the effluent;
- The soil type;
- The degree of saturation maintained in the soil;
- The amount of organic carbon in the effluent;
- The ability of the crop to take up nitrogen.

Effluent usually contains three forms of nitrogen:

- ***Organic Nitrogen*** mostly in the form of proteins
- ***Ammonium*** - NH_4^+
- ***Nitrate*** - NO_3^-

The relative proportions of these three forms is affected by the treatment process to which the effluent stream is subjected:

- Primary treated effluent (screening) has high levels of organic nitrogen and ammonium.
- Anaerobically treated effluent has a higher proportion of ammonium.
- Aerobically treated effluent also has higher levels of nitrate.

B-4.5.2 Ammonia Volatilisation

When effluent is applied by spray irrigation, some volatilisation of the ammonia occurs. The volatilisation process is highly variable and will be higher when the air temperature is high and pH is high. Volatilisation of up to 20% of the ammonia is thought to occur during spray irrigation (Pettygrove and Asano, 1985).

B-4.5.3 Nitrogen Retention in the Soil

Clay soils, particularly those that swell on wetting and shrink on drying, have the ability to trap ammonium ions within the structure of the clay. Once bound in this way, they are not easily displaced by other ions nor are they accessible to nitrifying bacteria. Although ammonium may be trapped in this way, in the long term the quantity involved does not account for a significant proportion of the annual nitrogen budget.

Ammonium ions may also be temporarily adsorbed and held on the clay particles. In all but very sandy soils, the soil is capable of adsorbing far more ammonium than would be applied in effluent. The ammonium adsorbed in this way is accessible to nitrifying bacteria and is oxidised to nitrate in a few weeks.

Ammonium may also be temporarily immobilised through assimilation by soil micro-organisms in the presence of decomposable carbon such as crop residues. This process predominates during the first few weeks of crop residue decomposition when as much as 20 - 40 kg/ha of nitrogen can be immobilised.

Proteins are also strongly adsorbed onto clay particles and held temporarily while bacterial processes occur.

Nitrate is not adsorbed onto clays and is therefore the most mobile form. High nitrate levels in the effluent are likely to lead to conditions in which pollution of the surrounding environment occurs.

B-4.5.4 Nitrogen Transformation in the Soil

There are three transformations which occur in the soil:

- ***Mineralisation*** in which proteins are broken down by aerobic and anaerobic bacteria to form ammonia. This process usually occurs rapidly.
- ***Nitrification*** in which other bacteria transform ammonia into nitrate through several steps. Nitrification usually occurs rapidly (6 - 80 kg/ha/day) and any ammonium (applied in the effluent or from mineralisation of protein) can be expected to be converted to nitrate in a few days. The process of nitrification occurs in aerobic conditions where oxygen is freely available. Such conditions are also required for healthy root growth and therefore commonly occur in well managed agricultural soils.
- ***Denitrification*** in which nitrate is reduced to nitrogen in the presence of decomposable organic matter and anoxic conditions. The rate of denitrification is primarily controlled by the availability of organic carbon. Therefore, wastes which have a high BOD are more likely to promote denitrification. Studies of disposal of abattoir wastes in New Zealand (Russell and Cooper, 1987) indicate that application of wastes that have been treated in an anaerobic lagoon require about double the area for safe disposal compared to wastes which have only received primary treatment (and therefore have high residual BOD). In the presence of high levels of BOD (>1,000 mg/L), denitrification losses of up to 40% are possible.

Studies of denitrification in soils in California (Pettygrove and Asano, 1985) indicate that the following rates of denitrification are possible:

- Sandy soils with low organic matter - negligible
- Sandy loams and loam soils - 10-20% loss
- Silt loams and clay loams - 20-40% loss

B-4.6 Phosphorus

Like nitrogen, phosphorus is essential for healthy plant growth and consequently there is no specific limit to the phosphorus concentration in effluent. Abattoir effluent will typically contain about 30 mg/L total phosphorus which will supply 30 kg/ha of phosphorus per 100 mm of effluent irrigation. This compares to the annual requirement of 10 - 15 kg/ha for pastures and up to 60 kg/ha for a high yielding maize crop. Fortunately, most Australian soils have a high phosphorus absorption capacity which can be expected to absorb any excess phosphorus for several decades.

B-4.7 Biochemical Oxygen Demand

When an effluent is initially applied to the land, the air held in the pores and the wetted surfaces of the soil and crops which are exposed to the atmosphere, provides oxygen to meet the biochemical oxygen demand (BOD) of the effluent. As the top layers of the soil becomes saturated, oxygen is no longer available to meet this demand and anaerobic conditions are likely to develop. Oxygen is still available at the soil and crop surface, but this will not prevent anaerobic conditions developing within the soil if BOD loadings are sufficiently high.

Anaerobic conditions produce two effects; they encourage the loss of nitrogen by denitrification but can also cause odours to occur. (Details of these processes may be found in Section B-4.5 above and Section B-1.6)

The beneficial effect is the improved removal of nitrogen from the effluent because denitrification, which is the conversion of nitrate to the gases nitrous oxide (N_2O) and di-nitrogen (N_2), occurs. In general, for denitrification to occur, the effluent must first have been exposed to nitrifying conditions so that ammonia is converted to nitrate.

Land disposal can handle high BOD loadings, probably hundreds of kg/hectare/day, and BOD levels are reduced to essentially zero after a few metres (often less) of percolation through soil. Nevertheless, the problems with odours leads to guidelines limiting BOD loading. In addition there is a need for resting periods to allow aerobic conditions to be restored to the soil, to both control odour and also allow the nitrification and denitrification processes to occur.

The general guidelines for BOD application rates are:

- Sandy soils - 10,000 kg/ha/year
- Sandy loams and loam soils - 15,000 kg/ha/year
- Silt loams and clay loams - 10,000 kg/ha/year

Generally the BOD loading rate requirements will not be the limiting factor for the rate at which effluent can be applied.

CHAPTER B-5: IRRIGATION SYSTEMS

*The users of this manual will either own and operate their own irrigation system or will be relying on a nearby farmer to utilise the abattoir effluent using the farmer's own irrigation system. We can presume, therefore, that an existing irrigation system is available and operating. The existing system may, however, need upgrading to provide more control over the watering regime or to reduce the risk of causing pollution to the local creeks or groundwater. In the course of any review of the operation of the existing system it is worth asking the question, **"Does the existing system meet current and future needs?"**.*

This section of the manual presents an overview of the characteristics of the main types of irrigation practiced in Australia and provides a guide to the usefulness of these systems for irrigation of abattoir effluent. The main design and operational features of different systems are also outlined.

CONTENTS

B-5.1 System Requirements

The basic intention of any irrigation system must be to supply the crop with sufficient water to meet the needs of the crop. In conventional irrigation, the usual concept of the water "requirements" of a crop are that the crop should not be placed under any stress that would hinder plant growth. This requirement usually means that the operator will seek to put on water whenever the soil moisture storage gets below about 50% of the moisture capacity of the root zone. The operator's attitude is often one of putting on a little bit extra, if in doubt.

Irrigation of abattoir effluent must be thought of in very different terms because it must seek to meet other requirements which are more important than the water needs of the crop:

- Nutrient load applied over the course of a growing season must be equal to the total that is taken up by the plant, transformed in the soil or immobilised in the soil.
- The risk of pollution of groundwater or surface water must be minimised. This calls for a much higher degree of control of when and how much water is applied.

> ***In planning an effluent irrigation system, it is best to forget about the water (it is just the means of transport). The real issue is managing and controlling the nutrients, particularly nitrogen.***

Traditional irrigation methods achieved control of water in two ways:

- Supplying water almost continuously at a rate which just matches the uptake by the plants. This is the basis of most trickle irrigation systems.
- Making use of the storage capacity of the soil to hold water for plants to take up over several days or weeks. For this arrangement to work effectively, the irrigation system must be capable of delivering just enough water to refill the soil before the store is depleted. This leads to the concept of irrigation "rotation" in which irrigation water is applied to different areas on successive days. The irrigation system must be designed and managed to provide enough water to replenish the soil moisture store before it is emptied. This arrangement, therefore, relies on being able to direct the water to different areas at different times.

The selection of an appropriate type of effluent irrigation system will involve consideration of a number of factors:

- ***Soil characteristics*** - available soil moisture storage, infiltration rate, nutrient storage and immobilisation. (Refer back to Chapter B-1 for more details).
- ***Crop type*** - water requirements, rooting depth, required frequency and uniformity of watering, nutrient requirements. (Refer back to Chapter B-2 for more details.)
- ***Capital costs.***
- ***Operating costs*** - particularly labour and pump running costs.
- ***Precision and control of application*** - this will govern the security against causing pollution.

There are a wide range of irrigation methods that can be employed. However the three most basic methods in current usage are:

- Spray Irrigation
- Surface Irrigation
- Micro Irrigation

Some of the main features of these various systems from an environmental perspective are set out in Tables B-5.1(a) and B-5.1(b). The tables also indicate the suitability of each system for irrigation of abattoir effluent. The main criteria used in making such an evaluation of suitability are:

- ***Simplicity of operation*** - the system should not require a high level of managerial skill to achieve reliable results.
- ***Ability to be controlled*** - the ability to easily place effluent in a controlled manner and to achieve uniformity of watering.
- ***Environmental security*** - the system should be capable of controlling the application of effluent so as to minimise environmental risk from the operation.
- ***Operation and maintenance*** - the system should not have high maintenance requirements or require high levels of skill to maintain.

Table B-5.1*(a)* *Suitability of surface irrigation systems for effluent application*

Irrigation System	Environmental Advantages	Environmental Disadvantages	Suitability
Surface Systems			
Furrow	• Potential to recirculate tailwater • High efficiency and uniformity on appropriate soils • Potential to prevent stormwater runoff	• Furrow erosion if inadequately designed • Deep percolation losses on light soils if poorly designed • Some tailwater runoff required for uniform water application • Leakage from canals and drains • Efficient conveyance of runoff from land requires control • Effect of above ground works on external overland flows • Could require extensive landforming cuts on uneven land	Recommended for heavy clay soils where other methods are unsuitable. Requires good control of supply rate and timing Requires tailwater drainage and re-use.
Border check	As above	As above, except: • Potential for erosion usually reduced • Landforming works potentially greater	As for furrow irrigation
Levelled bays	• Good control of tailwater • Some control of stormwater runoff • Good control of erosion • High water applications efficiency and uniformity, particularly if not ponded	• Excess application may lead to excessive infiltration • Leakage from canals and drains • Above ground works disturb external overland flows • Could require excessive landforming cuts on uneven land	Unsuitable - risk of deep drainage if poorly managed
Contour bays	• Tailwater runoff can be reduced • Some control of stormwater runoff	• Limited control of deep percolation • Leakage from canals and drains • Effect of above ground works on external overland flows	Unsuitable - risk of deep drainage
Wild flooding	• Minimal earthworks		Unsuitable - lack of control

Table B-5.1*(b)* ***Suitability of spray and micro irrigation systems for effluent application***

Irrigation System	Environmental Advantages	Environmental Disadvantages	Suitability
Spray Systems			
Hand-move Sprinkler	• Little or no tailwater • Diffuse stormwater runoff • Control of depth of application, reducing deep percolation • No channel losses and percolation • Little effect on external overland flows	• No control or re-use of tailwater or stormwater runoff • Water and dissolved nutrients carried off-target by spray drift • Requires almost complete clearing of trees • Uncontrolled runoff on heavy soils and/or steep slopes • Poor uniformity of watering if sprinklers not maintained	Flexible Satisfactory control Labour intensive
Side roll Sprinkler	As above		As above
Travelling gun	As above	• Increased potential for runoff on heavy soils and/or steep slopes • Poor uniformity of watering if not well managed	Satisfactory
Centre pivot	As above	• High instantaneous rate of application at end of lateral, resulting in runoff and erosion on heavy soils • Circular patterns makes pesticide over-spraying difficult to avoid under serial applications	Satisfactory
Travelling lateral	As above	• Supply canal may affect overland flows	Satisfactory
Micro-Systems			
Drip	• Good irrigation water control (no tailwater and little deep percolation)	• No control of stormwater runoff • Poor performance if system not well designed and maintained	High capital cost Effluent requires filtering Filters require good maintenance
Mini-sprinklers	As above		

- **Spray irrigation** systems are the most flexible type of irrigation system and are recommended for abattoir effluent irrigation in most situations. The main advantages of spray irrigation systems are that they are:

  - relatively easy to manage if correctly designed and set up,
  - suitable for a wide range of crops, soils and topography,
  - promote ammonia volatilisation.

  The type of spray system chosen for a particular situation will depend upon a number of considerations:

  - Topography, soil type and the shape of the available land. Some systems, such as lateral move irrigators, require a rectangular area of relatively uniform slope

  - Labour availability and cost. The self propelled systems require less labour than hand moving of irrigation pipes.

  - Irrigation regime. Centre pivot, travelling lateral machines and solid set systems are particularly useful for the frequent watering for re-use of effluent.

  - Application uniformity. The more control exercised over uniformity of watering, the less the risk of the unwanted escape of effluent into the surrounding environment. Centre pivot systems, for example, usually apply water more uniformly than travelling irrigators.

  In general, spray irrigation systems are capable of providing the necessary degree of control and are preferred for effluent irrigation. The exceptions to this are situations in which the effluent is used for special purposes and there is an appropriate (higher) level of management expertise available. Spray irrigation systems are of limited use on clay soils, particularly cracking clays, which have negligible infiltration rate once the surface is wet (see Section B-1.5.1 for further discussion on infiltration characteristics of soils).

- **Surface irrigation** systems account for nearly 80 % of Australia's irrigation and continue to be popular because they:

  - are suitable for clay soils found in many irrigation areas,
  - require minimal equipment to operate,
  - have minimal or no costs of pumping.

  Whilst these systems are popular for irrigation of large areas of wheat, pastures, cotton and rice, they have a number of drawbacks for irrigation of effluent because they require:

  - A high degree of management to achieve uniform watering necessary to minimise pollution,

  - Land with a uniform slope at a flat gradient which is not necessarily available adjacent to an abattoir.

  - A high labour input to manage properly.

Of the available surface irrigation systems, furrow irrigation is most suitable for effluent re-use because of the better control which can be exercised. There are a number of examples of effluent from different sources (municipal, food processing) currently being used successfully for furrow irrigation of trees.

- **Micro irrigation** systems have a number of advantages and disadvantages compared to surface and sprinkler irrigation. For effluent irrigation, the main factors to consider are that, because of the small diameter outlet from which water flows, the outlets are prone to blocking from:

  - Suspended solids carried in the water. This is a particular problem for partially treated abattoir effluent and expensive filtering equipment can be required to remove the suspended solids.

  - Algae growing in the outlet nozzles at times when the flow is turned off. This is a particular problem for abattoir effluent because the nitrogen and phosphorus in the effluent encourages algal growth.

  Micro irrigation is not recommended for abattoir effluent unless specialist skills are available and the value of the crop being irrigated warrants the higher capital and operating costs.

B-5.2 Spray Irrigation

B-5.2.1 System Features

Spray irrigation systems usually comprise four key elements shown in Figure B-5.1:

- A pump to pressurise the water from a storage in order for it to flow through the pipeline system.

- A main supply line which delivers the water from the pump to the irrigation area and which usually terminates in one or more hydrants to which an irrigation line can be attached.

- An irrigation line which is connected to a hydrant point and which distributes the water to a number of spray nozzles.

- A number of spray nozzles which distribute the water.

The main differences between different spray irrigation systems lie in the way in which water is applied sequentially to different areas. There are three basic arrangements:

Permanent systems which have all the necessary pipes and sprinklers in place to irrigate the whole area. Sequential watering of different areas is achieved by valves which control the flow of water to each different area in turn.

Sprayline systems which have a number of sprinklers arranged along a pipe laid out across the field. Once watering of an area is complete, the sprayline is moved to the next area. The differences between various sprayline systems lie in the way in which the sprayline is moved. Centre pivot and lateral move irrigation systems are sprayline systems which have sophisticated means of being moved.

Travelling irrigators which, instead of a line of sprays, have a single large spray head which is moved across the field.

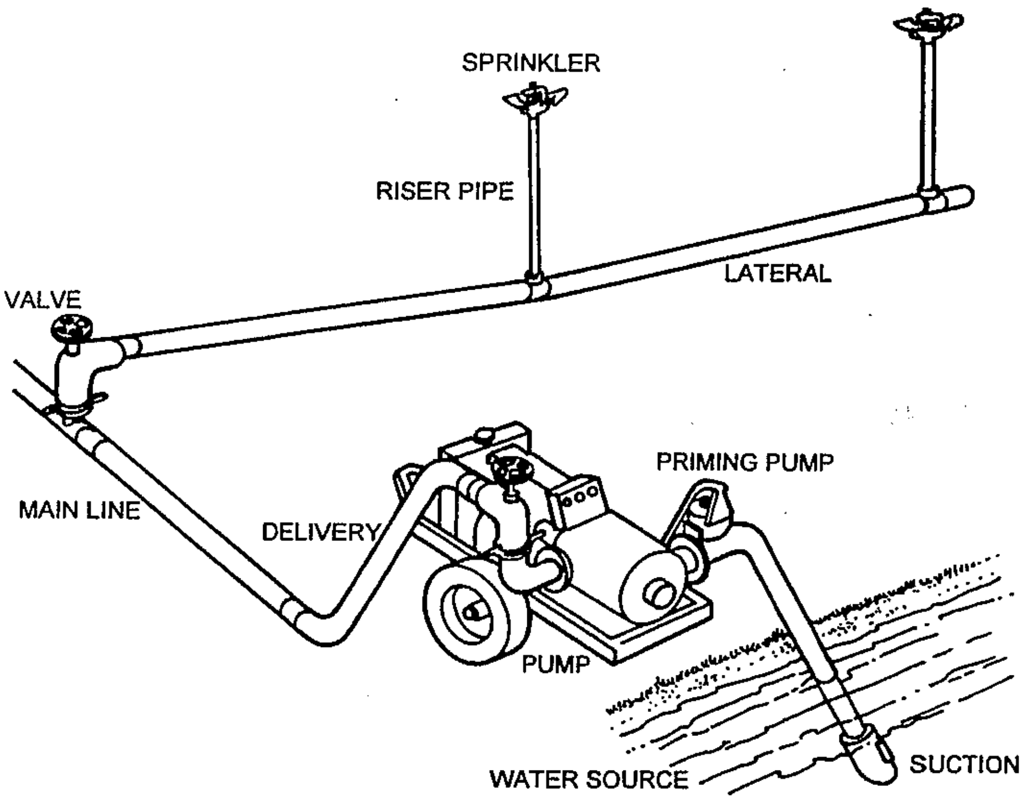


Figure B-5.1 ***Principal components of a spray irrigation system***
(adapted from Kay 1983)

The key points in the selection of a spray irrigation system are that it must:

- Be able to apply sufficient water to meet the crop's needs. The available equipment must be of sufficient capacity that it can cover the irrigation area in the time that it takes for the crop to use the applied water during the ***peak summer period***.

- Apply water at a rate compatible with the intake rate of the soil. Equipment which applies water at a rate which is too rapid for the soil, will lead to ponding of water on the surface and the potential for runoff to occur.

- Maintain a sufficiently even pressure distribution throughout the system to achieve an acceptable uniformity of application and drop breakup. Failure to achieve this can cause uneven crop growth and the potential for localised over-watering.

The degree to which these criteria are met will depend to a large extent on the spray irrigation system selected, its design and installation. Selection will be based largely on:

- cost (capital and operating),
- labour requirements,
- energy use,
- ease of management.

B-5.2.2 System Considerations

Solid Set Systems: These systems (Figure B-5.2) have a complete system of pipes which cover the whole area to be irrigated. Irrigation to a particular part of the area is controlled by turning on the supply to part of the area. These systems are often expensive to install but with remote control valves to control the flow of water can have very low labour requirements. They are favoured for tree and vine crops and for other high valued crops such as horticultural crops and cut flowers.

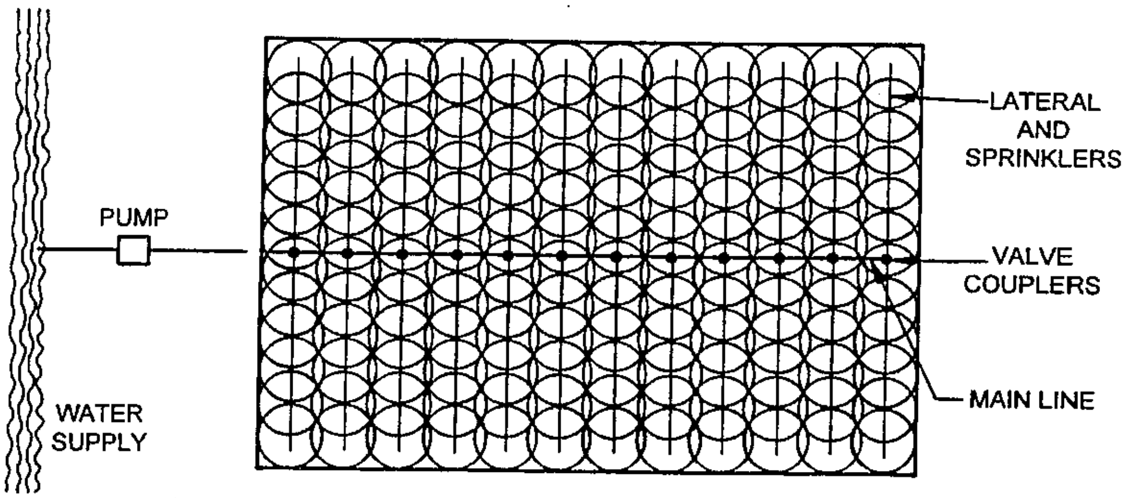


Figure B-5.2 ***General arrangement of a solid set irrigation system*** (adapted from Kay 1983)

Hand-Move Spraylines: These systems involve the use of lengths (up to 12 m) of aluminium irrigation lines which can be easily uncoupled and moved (Figure B-5.3). These systems are relatively cheap but have high labour requirements. For most hand-move irrigation schemes the practical limit is about 20 ha.

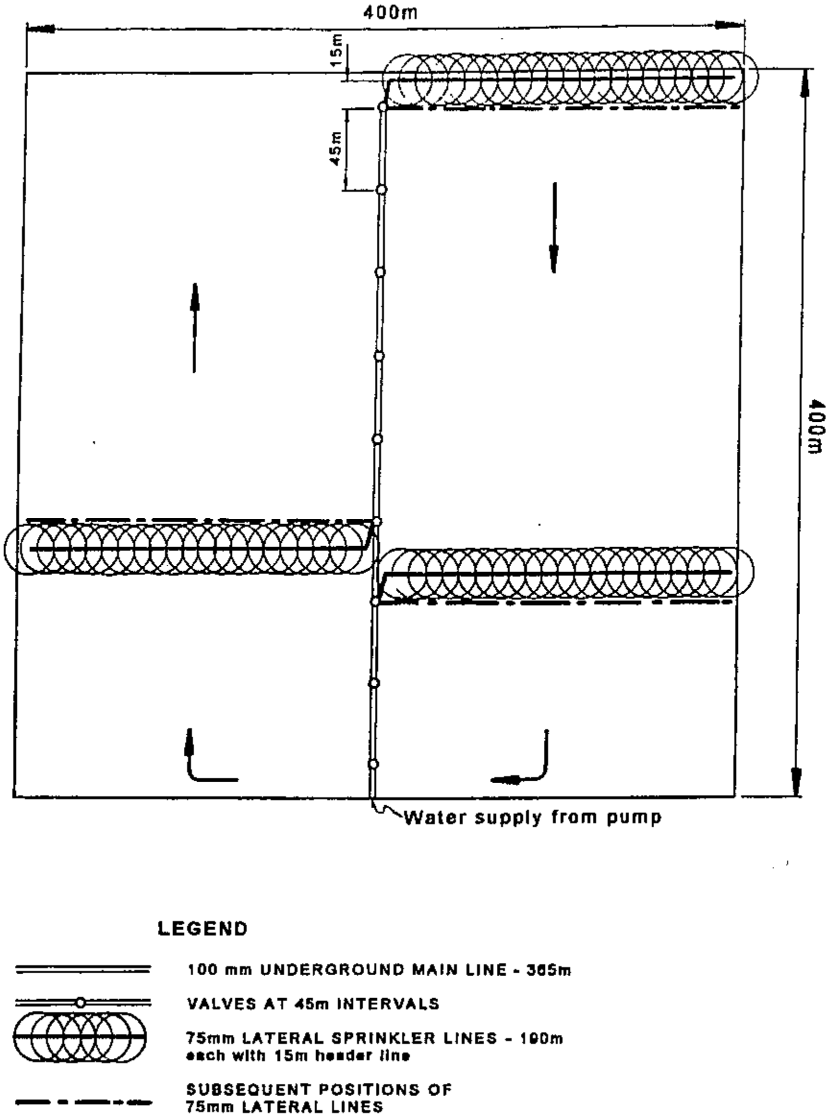


Figure B-5.3 ***General arrangement of a hand-move irrigation system***

Power Move Spraylines: These systems use a tractor, small attached motor or human power to move a complete spray line without the need to uncouple the individual pipes which make up the sprayline.

- End tow and angle tow systems rely on a tractor to tow the line to a new location. The space required to move the lines and the mode of moving generally limits these systems to large regularly shaped areas of pasture.

- Side roll systems can be moved manually by a large treadwheel (for lines up to about 200 metres long) or by a small petrol engine for lines about 400 metres long. Wheels up to about 2 m in diameter are available, allowing the use in reasonably tall crops. These systems may be viable on fairly flat, regular areas, but are not economic on small, irregular areas.

Centre Pivot: These systems (Figure B-5.4) have a single sprayline which rotates slowly around a central water supply hydrant. They have a high capital cost but give a high degree of control over watering and have low labour requirements. The development of low pressure sprinklers and droppers (see Figure B-5.8) has helped reduce the pumping cost associated with operating these systems. Centre pivots tend to be particularly suited to alluvial soils having good intake characteristics. While centre pivot systems can accommodate some undulation in the land surface, they are better suited to flat land. Uneven land will tend to cause the lateral to get out of alignment as it rotates and will lead to pressure variation which will upset the uniformity of watering.

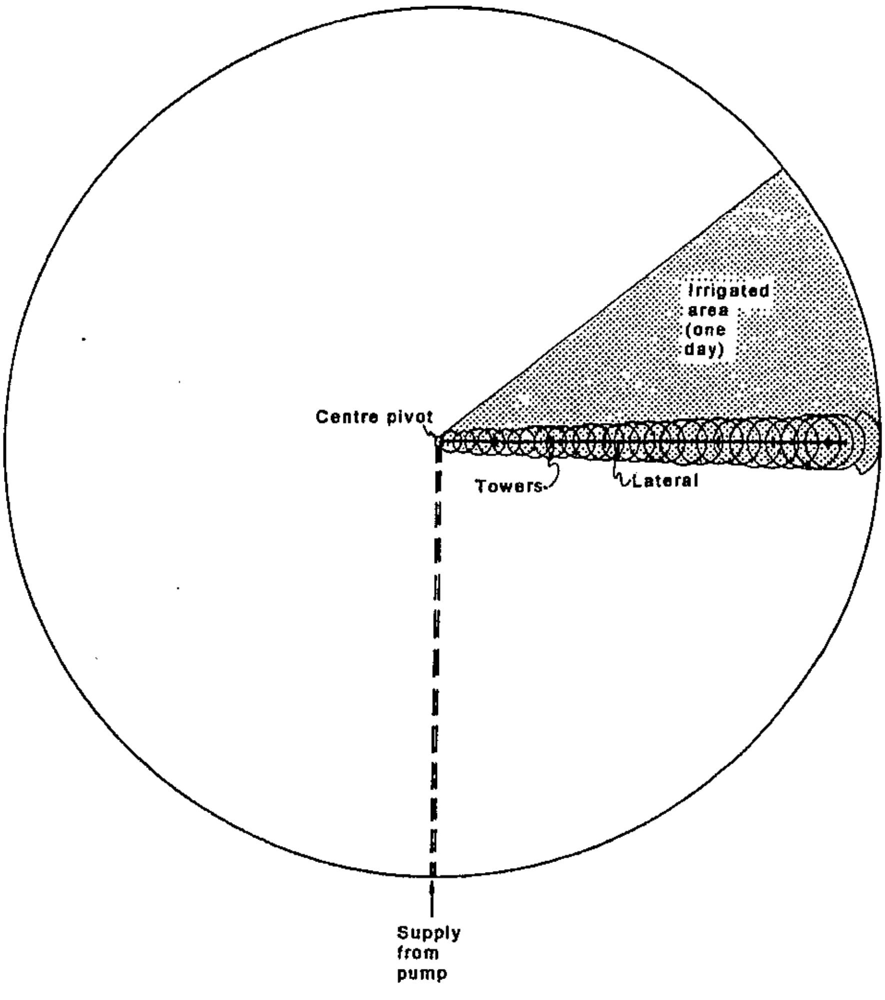


Figure B-5.4 ***General arrangement of a centre pivot irrigation system***

Because the outer end of the centre pivot spray line moves rapidly compared to the remainder of the line, the outer sprinklers must apply water more quickly. If the rate of application exceeds the infiltration rate of the soil, water ponds on the surface and may run off and cause a pollution problem. The problem of high instantaneous rates of application at the end of the spray line increases with the length of the line. Centre pivot systems also suffer from the fact that the highest flow rates from sprinklers are needed at the opposite end to the supply (where the pressure is highest). These considerations generally confine centre pivot irrigation to areas of 40 - 60 ha for any one irrigator.

Travelling Lateral Machines (lateral or linear moves): These systems (Figure B-5.5) have a long sprayline which is moved along the length of the field. They may be supplied either from a flexible hose or by means of their own pump drawing water from a canal running along the edge of the field. Because the whole line moves at the same speed, these systems do not have the same inherent hydraulic problems as centre pivots and can use lower pressures which reduce operating costs. These systems also overcome the limitations on farming and land utilisation imposed by the circular patterns of centre pivots.

Water application efficiency can be increased and pressures reduced by using droppers which release water just above ultimate crop canopy height (see Figure B-5.8). Even greater efficiency is claimed for low energy-precision application systems in which water is distributed directly to the furrow at very low pressure.

While travelling laterals have the ability to water large areas with good water control, a high level of management is necessary. A good understanding of irrigation scheduling is necessary for their effective use.

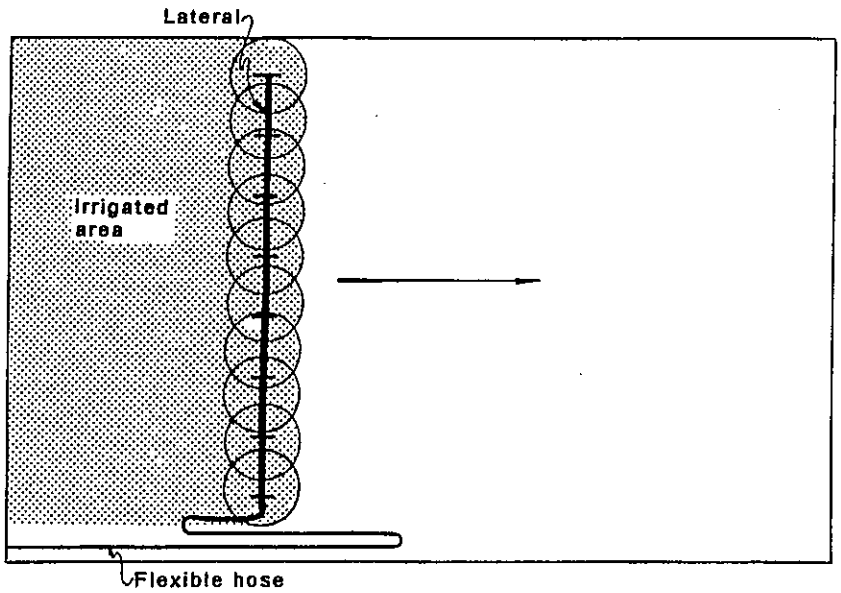


Figure B-5.5 ***General arrangement of a lateral move irrigation system***

Travelling Irrigators: These systems have a single irrigator head which has a large rain gun (see Figure B-5.7). The systems (Figure B-5.6) rely on the irrigator head being moved across the field by a winch arrangement driven by a water turbine which obtains its power from the flow of water on its way to the irrigator. They are recognisable by the large jet of water which may have a throw of 100 m or more. Travelling irrigators are relatively cheap to buy and install, but because they require high water pressure to create a large jet, they have high operating costs. Typically, the cost required to operate the large sprinkler and overcome the friction of the travelling hose is of the order of \$30 - \$40 per ML pumped. The large jet of water can be affected by wind and this can lead to uneven watering. For effluent irrigation, the susceptibility of the jet to being blown by wind increases the risk of nuisance caused to neighbours from spray drift. The uneven watering characteristic of travelling irrigators can be offset by reducing the distance between the "lanes" down which the irrigator travels. Problems of spray drift can be overcome by only watering during calm weather. Despite the shortcomings of travelling irrigators, their simplicity of operation and versatility have led to them being popular for effluent disposal.

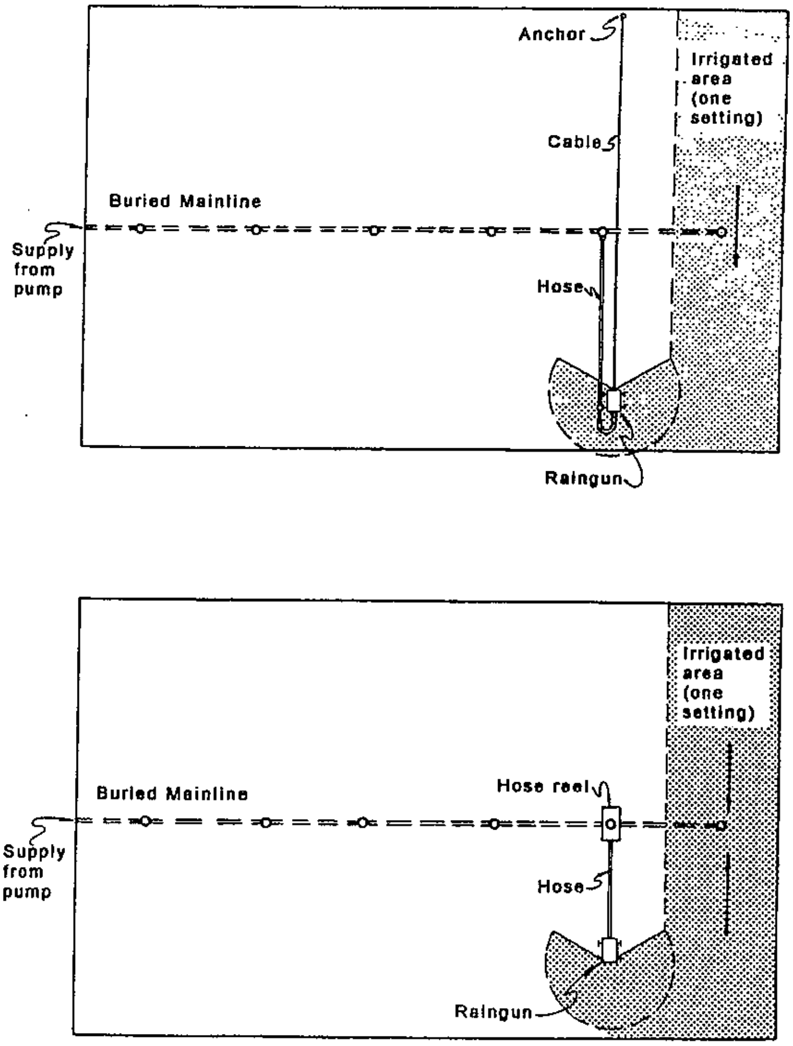


Figure B-5.6 *General arrangement of travelling irrigator systems*

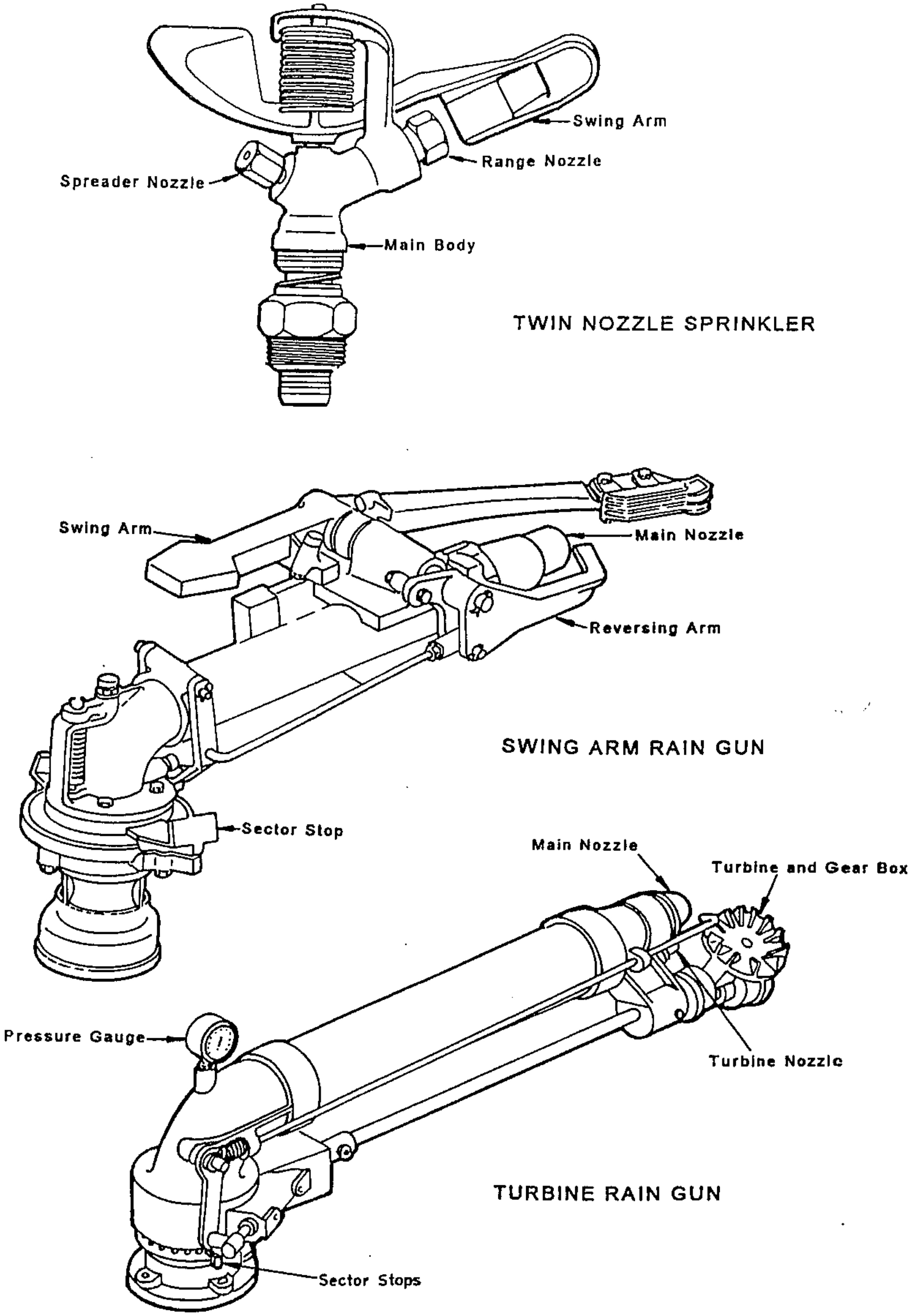


Figure B-5.7 *Typical sprinklers and rain guns*

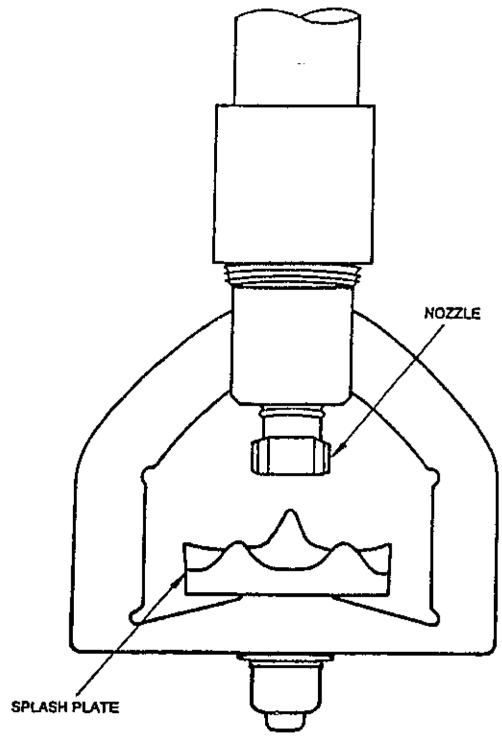


Figure B-5.8 ***Typical arrangement of low energy nozzles***

B-5.2.3 Design Considerations

System Capacity: The main requirement for any spray irrigation system is that it must have sufficient capacity to supply water to the whole of the irrigation area to meet the peak summer demand. (If the system was only capable of delivering the average daily demand, it would be unable to supply sufficient water when the evapotranspiration rate is high and there has been no rain.)

To meet this requirement, all elements of the system (pump, supply line, lateral or rain gun) must have sufficient capacity to water the whole of the irrigation area in the time that it takes a crop to reduce the soil moisture store from full to about the refill point. (For conventional irrigation the refill point is often about 50% of the soil moisture store, but as noted after Table B-5.2 and explained in Section B-6.2, effluent irrigation often requires a modification to this rule in order to not overload the land with nitrogen.) The number of days within which the system must water the whole area is referred to as the "irrigation interval" (D) and is calculated from:

D = [Full soil moisture capacity (mm)
- refill soil moisture (mm)] / Peak evapotranspiration rate (mm/day).

It can be seen that the irrigation interval is a function of:

- soil type - which affects the soil moisture holding capacity
- crop grown - which affects the depth of the root zone and the rate of evapotranspiration.
- local climate - which affects the peak evapotranspiration rate

EXAMPLE B-5.1

An 20 ha area which is being used for a maize crop, has the following characteristics:

- Full soil moisture store = 160 mm
- Refill soil moisture = 80 mm
- Peak evapotranspiration rate of 8 mm/day

Irrigation interval = [160 - 80]/8 = 80/8 = 10 days

The irrigation system would need to be capable of delivering 80 mm of water to 2 ha every day in order to be sure of applying enough water to the whole area. Assuming that the irrigation system worked 16 hours per day to meet the peak summer demand, the irrigation system would need to be able to deliver 80 mm of water to 2 ha in 16 hours. This is equal to a volume of 1.6 ML in 16 hours or 0.1 ML/hour.

The irrigation system would therefore need to have a capacity to pump and deliver about 28 L/s assuming that there were no losses.

In practice, a spray irrigation system can be expected to have a delivery efficiency of say 80% (see Table 5.5 in Section B-5.6). The irrigation system would therefore need to be capable of delivering additional water to account for the losses:

Flow required = 28 x 100/80 = 35 L/s

The approximate irrigation interval for different soils is given in Table B-5.2 for an assumed peak evapotranspiration rate of 200 mm/month (approximately 250 mm/month class A pan evaporation).

Table B-5.2 ***Irrigation interval, D (days) for different soil types assuming 200 mm/month evapotranspiration***

Root Depth (mm)	Sandy Loam	Loam	Clay
300	3.5	4.0	4.5
400	4.5	5.0	6.0
500	5.5	6.5	7.5
600	6.5	8.0	9.0
700	8.0	9.0	10.5
800	9.0	10.5	12.0
900	10.0	12.0	13.5

In the case of abattoir effluent, the required application of water will usually be governed by the amount of nitrogen which can be applied. Unless a supplementary supply of relatively fresh water is available (such as stored runoff from the irrigation area), a "deficit irrigation" strategy may be needed (see Section B-6.2.4) in which some of the elements might be:

- watering to keep only the top 300 mm of soil within a tolerable range of soil moisture,
- allowing the soil moisture to draw down to less than 50% capacity,
- refilling to only 85% of full capacity.

The requirements for such a deficit irrigation strategy are that the irrigation system must not only be capable of supplying only 85% of the evapotranspiration, but also supply small amounts of water more often.

To decide on an appropriate set of requirements for an irrigation system for effluent disposal purposes, the abattoir will need to work closely with an agronomist and an irrigation designer to ensure that the system is sufficiently flexible to meet the anticipated needs.

Sprinkler Spacing: In general, the amount of water applied decreases with distance from the sprinkler. To achieve a relatively uniform water coverage, sprinklers must be placed so that the spray patterns overlap the required amount. No two sprinklers give the same distribution of water onto the ground as illustrated by the various patterns shown in Figure B-5.9. It can be appreciated that the different patterns will require different degrees of overlap to achieve uniformity. It should also be noted that the distribution pattern of a sprinkler or rain gun can change significantly with pressure. For instance a sprinkler designed to produce pattern B will have pattern A if the pressure is too low and pattern C if the operating pressure is above the design specification.

For solid set, hand-move and similar equipment, it is usual to have rectangular, square or triangular pattern of sprinklers over a field. The required spacing is determined by the distribution pattern and is usually specified by the manufacturer. Typically, sprinklers with a distribution similar to A or B should not be placed at greater than 50% of the wetted diameter. Pattern C is suitable for spacing at about 60% of wetted diameter and D at 75%. These spacings do, however, assume that the area does not have a strong dominant wind. In that case, the general rules are:

- arrange spray lines to run at 90° to the wind direction
- reduce sprinkler spacing along the spray line by 15% of the wetted diameter,
- increase spacing between spray lines by 15% of wetted diameter.

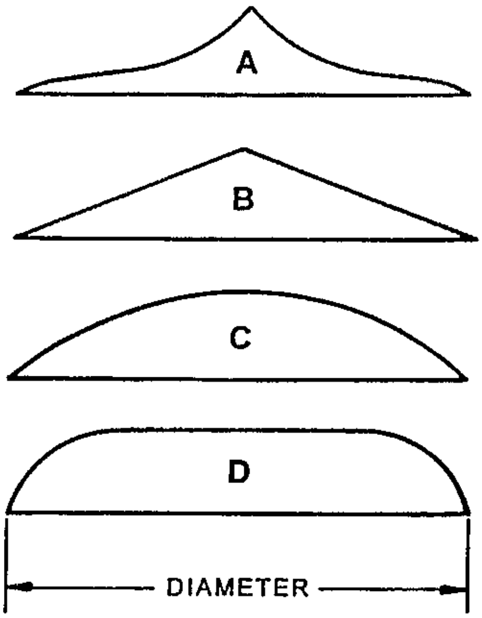


Figure B-5.9 ***Typical Sprinkler Distribution Patterns***

It will be appreciated that the spacing of sprinklers along the spray line and the distance between the positions of each successive spray line cannot be changed arbitrarily and a compromise must be made at the time the system is designed.

The exception is centre pivot or lateral move machines which move continuously and which only have a fixed sprinkler spacing along the line. On these machines, the effect of wind can be minimised by the use of low pressure droppers (see Figure B-5.8) set close to the crop canopy.

The size of sprinkler selected, its operating flow and pressure, and the spacing of sprinklers along the spray line are key factors which govern the hydraulic design of the whole irrigation system. Most manufacturers of sprinklers publish a recommended range of operating pressures. Use of pressure above the recommended range results in the spray being broken up into a fine mist which is more susceptible to the influence of wind and leads to excessive loss by evaporation and non-uniform irrigation. Pressure below the recommended range results in inadequate overlap of spray pattern, large droplets causing soil particle dislodgment and puddling that may result in surface crusting and runoff.

Irrigation sprinklers are not only sensitive to the operating pressure, but the performance can also be radically altered by wear of the nozzle or the swing arm mechanism. Wear of the nozzle will lead to an increase in flow for a given pressure and will upset the distribution pattern. Similarly, because the swing arm mechanism plays an important role in watering the area close to the sprinkler (as well as making the sprinkler rotate) any wear or damage can lead to uneven watering.

Size of Mains and Submains: The size of the main supply line between the abattoir and the irrigation area, and submains within the irrigation area generally affect the capital cost of the scheme substantially. A larger main costs more initially but results in lower pump pressures and thus smaller energy costs. These factors will all need to be taken into consideration at the time that the irrigation system is designed but are beyond the scope of this manual. For further information on this topic refer to any of the texts on irrigation listed in Chapter B-8.

Friction Loss in Spraylines: Once the designer has established the required spacing and size of sprinklers, the next task is to design the sprayline so that the pressure variation along the line does not cause unacceptable differences in spray patterns. Because the flow rate varies along the pipe, the estimation of pressure losses along a spray line is a complex hydraulic problem which requires the aid of design charts or computer programs to solve. As a general rule a variation of $\pm$10% in pressure along a spray line is considered acceptable.

This requirement to keep pressure variation within limits means that topography must be taken into account at the design stage. This means that even a simple hand move system cannot be reconfigured arbitrarily. Changing laterals so that they run uphill will cause a large variation in pressure along the line. This requirement to keep pressure variation within limits is one reason why a centre pivot system should only be used on relatively flat land (say $\pm$3 m over the area covered).

B-5.3 Surface Irrigation

B-5.3.1 System Considerations

Surface irrigation systems account for nearly 80% of Australia's irrigation and continue to be popular because:

- they are well adapted to the clay soils so widely spread throughout Australia's irrigation areas,
- there is an abundance of land of comparatively flat gradient,
- little equipment is required for irrigating,
- surface irrigation methods have a comparatively low energy requirement and are therefore cheaper to run.

For land that is flat and has clay soil, surface irrigation methods are often the cheapest and most effective. Properly designed, they can also be comparatively efficient. The systems most likely to be useful for effluent irrigation are:

- furrow irrigation for row crops such as maize or sorghum,
- border check irrigation for pastures.

The key element required for effluent surface irrigation is the ability to control the flow of water so that it is lying on the soil surface for an equal time on all parts of the paddock. To achieve this, the features required in a surface irrigation system are:

- Uniform gradient of the land from the supply canal to the "tailwater" drain,
- Low infiltration capacity of the soils,
- Ability to supply water to the land at a high rate,
- Ability to manage the time when flow starts and stops.

B-5.3.2 Irrigation Layout Masterplan

A surface irrigation system is a much more permanent fixture than the pipes and irrigators which make up a spray irrigation system. It is therefore essential that a surface irrigation system be carefully planned and designed to take account of the landform and soil types present in the irrigation area.

Before starting any earthworks it is important to plan the irrigation layout in the setting of the planned land use of the whole effluent irrigation area including any associated facilities. The plan should show a detailed layout of the position of all channels, drains, dams, pumps, tracks, buildings, tree plantations, gates, paddocks and irrigation bays (width, length and grade). The objective of preparing an irrigation masterplan is to ensure that all the facilities function properly as components of a coherent system so that:

- Water is applied and removed efficiently and uniformly in the most simple way,
- Cultural operations are made easier,
- Irrigation efficiency is maximised,
- Labour is minimised.

B-5.3.3 Border Check Irrigation

Border check is most suitable for pastures or close-growing crops on land of gentle terrain. The land is divided into strips, 10 to 25 m wide, running down the direction of the predominant slope. The strips are separated by low earth banks, generally called "check banks". A typical border check system is illustrated in Figure B-5.10. The length of borders is generally governed by the topography, soil type and the property or paddock boundaries. Some guidelines for typical lengths and widths of bays are given in Table B-5.3.

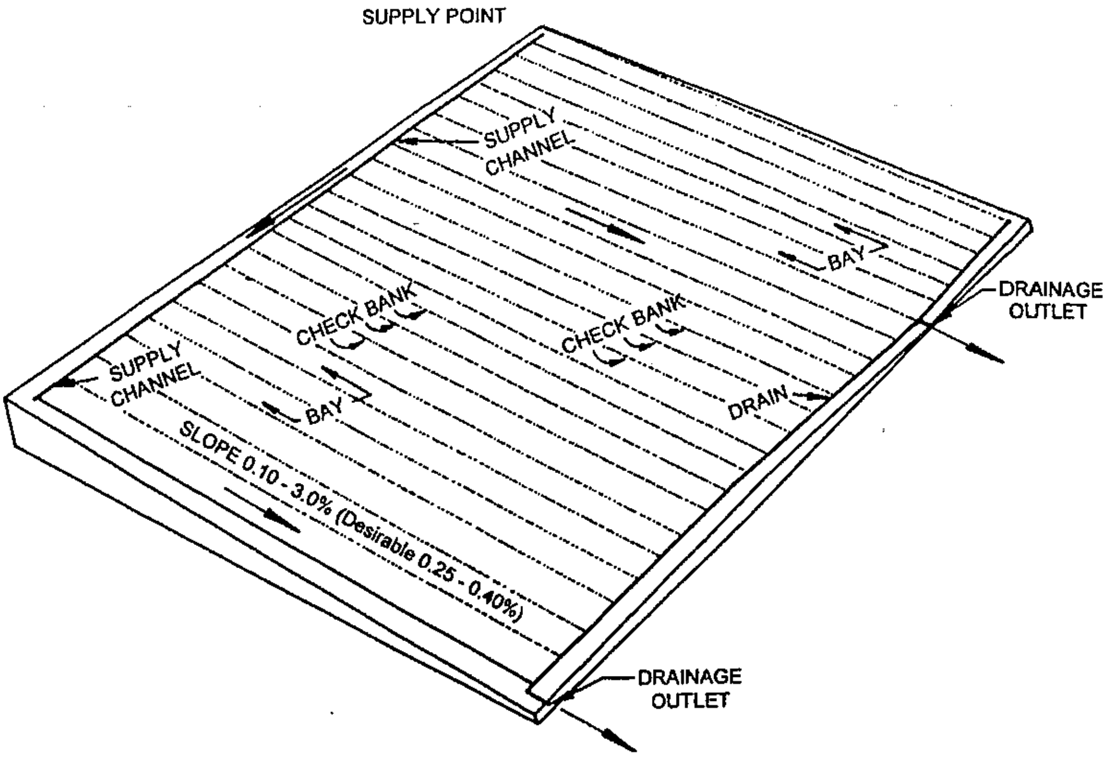


Figure B-5.10 ***Typical Layout of Border Check Irrigation System***

Table B-5.3 ***Typical dimensions and grades for irrigation bays***

	Clay	Clay loam	Sandy Loam
Grade (%)	0.1 - 0.25	0.2 - 0.6	0.25 - 1.0
Maximum Length (m)	240 - 300	160 - 200	90 - 120
Maximum Width (m)	20 - 25	15 - 20	10 - 15

The initial design should be based on making the bays as long as possible, keeping the overall layout simple and workable. The infiltration capacity of the soil and the water supply available have a dominating effect on the length of bay which can be irrigated efficiently, so these must be considered in conjunction with topography.

The required flow down a border is influenced by:

- the infiltration capacity of the soil,
- the flow rate into the bay,
- the resistance to flow offered by rough soil and/or vegetation,
- the slope of the bay,
- the length of the bay,
- the time when the inflow is stopped.

For any particular situation, however, most of the parameters are "fixed" by the soil and topography. The inflow rate and the time until the inflow is stopped are the only "free" variables.

The design of an efficient border check irrigation system requires professional assistance to balance the infiltration characteristics of the soil and the hydraulics of flow of irrigation water onto the land to achieve a uniform "opportunity time" for infiltration to occur across the field. Figures B-5.11 and B-5.12 illustrate how the flow of water advances down a bay. It can be seen that by manipulating how fast the water advances down the bay (a function of flow rate from the supply canal) and the time at which the flow is stopped, it is possible to create approximately equal infiltration "opportunity time" at all points along the bay. The calculations for this are complex and should only be undertaken by a competent irrigation designer.

B-5.3.4 Furrow Irrigation

Furrow irrigation is used extensively for row crops such as maize, grain sorghum, soya beans, cotton, linseed, safflower and sugar cane. Generally the furrows are run down the slope between individual rows of plants spaced 0.75 - 1.0 m apart. A series of furrows are watered either individually or in groups from a channel running across the top of the field. The general concept of furrows being irrigated using individual siphons is illustrated in Figure B-5.13. Sometimes crops such as fodder sorghum, wheat or oats are sown with a "combine" in rows about 200 mm apart, then "furrowed out" once the crop has started to grow to create beds about 2 m wide with a furrow between each bed.

The irrigation layout should aim for uniform row lengths with straight furrows as near as possible at right angles to the slope of the land. Land grading using laser levelling equipment is often used to achieve a uniform grade down the furrows and allow more efficient irrigation. Some general guidelines for furrow layout are given in Table B-5.4. Excess crossfall (>0.5%) is undesirable in furrow layouts because furrows can easily overflow with storm runoff into adjacent downhill furrows. This rapidly leads to rill erosion running down the slope.

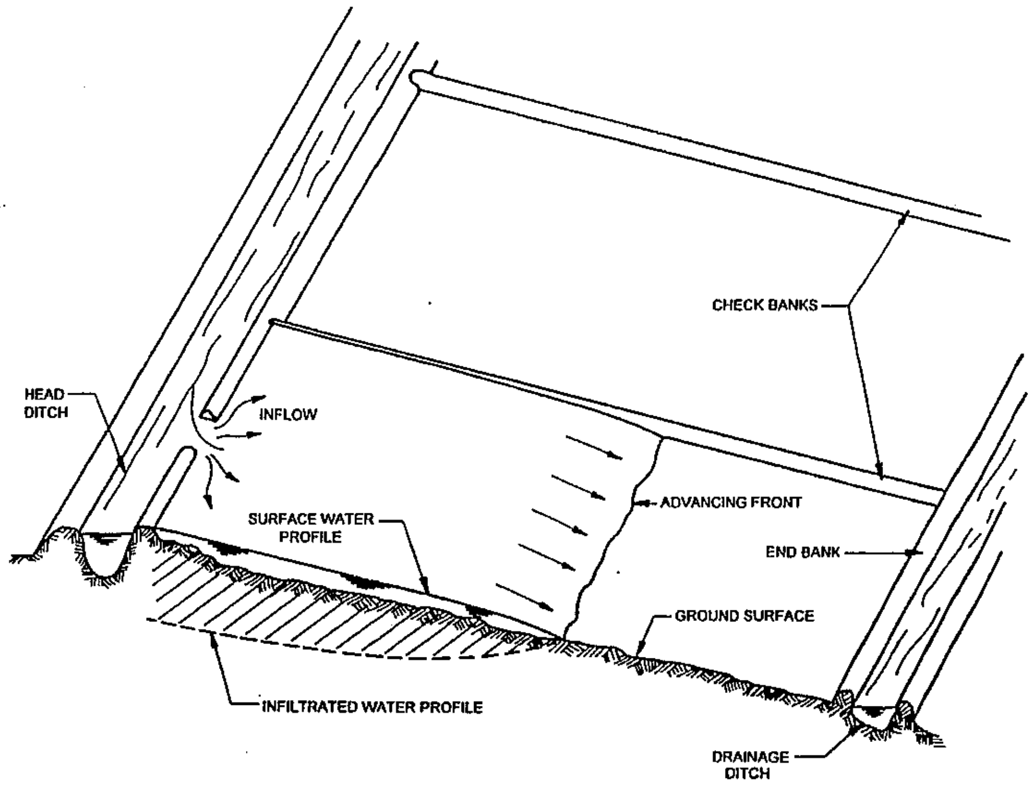


Figure B-5.11 *Advance of the Wetting Front Down a Bay*

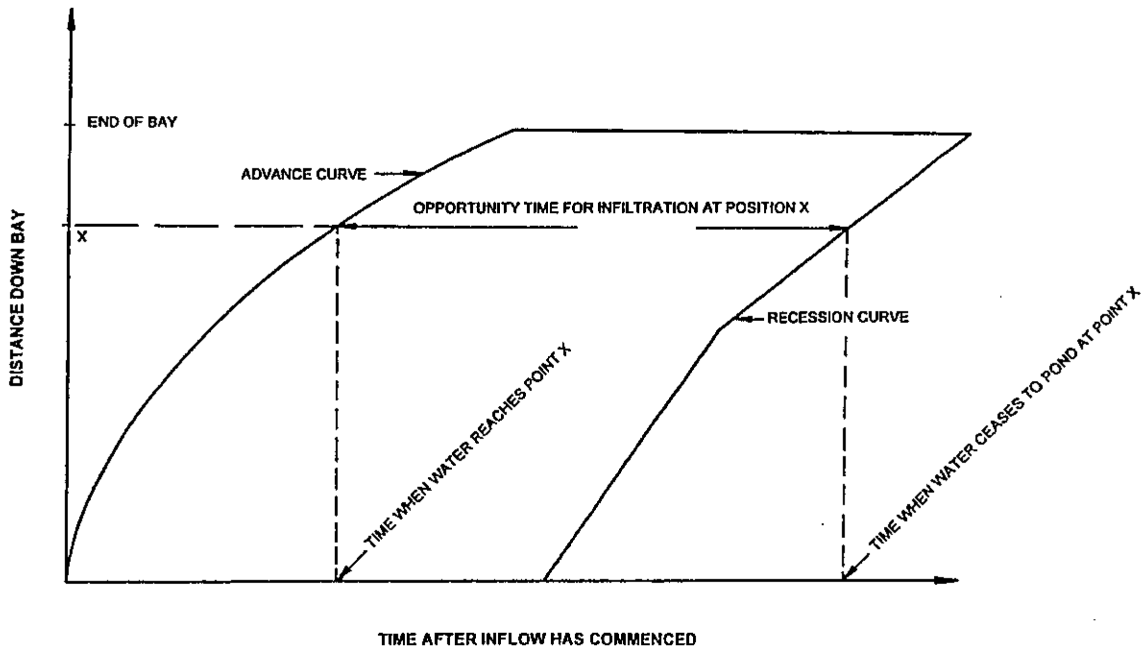


Figure B-5.12 *Opportunity Time Available for Infiltration*

Table B-5.4 *Typical grades, spacing and length of furrows*

	Clay	Clay Loam	Sandy Loam
Furrow Grade (%)	0.05 - 0.25	0.15 - 0.6	0.3 - 1.0
Furrow Spacing (m)	1.0	0.6 - 0.9	0.4 - 0.6
Grade (%)	Maximum Furrow Length (m)		
0.10	750	450	250
0.25	500	360	200
0.50	350	250	140
1.0	250	150	90
2.0	170	110	-

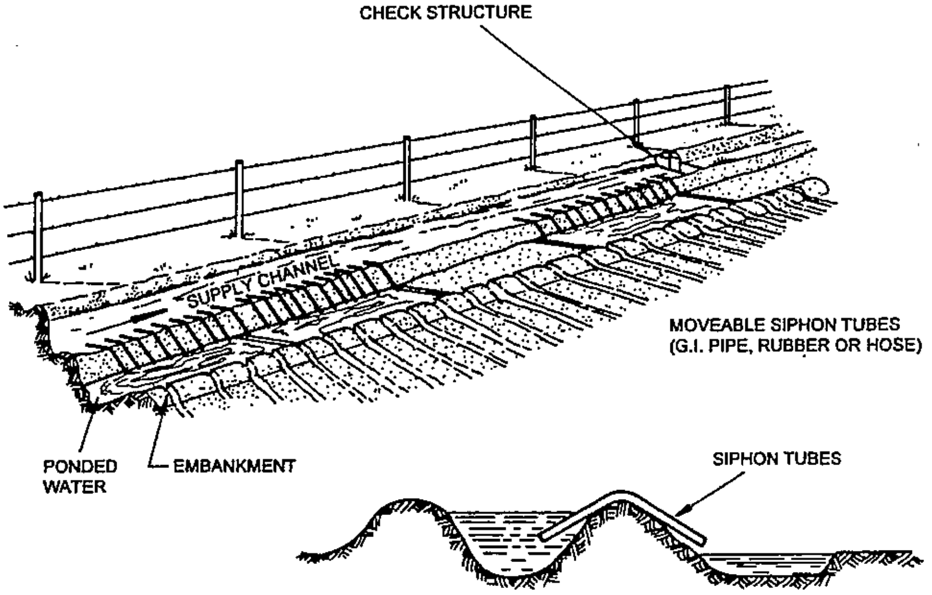


Figure B-5.13 *Flow of Water From a Head Ditch into Furrows Using Siphons*

For ease of management and best use of machinery it is common to aim for the maximum possible length of furrow. However, for effluent irrigation, the possibility of erosion from storm runoff must also be considered and furrow lengths limited accordingly. As with border check irrigation, the key factors which determine the efficiency of irrigation are the ability to provide the required flow rate to each furrow and to control the "opportunity time".

B-5.3.5 Landforming

Landforming is the practice of smoothing the surface of land to a predetermined grade. Most of this work is now done using laser-controlled equipment which allows the creation of uniform grades. The aim of landforming is to create a land surface that allows for uniform water application, improved drainage and easier management. If undertaken properly with good planning, landforming enables improved control over water application depth and gives improved uniformity of water application.

B-5.3.6 Water Application

Early methods of water application generally involved cutting through the head ditch bank with a shovel. The advent of aluminium and subsequently polyethylene pipe allowed the introduction of over-the-bank siphons for furrow irrigation, while precast gated outlets are popular for border check irrigation. The labour requirements of gated outlets for border check irrigation are quite low. However, numerous devices have been developed for automatic operation and to prevent over-watering.

Apart from labour saving, one of the greatest advantages of high capacity application systems is the ability to apply water rapidly. Commensurate with this must be the capacity to remove the tailwater rapidly, with good land grading to prevent pondage in the field. Shallow grades are required to prevent in-field erosion.

Small diameter siphons allow individual control of water application to each furrow, but the labour requirements are high and the use of individual siphons is losing favour.

B-5.3.7 Drainage

The collection of "tailwater" from the end of irrigation bays and furrows is necessary to:

- prevent waterlogging at the end of the bay or furrow.
- provide a means of capture and re-use of both excess irrigation and rainfall runoff.

The provision of tailwater drainage and its associated storage and recycling system are now becoming mandatory for all effluent irrigation areas. Section B-5.5 sets out the size requirements and operational features for tailwater drainage and runoff collection systems for effluent irrigation areas. Such systems are also becoming common "good practice" in commercial irrigation because of the economic advantage to be gained from better water management and increases in the total supply of water available.

B-5.4 Micro Irrigation

There is now an extensive range of micro irrigation equipment available for use on fruit, vegetables and many field crops. Micro irrigation systems are particularly favoured for high value crops such as vines and orchards but they require management skill and diligence. For effluent irrigation they require a careful attention to filtration of the effluent before it flows into the irrigation distribution system. For these reasons, the use of micro irrigation systems for utilisation of abattoir effluent are only likely to be considered if specialist advice is available and there is a specific use for the effluent. However, the level of design and management effort required is such that an abattoir which has such expertise available probably does not need this manual.

Don't consider micro irrigation for abattoir effluent unless you:

- ***have a special use for it and***
- ***really know what you are doing.***

Although micro irrigation cannot be recommended unless specialist advice is available, it is worth reviewing some of the major features of the systems available.

B-5.4.1 Advantages and Disadvantages

Advantages:

- Very adaptable to a wide range of crops, soils and management systems.
- Can be efficient in water and power use.
- Highly suited to automation and labour savings.
- Can enable precise quantities of water to be delivered to each plant or group of plants and accurate control of moisture in the root zone.
- Suited to the application of nutrients dissolved in the irrigation water such as in the case of effluent.
- Suited to irrigation from limited water sources.

Disadvantages

- Blockages and stoppages are problems. Insects and rodents may block and damage the system. Water filtration and system hygiene are important.

- Frequent watering is required, especially when only a portion of the crop's root zone is being wetted.

- Capital cost can be high compared to surface and some forms of travelling irrigation.

B-5.4.2 System Features

The following broad groups of micro irrigation systems need to be examined when making a decision on the type of equipment to be used.

Trickle or Drip Irrigation: Trickle irrigation applies water at very low flow rates to an individual point. Flow rates commonly used are from 2 to 8 L/h at each outlet (often termed an emitter). The emitter can be positioned at each plant or spaced to give a continuous wetted strip. In tree crops, several emitters are usually required to wet at least 30% of the normal root system. Trickle irrigation is suited to high frequency irrigation to maintain the soil moisture within close limits. Trickle irrigation needs a reliable water source and a high level of filtration. Typically the filter must have screen openings of no more than 0.1 mm. A filter with such fine openings is likely to block rapidly with abattoir effluent and would require very frequent back flushing.

There are a variety of systems which compensate for pressure variation along the lateral and give uniform watering. Irrigation lines with preformed emitter spacing and discharge characteristics are available in lengths up to 2,000 m which are suitable for a wide range of vegetable and row crops.

Microjets: The emitter consists of a small (0.8 - 1.5 mm) outlet hole and sloped distributor to spread the water over a wider area than can be achieved with a trickle emitter. The microjet usually has no moving parts to assist in water distribution and the jet either screws directly into the lateral or can be mounted on a riser. Microjets usually operate at a pressure of 100 - 150 kPa and discharge 20 - 120 L/h. Microjets are manufactured in a variety of types and wetting patterns and are most commonly used in permanent tree crops.

Because they have larger openings than drip emitters, microjets are not as prone to blockage from suspended solids in the water and do not require such a high standard of filtration. Nevertheless, filtration is still required for effluent such as that from abattoirs. In addition, microjets, like all forms of micro irrigation, are prone to blockage by algal growth which is encouraged by the nutrient rich effluent.

Microsprinklers: A rotating vane device is used to assist distribution of water after it passes through a jet. Microsprinklers have flow rates up to 200 L/h and wetted diameters of 1 - 2.4 m. Microsprinklers are mainly used in orchards and may be laid out to give close to total wetting of the ground surface area.

Because of the larger nozzle size, microsprinklers are less prone to blockage by suspended solids than drip emitters or microjets. However, because water is sprayed into the air they are subject to higher evaporative losses than drip emitters.

B-5.5 On Farm Water Recycling and Storage

The possibility of excess irrigation effluent running off the irrigation area or of rainfall causing runoff soon after irrigation has occurred are both circumstances which could lead to pollution of the local creeks. Most regulatory authorities now require any effluent irrigation system to have a tailwater capture and re-use system. Such a system, besides protecting the environment, provides additional water for irrigation and would assist in obtaining a better balance between the water and nutrient requirements.

While tailwater capture is becoming mandatory for environmental protection purposes, it also has a potential significant benefit for areas irrigated with abattoir effluent. For most abattoirs, the limitation on how much effluent can be applied will be the nutrient load - not the amount of water applied. In Section 2.6, examples were given showing how a relatively small amount of effluent would be required to meet the nutrient requirements of a typical pasture crop grown for hay. The examples showed that although the nutrient requirements could be satisfied easily, an excess of nutrients would be applied if sufficient effluent was applied to meet the water requirement of the crop. Most systems can therefore expect to be applying less water than the plants could use. Any additional water provided by a tailwater drainage system will aid plant growth and utilisation of more nutrients.

B-5.5.1 Drainage

Tail drains are required to remove furrow or bay runoff following irrigation or rainfall. In most areas, the required drain capacity is dictated by the rate at which water must be removed in order to avoid damage to the crop through waterlogging of the soil. Most pastures and forage crops will start to show a decline in production if water is left lying for 2 to 5 days. In the case of an effluent irrigation area, where considerations of pollution control are paramount, drainage of runoff within 24 hours is desirable. Typically the drainage system is designed to take the flow from the once in 10 year, 24 hour storm. For more severe storms, the requirement to drain the area within 24 hours is relaxed but any escape of runoff should only be in a carefully controlled location such as a spillway from the storage dam.

B-5.5.2 Storage

Tailwater and runoff should be collected in a separate storage from the main effluent supply. When sufficient volume has collected, the water can be pumped to a main storage or directly back into the irrigation system.

There are no generally applicable guidelines for the required size of the tailwater collection storage. Various design criteria have been proposed by different States but there is no uniformity of methodology. Two general approaches are used:

- Specify the depth of runoff from the irrigation area which must be stored. In NSW, the EPA is promoting the adoption of a tailwater storage with a capacity to capture 12 mm of runoff from all irrigation land, not just that on which effluent is irrigated. This requirement would entail the provision of 12 ML of storage per 100 ha of irrigated land.

- Specify the probability of occurrence and the duration of the storm which leads to the runoff which must be captured. (eg the runoff from the 1 in 20 year, 24 hour storm). To interpret this criterion into an actual volume of storage requires a specialist with skills in hydrology. The main factors which will govern the storage size are the storm rainfall, irrigation area, soil type and general slope of the land.

Whatever the size of the storage provided, it is important that it be designed as a "first flush" capture storage and be arranged so that once the storage is full any additional runoff discharges out of the drainage system without entering the storage. Figure B-5.14 shows a general arrangement for such a system which ensures that the initial runoff, which is likely to contain the majority of any pollutants, is captured in the storage while the cleaner subsequent runoff is allowed to discharge to the environment.

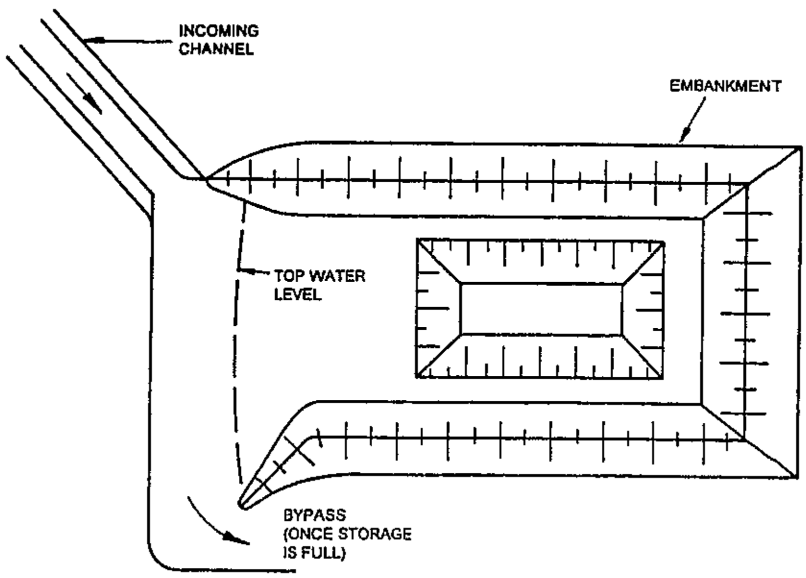


Figure 5.14 ***General Arrangement of a First Flush Capture System***

B-5.6 Irrigation Efficiency and Uniformity

Water application efficiency is an irrigation concept that is very important both in system selection and design, and in irrigation management. The ability of an irrigation system to apply water uniformly and efficiently to the irrigated area is a major factor influencing the agronomic and economic viability of the farming enterprise. Uniform watering is essential to avoid waterlogging a section of the irrigation area which could lead to runoff or drainage to the groundwater.

Attainable water application efficiencies vary greatly with irrigation system type and management. Some idea of the efficiencies that may be achieved with reasonable design and management are shown in Table B-5.5.

Table B-5.5 *Water Application Efficiencies*

Type of System	Attainable Efficiency
Surface Irrigation	
Basin	80 - 90%
Border	70 - 85%
Furrow	60 - 70%
Sprinkler Irrigation	
Permanent	70 - 80%
Hand-Move	65 - 75%
Travelling Gun	60 - 70%
Centre Pivot & Linear Move	75 - 90%
Micro Irrigation	
Point Source Emitters	75 - 90%
Line Source Emitters	70 - 85%

Irrigation efficiency can be divided into two components:

- water losses
- uniformity of application.

If either the water losses are large, or application uniformity is poor, efficiency is low. Although both components of efficiency are influenced by system design and management, losses are predominantly affected by management, while uniformity is predominantly affected by system design.

B-5.6.1 Water Losses

Over-watering is probably the most significant cause of water loss in any irrigation system. No matter how good the system design, if more water is applied than can be beneficially used by the crop, efficiency declines. Thus, proper irrigation scheduling (see Section B-6.2) is important if high efficiencies are to be achieved. Scheduling on its own will not, however, guarantee high efficiency because the water might be applied unevenly so that some ares are over-watered while others do not receive sufficient water.

Aside from over-watering, the major losses associated with surface irrigation systems are direct evaporation from the wet soil surface, runoff losses, and seepage and evaporative losses from water distribution ditches. Runoff losses can be virtually eliminated by return flow systems that capture the runoff water and direct it back for re-use. The seepage loss from unlined ditches depends on soil characteristics and the extent of the ditch network, but usually ranges from 10% to 15% of the supplied water. Lined canals or pipe distribution systems are necessary to completely eliminate seepage losses.

The primary losses associated with sprinkler irrigation (other than those due to over-watering) are direct evaporation from wet soil surfaces, wind drift and evaporative losses from the spray, system drainage and leaks. Evaporation from the soil surface depends upon irrigation frequency and the extent of bare soil between the plants to be irrigated. Some of the water "lost" to wind drift and evaporation from the sprinkler spray is not actually lost, since it substitutes for crop transpiration. Net losses in this case may be as low as 2 - 3%, or as high as 15 - 20% under adverse windy conditions. Well maintained sprinkler systems should have leak and drainage losses below 1%, but poorly managed systems have shown losses of near 10%.

B-5.6.2 Irrigation Uniformity

Ideally, an irrigation system applies water in a completely uniform manner, so that each part of the irrigated area receives the same amount of water. Unfortunately, there seems to be no way to achieve this. Even natural rainfall is not completely uniform. So the phrase "irrigation uniformity" actually refers to the variation or non-uniformity in the amount of water applied to locations within the irrigated area. Significant effort in irrigation system design and management is directed towards dealing with problems related to irrigation uniformity, or the lack of it.

Whenever water is applied with less than perfect uniformity, some parts of the crop receive more water than others. If the irrigation system is operated so that the part of the crop receiving the least amount of water has its requirements met, then the remainder of the crop is over-irrigated and is likely to cause waterlogging or runoff.

B-5.7 Irrigation Area and Wet Weather Storage Requirements

The question which is always asked about effluent irrigation systems is, "Has this abattoir got enough irrigation area?"

The question which is less often asked, but is closely connected to the first is, "Has this abattoir got enough wet weather storage?"

Unfortunately the answers to these two questions are quite specific to an individual location and to the effluent produced by the particular abattoir. Also, to make a full assessment for a particular situation requires detailed analysis by an expert and is beyond the scope of this manual. The following outline is intended to give an overall appreciation of the major considerations, and is not intended to be used as a detailed "do it yourself" guide.

B-5.7.1 Irrigation Area

The minimum required irrigation area is found by calculating the area required to dispose of the water, nitrogen, phosphorus and BOD, and taking the largest of these numbers.

The area required in each case will be the total annual mass of water, nitrogen, etc, divided by an acceptable loading rate:

- **Water** - The amount of water which can be added is the difference between the evapotranspiration loss (mm) from the crop (see Section B-2.2) and the effective rainfall (mm) (after allowing for some runoff).

- **Nitrogen** - The net nitrogen uptake (kg/ha/year) by the crop must be calculated after allowing for volatilisation and denitrification losses (see Sections B-2.6 and B-6.1) and any nitrogen returned to the land by grazing animals. The nitrogen uptake by the crop(s) will depend on the type of crop(s) grown and the crop yield (which will also depend on how well it is supplied with water).

    - Typical nitrogen uptake by healthy crops is between 100 and 350 kg/ha/year (see Tables B-2.3 and B-2.5).

    - Losses by volatilisation and denitrification are highly variable and range between 5% and 50% of the nitrogen in the effluent, depending on the irrigation method, the BOD of the effluent and the irrigation management regime.

- **Phosphorus** - The phosphorus uptake by a healthy crop depends primarily on the type of crop and the crop yield. Typical crop uptake rates (see Tables B-2.3 and B-2.5) are in the range 20 to 40 kg/ha/year. In many cases Australian soils are deficient in phosphorus and adsorb it so strongly that additional phosphorus can be added (see Table B-1.8).

- BOD - The BOD loading can be up to 50 kg/ha/day for a short period but the overall average throughout the year should be nearer to 40 kg/ha/day (15,000 kg/ha/year).

EXAMPLE B-5.2

An abattoir produces effluent with the following characteristics

- Flow: 1 ML/day
- Total Nitrogen: 130 mg/L
- Total Phosphorus: 35 mg/L
- BOD 300 mg/L

The average annual rainfall at the locality is 590 mm per year and the average crop evapotranspiration is 1,400 mm.

Based on these data, the area requirements are:

Flow

• Evaporation demand	= 1,400 - 590 x (1-0.15) (mm) (assuming 15% runoff) = 900 mm	
• Effluent load	= 1 x 365 (ML/year)	= 365 ML/year
• Area required	= (365 x 100[a])/900	= 40 ha

Nitrogen

• Crop demand (say)	= 300 kg/ha/year	
• Losses (say)	= 40%	
• Net loading including losses	= 300/(1-0.4)	= 500 kg/ha/year
• Effluent load[b]	= 365 ML/year x 130 mg/L	= 47,450 kg/year
• Area required	= 47,450/500	= 95 ha

Phosphorus

• Crop demand (say)	= 20 kg/ha/year	
• Effluent load	= 365 ML/year x 35 mg/L	= 12,775 kg/year
• Area required	= 12,775/20	= 638 ha

BOD

• Permissible loading (say)	= 15,000 kg/ha/year	
• Effluent load	= 365 ML/year x 300 mg/L	= 109,500 kg/year
• Area required	= 109,500/15,000	= 7.3 ha

Assuming that the soils in the area are deficient in phosphorus, then the area required will be governed by the nitrogen loading = 95 ha.

[a] 1 ML of water = 100 mm depth over 1 ha
[b] 1 mg/L in 1 ML = 1 kg

In most cases the area required for disposal of abattoir effluent will be governed by the nitrogen loading. As explained in Section B-6.1, there is often an advantage in reducing the average nitrogen concentration, even by dilution, in order to reduce the required irrigation area.

B-5.7.2 Wet Weather Storage

Wet weather storage is essential in any effluent irrigation system. It is needed to hold the effluent during times when the soil is saturated by steady rainfall and cannot accept any more water.

The size of wet weather storage is governed by the climatic characteristics of the locality, the hydraulic loading and the effluent characteristics. The effluent characteristics need to be considered because they are a factor in how often the wet weather storage can be allowed to overflow and discharge to the environment. The greater the nutrient load in the effluent, the less frequently it should be allowed to discharge. Draft guidelines for the classification of wastes prepared by the EPA of NSW are set out in Table B-5.6

Table B-5.6 ***Classification of Effluent***
(EPA of NSW, 1995)

Constituent	Average Concentration (mg/L)		
	Low	Intermediate	High
Total nitrogen	<50	50-100	>100
Total phosphorus	<10	10-20	>20
BOD	<40	40-1500	>1500
Total dissolved salts	<500	500-1000	>1000
Permitted overflow frequency (years)	2	4	10

It can be seen that differences in the strength of the waste makes considerable difference to how frequently overflow can be permitted. In NSW, high strength effluent would only be allowed to overflow once in 10 years. It follows that a larger storage would need to be provided.

Just what sized storage is required in any particular situation can only be determined form a detailed analysis of long term rainfall records and a detailed analysis of soil water balance which would occur under any particular pattern of cropping. This type of analysis is beyond the scope of this manual. However, to provide a guide to the size of storage required, analyses have been undertaken for a series of locations which are representative of the climatic regions of Australia (see Figure B-3.1) and the areas where the animal industries are located. For each chosen location, a water balance analysis has been undertaken to assess the wet weather storage requirements.

The analysis has been generalised to allow it to be used for any sized operation and uses the following basic terminology:

- Basic irrigation area = Irrigation area determined from hydraulic loading

  From Example B-5.2, above this equals 40 ha.

- Multiples of "Basic" area = Actual irrigation area / "Basic" irrigation area

  If actual area was determined by nitrogen loading in Example B-5.2 above, then:

  Multiples of "basic" area = 95/40 = 2.4

- Storage requirements are specified in days of effluent flow

The analysis has been carried out for two cases of the permitted frequency of overflow:

- Once in two years - Table B-5.7
- Once in ten years - Table B-5.8

The use of these tables is best explained by reference to Example B-5.2 Suppose the abattoir was located in the same climatic region as Toowoomba, then for an irrigation system which has an irrigation area about 2.5 times the "basic" area, the required storage capacity can be read from the last column in Tables B-5.7 and B-5.8:

- Median year overflow - storage needed = 5 - 45 days
  For a daily flow of 1 ML/day, storage = 5 - 45 ML
  (Note that the median year is the same as once in two years)

- Once in ten year overflow - storage needed = 15 - 80 days
  For a daily flow of 1 ML/day, storage = 15 - 80 ML.

The tables present a range of storage required in order to represent the historic variability in the pattern of rainfall which occurs in different years with very similar rainfall. Because the required storage is a function of the sequence of rainfall and the time of year when the wet period occurs, it is possible to get two years which have similar total rainfall but have a different pattern within the year, which leads to different storage requirements. The range shown in Tables B-5.7 and B-5.8 reflects this variability from year to year, with an average value giving a reasonable level of service. Remember that the data presented in these tables should only be used as a guide to check on the size of the system needed to meet certain requirements. The data in these tables ***is not suitable for design purposes***.

Appendix C-2 contains graphs of the data which is summarised in Tables B-5.7 and B-5.8. This data might be useful for interpolation between values given in the tables or for gaining an appreciation of the general relationship between irrigation area and wet weather storage for the selected locations.

Table B-5.7: ***Wet weather storage requirements (days) for various locations for the median rainfall year.***

LOCATION	RAINFALL (mm/year)	MULTIPLES OF "BASIC" AREA				
		0.5	1.0	1.5	2.0	2.5
ADELAIDE (SA)	520	200 - 215	155 - 185	140 - 170	130 - 165	120 - 155
ALBURY (NSW)	760	255 - 280	230 - 255	210 - 235	195 - 225	190 - 220
CARNARVON (WA)	230	130 - 160	70 - 90	40 - 55	20 - 30	10 - 20
DARWIN (NT)	1620	170 - 230	135 - 195	110 - 175	90 - 150	75 - 130
ECHUCA (VIC)	450	175 - 210	150 - 180	130 - 165	125 - 160	120 - 150
HOBART (TAS)	600	230 - 280	205 - 260	195 - 245	190 - 240	190 - 230
NOWRA (NSW)	1210	100 - 200	35 - 130	20 - 70	15 - 65	15 - 65
PERTH (WA)	790	105 - 120	80 - 100	70 - 95	60 - 90	60 - 90
SALE (VIC)	630	200 - 240	170 - 210	160 - 190	145 - 180	140 - 170
SCONE (NSW)	630	225 - 330	150 - 285	110 - 250	85 - 215	70 - 190
TOOWOOMBA (QLD)	640	110 - 180	40 - 115	15 - 85	10 - 60	5 - 45
TOWNSVILLE (QLD)	1050	15 - 80	10 - 45	10 - 40	5 - 40	5 - 40

NOTES: The data presented in this table is a simplified version of more detailed data in the "System Performance Diagrams" in Appendix C-2.

Table B-5.8: ***Wet weather storage requirements (days) for various locations for the wettest year in ten.***

LOCATION	RAINFALL (mm/year)	MULTIPLES OF "BASIC" AREA				
		0.5	1.0	1.5	2.0	2.5
ADELAIDE (SA)	640	200 - 220	125 - 145	115 - 135	100 - 125	90 - 120
ALBURY (NSW)	1130	285 - 320	270 - 285	270 - 280	270 - 275	270 - 275
CARNARVON (WA)	350	155 - 165	90 - 105	55 - 75	40 - 65	30 - 50
DARWIN (NT)	2180	185 - 235	155 - 210	130 - 195	115 - 195	95 - 195
ECHUCA (VIC)	590	200 - 230	170 - 200	160 - 190	155 - 185	150 - 185
HOBART (TAS)	800	275 - 300	210 - 265	180 - 265	180 - 265	180 - 265
NOWRA (NSW)	1700	115 - 160	65 - 110	40 - 90	30 - 80	20 - 75
PERTH (WA)	940	140 - 160	130 - 145	115 - 135	110 - 130	110 - 130
SALE (VIC)	820	230 - 240	180 - 195	150 - 180	135 - 165	130 - 150
SCONE (NSW)	900	110 - 155	70 - 110	40 - 90	30 - 70	20 - 55
TOOWOOMBA (QLD)	770	190 - 200	90 - 135	35 - 110	20 - 90	15 - 80
TOWNSVILLE (QLD)	1680	80 - 185	60 - 150	45 - 125	40 - 110	40 - 110

NOTES: The data presented in this table is a simplified version of more detailed data in the "System Performance Diagrams" in Appendix C-2.

CHAPTER B-6: IRRIGATION MANAGEMENT

The users of this manual will either own and operate their own irrigation system or will be relying on a nearby farmer to utilise the abattoir effluent using the farmer's own irrigation system.

This section of the manual sets out some of the main considerations to be kept in mind for operating an existing system. This chapter assumes that some checks have been made to ensure that the system is able to meet the disposal needs of the quantity and quality of effluent produced by the abattoir. Therefore, managing the available resources (effluent, land, equipment and labour) to make best use of them, is focused on.

CONTENTS

B-6.1 Nutrient Management

> ***Abattoir effluent typically has 130 - 250 mg/L of nitrogen***
>
> ***300 mm of irrigation will provide 450 kg/ha/year of nitrogen***
>
> ***Most crops and pastures only need 100 - 300 kg/ha/year of nitrogen***
>
> ***The main issue to be considered is managing the nitrogen, not the water***

Abattoir effluent contains high levels of nitrogen and phosphorus. Conventional lagoon treatment of effluent does not remove significant quantities of these nutrients (see Table B-6.1). Note that the data in this table is based on typical values from the meat processing industry, but it is important to appreciate that there is considerable variability depending on waste management practices within the abattoir, and the effectiveness of the effluent treatment system.

The main effect of treating effluent in lagoons is to:

- Significantly reduce the BOD
- Convert most of the organic nitrogen (proteins) into ammonium.

B-6.1.1 Nitrogen Processes in the Soil

Nitrogen is subject to a number of processes described elsewhere in this manual:

- Section B-1.6 - the processes affecting nitrogen in the soil.
- Section B-2.6 - nitrogen removal by crops and livestock.
- Section B-4.5 - nitrogen losses and transformations occurring in the process of irrigation
- This section sets out the main considerations for the overall management of nitrogen in a field.

Nitrogen proteins and ammonium are both typically absorbed by soil particles, thus slowing leaching to groundwater if there is any through drainage occurring. The principle form of nitrogen lost from effluent disposal is in the form of nitrates. Nitrates are of serious concern to the health of groundwaters, local waterways and even crops. The recognised limit for nitrate levels in drinking waters is 10 mg/L.

Table B-6.1 *Typical abattoir effluent quality after different levels of treatment*

	Treatment	Total N[1] (mg/L)	Total P (mg/L)	BOD (mg/L)	Oil & Grease (mg/L)
Primary Treatment					
1.	***Fine screening (1 mm)***, with a well designed and operated saveall;	200	30	1500	300-750
2.	***Screening coarser than 5 mm***, over-loaded and poorly operated saveall;	250	40	3000	800-1500
3.	***Well designed and operated DAF*** (dissolved air flotation) unit.	200	30	1500	50-150
Secondary Treatment					
1.	***Anaerobic lagoons/ponds*** which receive effluent from:				
	(a) good primary treatment, 1 or 3;	180	30	250	10-150
	(b) poor primary treatment, 2;	200	40	350	10-1500
2.	***Aerobic/facultative (oxidation) pond*** following anaerobic lagoon(s), (with or without subsequent maturation ponds):				
	(a) well designed and operated pond(s) receiving good anaerobic effluent;	130	30	50	5-20
	(b) poorly designed and operated pond(s) receiving poor anaerobic effluent;	170	40	100	5-150
3.	***Aerated pond*** (with mechanical aerator(s)) following anaerobic lagoon(s), (with or without subsequent maturation ponds):				
	(a) well designed and operated pond(s) receiving good anaerobic effluent;	130	30	50	5-20
	(b) poorly designed and operated pond(s) receiving poor anaerobic effluent.	150	40	100	5-150

1 *If low temperature rendering unit is operated or abattoir has associated tannery or fellmongery, total N values shown in Table B-6.1 should be doubled.*

Bacteria in the soil transform nitrogen in three ways:

- ***Mineralisation*** of proteins to form ammonia.
- ***Nitrification*** of ammonia into nitrate through several steps.
- ***Denitrification*** of nitrate to nitrogen in the presence of decomposable organic matter and anoxic conditions.

B-6.1.2 Nitrate Production

Nitrogen is subject to several processes which are important in its disposal and removal from effluent:

- nitrogen absorption by the soil,
- nitrate production by soil organisms,
- denitrification in the soil,
- plant uptake of nitrogen,
- availability of excess water to leach nitrogen past the root zone.

The relative proportions of organic nitrogen, ammonium and nitrate in wastewater is a function of the treatment process. In general, primary treated effluent can be expected to have most of the nitrogen present in the organic form.

Treatment of effluent in anaerobic lagoons converts some of this into ammonium. Although the ammonium ion can be temporarily adsorbed onto clay, the adsorption does not prevent nitrification from occurring to release nitrate which is soluble in water and not adsorbed by the clay. The treatment of effluent in lagoons has the overall effect of making nitrate available more readily and therefore increasing the risk of it being transported by runoff or through drainage. The presence of ammonium in irrigated effluent does, however, promote volatilisation of ammonia into the atmosphere during spraying and while water is lying on the surface or on leaves. This volatilisation process can account for as much as 20% loss of the ammonia.

Nitrogen proteins are strongly adsorbed by soil particles, and ammonia nitrogen anions are bound by iron, manganese and calcium phosphate cations. These complexes have very low solubilities in water.

The conversion of nitrogen proteins to ammonia is a much slower process than the conversion of ammonium to nitrate. Therefore there seems little benefit to be gained, in terms of preventing nitrogen pollution, by carrying out secondary treatment.

Denitrification is a microbial process that transforms nitrates into gaseous nitrous oxide and nitrogen. This conversion requires anaerobic conditions.

Experiments in New Zealand (Russell and Cooper, 1987) have shown that an effluent with a high BOD (ie only primary treated) is more likely to lead to conditions within the soil in which denitrification occurs. The process of denitrification requires a supply of organic carbon for the bacteria as well as anaerobic conditions which occur if the soil is saturated. The monitoring of effluent irrigation sites showed that concentrations of ammonium and phosphorus were similar in the leachate from areas on which anaerobic and primary treated effluent had been applied. This similarity occurred despite higher levels of ammonium in the applied effluent which had received anaerobic treatment. This indicates that soils have sufficient capacity to adsorb high ammonium concentrations. Nitrate concentrations were as much as three times greater in leachate from areas receiving anaerobically treated effluent.

In order to minimise the risk of contaminating groundwater, it appears that the effluent irrigation area will need to be up to twice as large for anaerobically treated effluent as that for primary treated effluent.

Primary Effluent Denitrification

When primary effluent is applied, there are two transformations required for denitrification to occur. Firstly, the protein wastes are transformed to nitrate under aerobic conditions, and secondly anaerobic conditions are required for denitrification. Maximum denitrification rates occur in the 24 hours after pasture irrigation, when the soil is fully saturated and contains many anaerobic sites.

Anaerobically Treated Effluent

Irrigation with anaerobically treated effluent results in lower denitrification rates than for primary treated effluent. The lower denitrification rates are caused by a lack of soluble carbon in anaerobically treated waste. Micro-organisms that cause denitrification, require a source of organic carbon. Without this, denitrification occurs at a slower rate.

Effects due to pH

A further variable is the soil pH. When ammonium is converted to nitrate, alkalinity is consumed and pH decreases. Conversely, when denitrification occurs, alkalinity is produced and pH increases. However, at sites where anaerobically treated effluent is irrigated, denitrification is limited by a lack of carbon. Soil acidity will therefore tend to increase on land which is irrigated with anaerobically treated effluent.

B-6.1.3 Nitrogen Management Guidelines

Because nitrogen is subject to complex processes in the course of treatment and within the soil, there are a number of often conflicting requirements at work. The following guidelines may be useful:

1. The annual nitrogen load on the irrigation area should not exceed the nitrogen which can be used by:

   - metabolisation into the growing plant material,
   - volatilisation into the atmosphere,
   - denitrification.

2. A crop will typically contain 50 - 75% of the nitrogen applied in the effluent. In order to maximise removal of nitrogen from the area, the crop ***should be harvested and removed from the field.***

3. Grazing of animals on an irrigated pasture significantly reduces the nitrogen removal because about 90% of the nitrogen in the feed is returned to the land in urine and faeces.

4. For nitrate to become a pollutant, it must be transported from the effluent irrigation area in water. If the irrigation is scheduled to only replace the water lost by evapotranspiration, there will be minimal free water to drain to the groundwater or to run off the surface.

5. Soils which do not drain freely are more likely to allow conditions for denitrification to occur. Studies of denitrification in soils in California (Pettygrove and Asano, 1985) indicate that the following rates of denitrification are possible:

   - Sandy soils with low organic matter - negligible
   - Sandy loams and loam soils - 10-20% loss
   - Silt loams and clay loams - 20-40% loss

6. Denitrification can be promoted by creating saturated conditions in the soil. In order to minimise the opportunities for deep drainage as a result of saturation, the saturated zone should be restricted to the top 300 mm of the soil. This can be achieved by frequent application of small depths of irrigation to replace the evapotranspiration loss every 3 - 4 days. These conditions are also advocated as one method of dealing with the need for "deficit irrigation" (see Section B-6.2).

7. Spray irrigation provides the best opportunity to maximise loss of nitrogen by volatilisation of ammonia.

8. Denitrification is also promoted by conditions in which there is decomposable organic carbon present. This can be achieved by:

   - Irrigating with primary treated effluent with high BOD. Care must be taken if this is done to ensure that saturated soil conditions are not allowed to persist for more than a few days or odour problems may occur. It is therefore not advisable to irrigate with primary treated wastes during winter in the winter rainfall areas.
   - Irrigating with secondary treated effluent shortly after ploughing in the stubble from a previous crop. This crop residue provides the organic carbon source necessary for denitrification for up to 3 - 4 weeks after being ploughed into the soil.

9. While lucerne is an attractive irrigation crop, because of its deep roots and ability to utilise water, it is a legume which is capable of fixing its own nitrogen. The rate of nitrogen fixing by lucerne will decline if high levels of nitrogen are available in the soil. Lucerne should only be used as a crop in an abattoir effluent irrigation area after careful analysis of the overall nitrogen balance which can be achieved.

B-6.1.4 Balancing Nitrogen and Water Requirements

Effluent which has 1 mg/L of nitrogen will provide 1 kg of N/ha for every 1 ML of water. Thus irrigation of 400 mm (4 ML/ha) of effluent over a year would, at a typical concentration of 150 mg/L, provide 600 kg/ha of nitrogen. Various data (see Table B-6.2) indicate that typical nitrogen requirements for pastures and fodder crops are of the order of 150 - 350 kg/ha. Therefore, the limit to the applied water will be of the order of 150 - 350 mm if the effluent has 100 mg/L of N and even less for higher strength effluent.

The quoted nitrogen use by healthy crops assumes that there is enough water (rain and irrigation) to meet all the water requirements for a crop. If insufficient water is available to permit maximum yield, then the crop growth will be retarded and the total amount of nitrogen which can be taken up will be reduced.

Table B-6.2 ***Nitrogen Removed by some Typical Pasture and Fodder Crops***

Crop or Pasture	Dry Yield (t/ha)	Nitrogen Removed (kg/ha)	Nitrogen (% dry weight)
Maize (grain +stubble)	14	160	1.1
Lucerne hay	15	340	2.3
Forage sorghum	14	210	1.5
Clover/grass pasture	8	160	2.0

Besides the guidelines outlined in Section B-6.1.3 above, any abattoir effluent irrigation system must ensure that over the whole year, the total applied nitrogen can be taken up by the crop or lost through volatilisation or denitrification.

The problem can be visualised by looking at the example in Figure B-6.1 which shows a hypothetical situation in which a crop being grown has the following characteristics:

- Maximum crop yield with full water supply = 15 t/ha
- Water required for full production = 900 mm
- Rainfall during growing season = 300 mm
- Nitrogen content of crop = 2% of crop dry weight

The problem can be posed in two ways:

1. For a given concentration of N in the effluent, how much irrigation can be applied so that the nitrogen requirement matches the water requirement for a particular yield?

2. What concentration of N in effluent is necessary so that the maximum yield is achieved and both nitrogen and water requirements are satisfied?

In Figure B-6.1, the solid line marked "yield" represents the expected yield response to additional water supplied by irrigation. The dashed lines marked, for example "150 mg/L", represent the amount of nitrogen (right hand scale) which would be supplied with additional irrigation. The intersection of the yield line and each dashed line represents the irrigation which can be applied without overloading the crop with nitrogen and risking pollution of the environment. It can be seen from this figure that in order to achieve full production and satisfy both nitrogen and water needs simultaneously, an effluent concentration of 50 mg/L would be required in this case. For an effluent concentration of 100 mg/L, 150 mm of water would just satisfy both the nitrogen and water requirements for a yield of 7.5 t/ha.

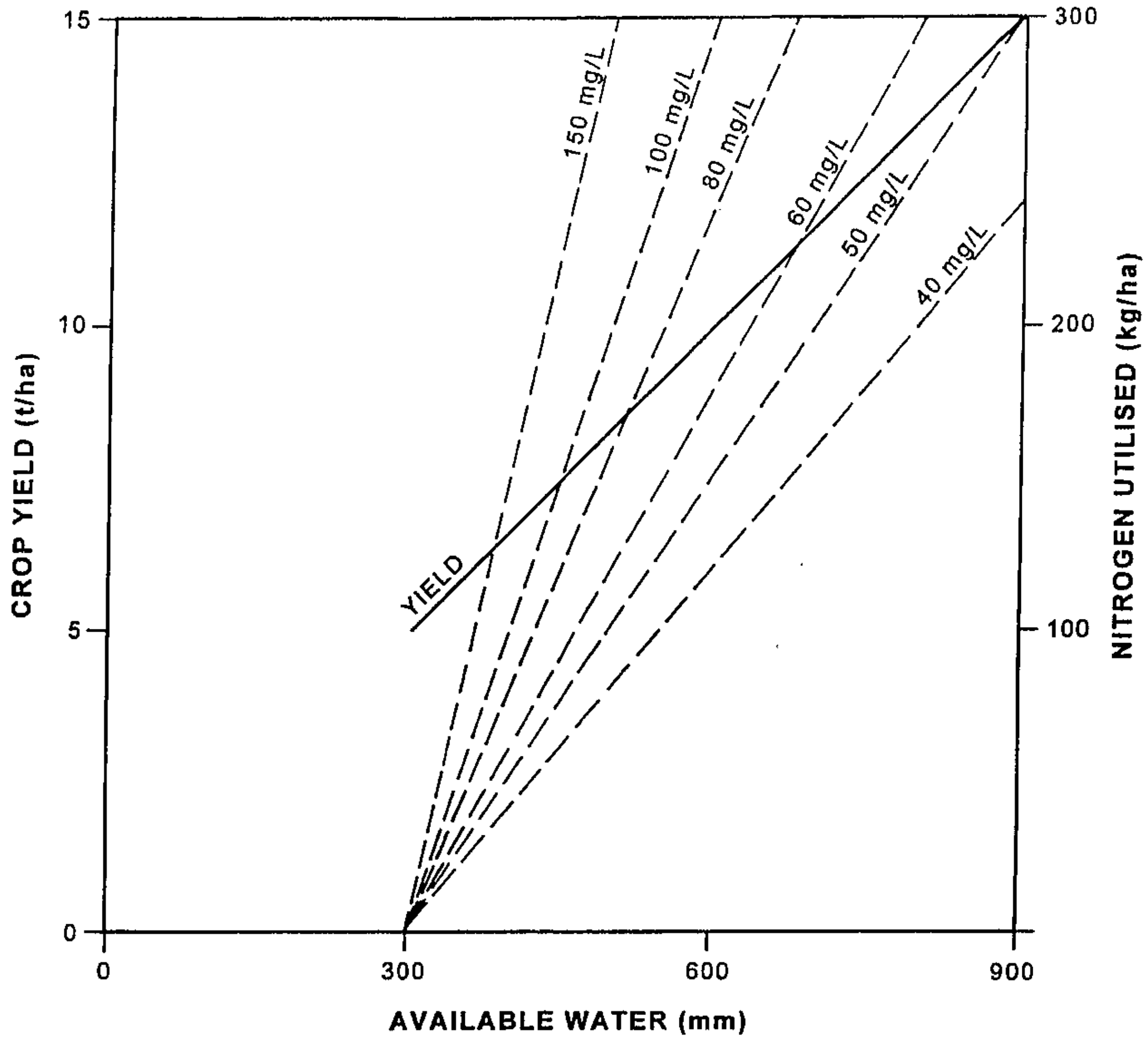


Figure B-6.1 *Crop Yield and Nitrogen Uptake for Different Levels of Irrigation*

It can also be appreciated from Figure B-6.1 that the solution to the problem is unique to each combination of:

- maximum crop yield (Y_m),
- maximum water requirement (ET_m),
- growing season rainfall,
- nitrogen content of the crop,
- crop response to water.

For instance, if the rainfall for the growing season was 600 mm, then the whole "fan" array of dashed lines would move across to start at the 600 mm point on the bottom axis. Under these conditions full crop yield would be achieved with 300 mm of water at 100 mg/L of N. The relationship between the amount of irrigation which can be applied and the crop yield for the cases of 300 mm and 600 mm of rainfall are summarised in Table B-6.3.

In practice, the analysis illustrated in Figure B-6.1 can be expanded to take account of some loss of nitrogen in the soil or to account for a residual level of nitrogen in the soil at the time of planting.

Table B-6.3. ***Crop Yield which Matches Various Combinations of Irrigation Depth and N Concentration in Figure B-6.1***

N Concentration in Effluent	Rainfall = 300 mm		Rainfall = 600 mm	
	Irrigation (mm)	Yield (t/ha)	Irrigation (mm)	Yield (t/ha)
150	86	6.45	171	12.90
100	150	7.50	300	15.00
80	214	8.55	-	-
60	375	11.25	-	-
50	600	15.00	-	-

Tables B-6.4a and B-6.4b summarise the amount of irrigation which can be applied without overloading the nitrogen utilisation capacity of the crop and soil for a variety of typical crops. This data can also be interpreted to assess what treatment or dilution is necessary to achieve increased production.

NOTE

The data in Tables B-6.4a and B-6.4b indicate that for typical abattoir effluent, more effluent can be disposed of if additional water is available.

This situation occurs because in most abattoir effluent irrigation systems, there is ample nitrogen for crop growth but insufficient water.

If additional water is not available to meet the crop needs for both water and nitrogen, deficit irrigation scheduling will need to be used.

Table B-6.4a *Irrigation Amount and Crop Yield for Various Concentrations of Total Nitrogen in Effluent*

FROMH:MV371/WORK/SUMBAL.DOC

Table B-6.4a

GRASS AND CLOVER
Crop Water Requirement: 900 mm
Nitrogen required for 100% yield : 520 Kg

Growing Season Rainfall 300 mm			Growing Season Rainfall 500 mm			Growing Season Rainfall 700 mm			Growing Season Rainfall 800 mm		
Effluent conc (mg/L)	Irrigation (mm)	Crop Yield	Effluent conc (mg/L)	Irrigation (mm)	Crop Yield	Effluent conc (mg/L)	Irrigation (mm)	Crop Yield	Effluent conc (mg/L)	Irrigation (mm)	Crop Yield
250	105	51%	250	110	60%	250	179	97%	400	118	100%
200	141	54%	200	150	65%	240	189	98%			
150	212	61%	150	237	77%	230	200	100%			
100	433	82%	130	309	87%						
90	547	95%	120	364	95%						
88	594	99%	117	385	98%						
87	612	100%	115	400	100%						

CORN
Crop Water Requirement: 900 mm
Nitrogen required for 100% yield :343 Kg

Growing Season Rainfall 300 mm			Growing Season Rainfall 500 mm			Growing Season Rainfall 700 mm			Growing Season Rainfall 800 mm		
Effluent conc (mg/L)	Irrigation (mm)	Crop Yield	Effluent conc (mg/L)	Irrigation (mm)	Crop Yield	Effluent conc (mg/L)	Irrigation (mm)	Crop Yield	Effluent conc (mg/L)	Irrigation (mm)	Crop Yield
250	27	21%	250	106	59%	250	173	96%	400	114	100%
200	38	22%	200	115	65%	200	235	100%			
100	109	32%	120	346	92%						
90	135	35%	115	379	96%						
60	464	81%	110	418	100%						
57	613	100%									

LUCERNE
Crop Water Requirement: 1500 mm
Nitrogen required for 100% yield :263 Kg

Growing Season Rainfall 500 mm			Growing Season Rainfall 700 mm			Growing Season Rainfall 900 mm			Growing Season Rainfall 1000 mm		
Effluent conc (mg/L)	Irrigation (mm)	Crop Yield	Effluent conc (mg/L)	Irrigation (mm)	Crop Yield	Effluent conc (mg/L)	Irrigation (mm)	Crop Yield	Effluent conc (mg/L)	Irrigation (mm)	Crop Yield
250	30	29%	250	63	46%	250	86	62%	250	97	70%
200	39	30%	200	81	47%	200	110	64%	200	125	72%
180	54	31%	150	114	50%	150	155	67%	150	175	76%
100	87	33%	100	190	55%	100	258	75%	100	292	85%
50	229	43%	60	409	71%	60	555	97%	80	398	88%
30	656	75%	50	575	83%	55	648	100%	70	487	99%
26	1049	100%	45	720	100%						

Table B-6.4b *Irrigation Amount and Crop Yield for Various Concentrations of Total Nitrogen in Effluent*

FROMH:MV371/WORK/SUMBAL.DOC

Table B-6.4b

SUNFLOWER Crop Water Requirement: 800 mm Nitrogen required for 100% yield : 226 Kg											
Growing Season Rainfall 300 mm			Growing Season Rainfall 500 mm			Growing Season Rainfall 600 mm			Growing Season Rainfall 700 mm		
Effluent conc (mg/L)	Irrigation (mm)	Crop Yield	Effluent conc (mg/L)	Irrigation (mm)	Crop Yield	Effluent conc (mg/L)	Irrigation (mm)	Crop Yield	Effluent conc (mg/L)	Irrigation (mm)	Crop Yield
250	53	59%	250	65	72%	250	89	99%	450	53	100%
200	69	61%	200	84	74%	220	103	99%			
150	96	64%	150	118	78%	200	115	100%			
100	162	72%	100	199	88%						
90	188	75%	90	231	92%						
80	223	79%	80	274	97%						
70	275	85%	75	302	100%						
60	358	95%									
55	422	103%									

SOYBEAN Crop Water Requirement: 700 mm Nitrogen required for 100% yield : 337 Kg											
Growing Season Rainfall 300 mm			Growing Season Rainfall 400 mm			Growing Season Rainfall 500 mm			Growing Season Rainfall 600 mm		
Effluent conc (mg/L)	Irrigation (mm)	Crop Yield	Effluent conc (mg/L)	Irrigation (mm)	Crop Yield	Effluent conc (mg/L)	Irrigation (mm)	Crop Yield	Effluent conc (mg/L)	Irrigation (mm)	Crop Yield
250	102	76%	250	122	91%	400	82	98%	400	94	111%
200	135	80%	220	142	93%	350	96	99%	350	109	100%
150	196	87%	200	160	95%	300	114	100%			
130	240	93%	180	183	98%						
120	271	96%	170	197	100%						
110	310	100%									

SORGHUM-SOUDAN Crop Water Requirement: 600 mm Nitrogen required for 100% yield : 177 Kg											
Growing Season Rainfall 200 mm			Growing Season Rainfall 300 mm			Growing Season Rainfall 400 mm			Growing Season Rainfall 500 mm		
Effluent conc (mg/L)	Irrigation (mm)	Crop Yield	Effluent conc (mg/L)	Irrigation (mm)	Crop Yield	Effluent conc (mg/L)	Irrigation (mm)	Crop Yield	Effluent conc (mg/L)	Irrigation (mm)	Crop Yield
250	44	62%	250	55	78%	300	55	93%	400	47	107%
200	56	63%	200	71	81%	280	59	94%	350	55	100%
150	79	67%	150	100	85%	250	67	95%			
100	132	75%	100	168	95%	220	78	97%			
90	153	78%	90	195	99%	200	87	100%			
80	182	82%	95	181	97%						
70	224	89%	90	195	100%						
60	290	99%									
59	299	100%									

B-6.2 Irrigation Scheduling

> ***The first rule of irrigation management is to know from day to day how much moisture is in the soil moisture store so that you know when to irrigate and how much water to apply.***

The key to successful effluent irrigation is scheduling the application of water so that:

- The crop always has sufficient water to maintain growth.
- The soil is not over-watered to the point where runoff or drainage occurs.

To do this we have to know:

- How much water must be to applied?
- When must water be applied?

Conventional irrigation farming is usually based on replenishing the soil moisture store when it becomes depleted by about 50% of the moisture holding capacity of the root zone. (For effluent irrigation we need to change this rule a bit, as explained in Section 6.2.4).

For an abattoir effluent irrigation system, the questions of when to apply water and how much to apply, need to be considered in terms of:

- An overall monthly water budget which seeks to manage the water requirements for irrigation with the effluent supply. As we have seen in Section 6.1, most abattoirs are likely to have to operate a deficit irrigation regime in order to get rid of the available nitrogen. Forward planning and an understanding of the seasonal patterns of supply (effluent and rainfall) and demand are required.
- The soil moisture status from day to day which dictates when irrigation should take place.

B-6.2.1 Soil Moisture Storage Capacity

Section B-1.5.3 gives an introduction to the moisture holding characteristics of soils in which the capacity of the soil moisture store, measured on a volumetric basis (W_v), is defined as:

$$W_v = AWC \times d$$

where:

d = the rooting depth of the crop or pasture (m). (from Table 6.5).

AWC = the available water capacity of the soil (mm of water per m depth of soil) (from Table B-1.6).

Table B-6.5 ***Root depths for typical crops***

Crop	Root Depth (m)
Barley	0.6 - 1.2
Cotton	0.9 - 1.2
Lucerne	1.5 - 3.0
Maize (corn)	0.9 - 1.3
Orchard Trees	1.0 - 1.8
Pastures	0.6 - 1.2
Sorghum	0.9 - 1.2
Soybeans	0.6 - 1.0
Sugar Cane	0.9 - 1.2
Vines	1.0 - 2.0
Wheat	0.6 - 1.2

B-6.2.2 Soil Moisture Storage Contents

The capacity of the soil moisture store (calculated above) only gives an estimate of the maximum depth of water which could be held in the root zone of a mature crop. At any point in time, the actual moisture within the root zone will be less than the storage capacity. The actual soil moisture available within the root zone can be measured or estimated in a number of ways:

1. Many experienced irrigation farmers judge the surface soil moisture content of the soil by feel (Table B-6.6 may be used as a guide). This method is useful as a quick check but should not be considered reliable without years of experience.

2. Objective methods, which are described in Chapter B-7, including a range of probes and sensors which can be used to measure the soil moisture throughout the soil profile.

3. Taking soil samples which are weighed before and after drying to calculate the moisture content. This can be achieved quite accurately enough with a small electronic scale used to weigh mail or with an ordinary domestic microwave oven. (Details are also set out in Chapter B-7).

4. Based on keeping a water balance "account" which makes allowance for all rainfall and irrigation added and for evapotranspiration lost.

Table B-6.6 *Soil Moisture and Appearance Relationship Chart*

This chart indicates approximate relationships between field capacity and wilting point. For more accurate information the soil must be checked by drying samples.

Moisture Deficit (mm/m)	Loamy Sand	Sandy loam	Loam	Clay loam
0	**0** - Leaves wet outline on hand when squeezed	**0** - Appears very dark, leaves wet outline on hand, will make a short ribbon	**0** - Appears very dark, leaves a wet outline on hand, will ribbon out to about 25 mm	**0** - Appears very dark, leaves light moisture on hand when squeezed, will form ribbon to about 50 mm
20	**20** - Appears moist, makes a weak ball	**25** - Quite dark colour, makes a hard ball	**25** - Dark colour, forms a plastic ball, slicks when rubbed	
40	**40** - Appears slightly moist, sticks together slightly			**30** - Dark colour, will slick, ribbons easily
		50 - Fairly dark colour, makes a firm ball	**50** - Quite dark, forms a hard ball	
60	**60** - Dry, loose, flows through fingers (wilting point)	**60** - Slightly dark colour, makes a weak ball		**55** - Quite dark, makes thick ribbon
80		**80** - Lightly coloured by moisture, will not form a ball	**75** - Fairly dark, forms a firm ball	**80** - Fairly dark, makes a firm ball
100			**90** - Slightly dark, forms a weak ball	**100** - Forms a ball, small clods will flatten out rather than crumble
		110 - Very slight colour due to moisture (wilting point)	**115** - Lightly coloured, small clods crumble fairly easily	
120				**125** - Slightly dark, clods crumble
140			**140** - Slight colour due to moisture, small clods are hard (wilting point)	
160				**160** - Some darkness due to unavailable moisture, clods are hard, cracked (wilting point)

Whatever measurement method is used, the soil moisture must be measured:

- down to the depth of the roots of the crop. (Do not forget that the roots on a crop will not reach their full depth until the crop has reached its full height.)
- at several (at least three) places in each irrigated paddock.
- below the root depth to determine if and when through drainage occurs.

A practical combination of these methods is to carry out a periodic check of the soil moisture (at least once per month, preferably once per week) using one of methods 1 - 3 and keeping track of the irrigation, rainfall and estimated evapotranspiration losses in between soil moisture checks.

B-6.2.3 Water Balance Accounting

In order to keep track of soil moisture conditions, daily records will need to be kept:

- rainfall.
- irrigation amount expressed as mm depth of water over the area watered each day.
(***Remember that 10 kL applied on 1 ha = 1 mm***)
- evapotranspiration (estimated using one of the methods in Section B-3.3).

An excellent way to keep track of soil moisture is to plot a daily soil moisture chart similar to the example in Figure B-6.2. A chart like this will be required for each separate paddock or each irrigation block which is irrigated separately. For a centre pivot or other travelling irrigator, each area which can be irrigated in one day will need to be treated as a separate paddock or block for record keeping purposes.

B-6.2.4 When to Irrigate

As has been noted several times in this manual, conventional irrigation scheduling is based on applying enough irrigation water to just refill the soil moisture store when it is half empty. This rule only applies, however, if the effluent has a low enough nitrogen content so that it can supply the full water needs of the crop or pasture (see Section B-6.1 for details of this issue) while not overloading the area with nitrogen. Otherwise additional water will be needed or a strategy of "deficit irrigation".

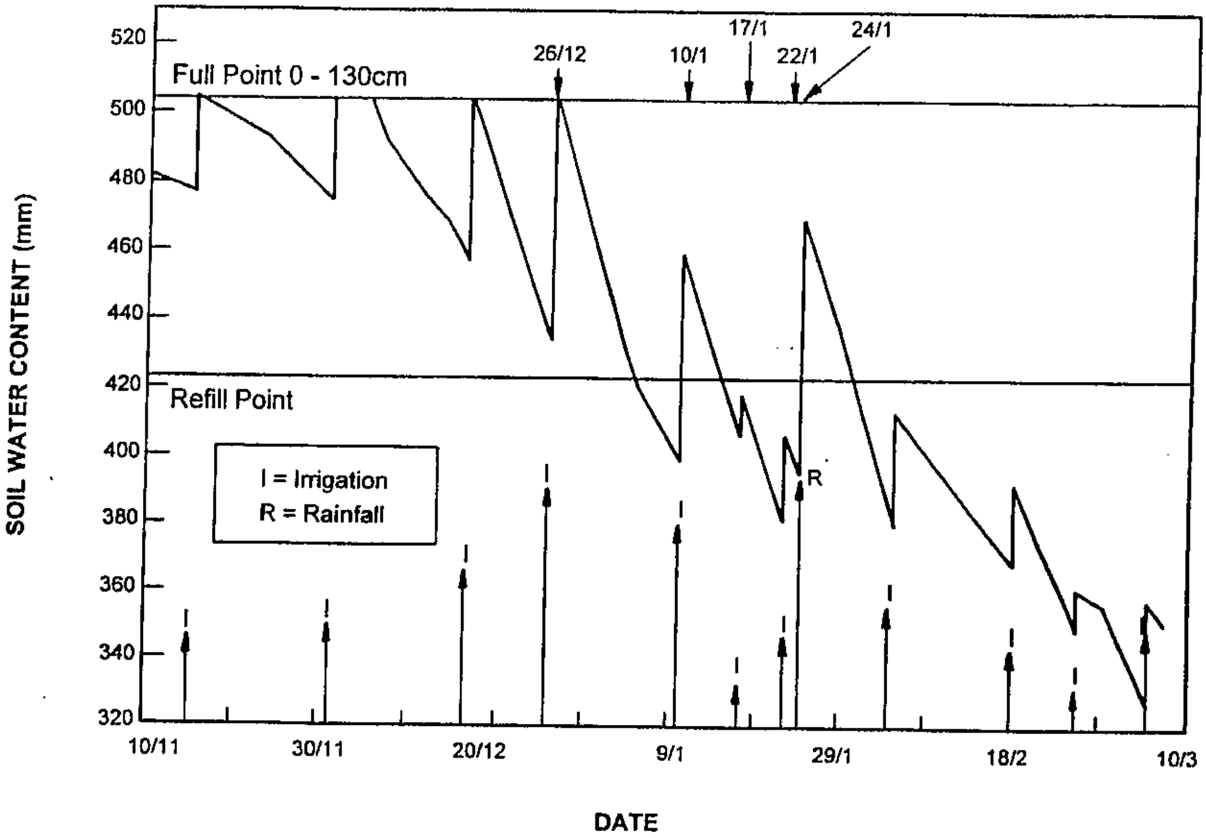


Figure B-6.2 ***Soil Moisture Content (0-130 cm depth) Chart Over a Four Month Irrigation Season***

When limited water is to be applied to a crop, it is essential to apply it when it is of most benefit. Usually this corresponds to stages of crop growth which are most critical for potential yield. With surface irrigation systems, it is often difficult to precisely control quantities applied. Most surface irrigation systems apply a minimum "unit" of water of about 40 - 80 mm at one time, and the timing of water application becomes the key factor. However, with spray irrigation systems, water can be applied more frequently and in smaller quantities.

The soil water-holding properties can also affect the strategy to be adopted for dealing with deficit irrigation. On deep heavy soils, which can store a reasonable amount of water, deep rooted crops which are stress tolerant can be grown on a full soil moisture profile. When supplemented with a strategic timed watering, good yields can be achieved.

Experience in the irrigation industry has shown that, when faced with moderate shortages of irrigation water, farmers often improve their water management and efficiency to produce crop yields almost as good as when full supply is available. Improved irrigation efficiency is usually achieved through:

- avoiding over-watering,
- re-circulating irrigation and rainfall runoff,
- irrigation scheduling,
- ensuring good soil structure.

There are a number of key aspects of ***"deficit irrigation"*** which should be kept in mind:

1. Fill the soil moisture storage to the full depth of the root zone at the time of planting or at the onset of the Spring growth period for permanent pastures. (This may mean that effluent will need to be "saved up" for a while before planting a crop.) This initial irrigation also provides a nitrogen supply for the main growing phase of the crop. If the strength of the effluent is such that only a single irrigation of about 80 mm can be afforded, it should be done at this time.

2. If a crop is being grown (as opposed to a pasture), the soil moisture in the top 300 mm should be maintained at greater than 50% of the moisture storage capacity for the first 2 - 3 weeks after planting.

3. In dry weather, irrigate frequently to maintain the moisture content in the top 300 mm above 30% of full capacity.

4. Only irrigate up to a maximum of 85% of the soil moisture storage.

5. A number of crops have a particular growth phase which is particularly sensitive to water stress (see Table B-6.7). Save some water to apply additional irrigation at this time.

6. Experiments on "deficit irrigation" in the USA indicate that almost full crop production can be achieved with a saving of 15 - 30% on the normal irrigation requirements. The key strategy seems to be the application of small quantities of water frequently (every 2 - 3 days).

Table B-6.7 ***Sensitive growth periods for water deficit***
(adapted from Doorenbos and Kassam, 1979)

Crop	Growth Period
Cotton	flowering
Lucerne	just after cutting
Maize	flowering and grain filling
Orchards	flowering and fruit filling
Sorghum	flowering and grain filling
Sugar Cane	vegetative growth and stem elongation
Sunflower	flowering and seed formation
Vines	flowering and fruit development
Wheat	flowering and seed formation

B-6.2.5 Monthly Watering Balance

Assuming that you are faced with the problem of preparing a schedule for managing effluent which calls for a limited amount of water to be applied so that the nitrogen requirements are not exceeded, then a monthly water management plan will need to be prepared to indicate how much water you consider will be available throughout the year. Prepare a monthly water balance plan similar to the example in Table B-6.8, the components of which are set out below.

For this example, the hypothetical abattoir at Warialda in NSW produces 35 ML of effluent per month except in January when the abattoir shuts down. The median annual rainfall for Warialda is 674 mm. The irrigation area is 100 ha on which, for this example, a crop of maize is being grown. The irrigation system includes two water storages:

- A storage to hold effluent which cannot be irrigated (**Note** this storage is in addition to the volume of ponds used for treatment of effluent). In the example, because only a single crop is being grown, effluent must be stored until it is required. For this example the storage size would be 200 ML.
- A storage to hold runoff from the irrigation area. In the example the storage is set at 80 ML in order to store water for re-use rather than allow runoff to escape to the environment. If only the minimum required for environmental protection was provided, the storage might be only 12 ML in size but this would reduce the ability of the system to meet the water needs of the crop.

For the sake of keeping the example simple, evaporation and seepage losses have been ignored.

Column 1. Month You must first decide which month of the year to start the water balance analysis. Any month can be chosen, but it makes the analysis easier if the starting point is taken as the month when the effluent storage volume is a minimum. When this occurs will depend on where the abattoir is located. As a general rule, start the analysis at the end of the main growing season.

In the example, the analysis starts in March after the maize crop has been harvested.

Column 2. Monthly Rainfall totals for a representative median rainfall year and a 90th percentile wet year. (See Section B-3.2 for how to carry out this analysis).

In the example, a median rainfall year has been used for analysis.

Column 3. Crop Evapotranspiration (ET_c) should be estimated from the crop or pasture to be irrigated. Note that these estimates must take account of the growth characteristics of the crop as well as the "crop factor" (K_c) to be applied when it is fully grown. (See Section B-3.3 for evaporation data and Section B-2.2 for typical values of K_c).

The example is based on a crop of maize which has evapotranspiration over the growing season (September to February) of 900 mm, plus an allowance of 10 mm per month for soil evaporation when the land is fallow.

Column 4. Effluent Flow This represents the monthly pattern of flows expected to be produced by the abattoir. This data should be available from the abattoir operating records. The effluent flow can vary from month to month depending on the seasonal pattern of work at the abattoir.

For the example, all volumes of water are expressed as the depth of water (mm) over the available irrigation area. (See Table A-4.2 for common conversions between different units. 1 ML of water on 1 ha = 100 mm depth. Therefore 35 ML/month = 35 mm/month depth on 100 ha)

Column 5. Runoff An estimate is needed of the average monthly runoff volume from the irrigation area. Runoff is a lot more variable in its occurence than rainfall because it is affected by many factors, particularly soil type and the local rainfall pattern. In many parts of Australia runoff only occurs a few times a year in normal conditions and does not occur at all in a drought. The task of estimating runoff volume should preferably be undertaken by an experienced irrigation designer or hydrologist. Even with expert assistance, the reliability of the estimate will depend upon the available data in the locality:

- The most reliable estimate will be obtained when there are simultaneous records of rainfall and runoff from a similar sized irrigated area in the locality over several years.

- Local observations of how often farm dams in the area fill may be used to give a guide to the rainfall conditions which lead to substantial runoff.

- Runoff estimation from catchment areas of the size of an effluent irrigation area, based only on observed rainfall and a knowledge of the soils and topography, is an imprecise science. As a rough guide you could assume that 15% of rainfall will runoff during a median rainfall year and 25% in a 90th percentile wet year. (Adjust these percentages as necessary to account for local conditions - eg an arid zone area in which the median annual rainfall is only 200 mm is likely to experience less than 10% runoff in a median year. Bear in mind that an effluent irrigation area can be expected to be much wetter than the surrounding land and therefore more likely to produce runoff).

(**Note** Procedures for estimating runoff volume are different to those for estimating peak runoff rate. Many surveyors, engineers and other professionals are familiar with the so called "Rational Method" for estimation of peak runoff rate, and variants on this procedure which have been developed for various States - see Australian Rainfall and Runoff - Volume 1 (1987). Although the procedures for estimating runoff rate and volume appear similar, the duration of rainfall considered and the runoff coefficients used are quite different and must not be confused.)

For the sake of keeping the example simple, it has been assumed that 15% of rainfall appears as runoff.

Column 6. Effective Rainfall This is the amount of rainfall which contributes to the soil moisture store and is equal to the total rainfall (Column 2) minus the runoff (Column 5).

Column 7. Irrigation Irrigation water is taken from the effluent storage (Column 9) or the runoff storage (Column 10). The objective is to allocate irrigation water so as to keep the soil moisture store within the desired range (depending on the deficit irrigation strategy - see Section B-6.2) while also keeping the volume in storage to a minimum.

In the example, irrigation is applied in September to build up the soil moisture store at planting. Thereafter, the irrigation water is allocated to keep the soil moisture store up to 85% full while ensuring that some water is retained for irrigation during flowering and grain filling (see Table B-6.7). For the sake of simplicity, it is assumed in the example that the application of irrigation water is 100% efficient. In practice, all irrigation systems are subject to losses from evaporation and non-uniform watering (see Section B-5.6).

Column 8. Soil Moisture Storage This calculation is based on a simple mass balance:

End of current month =	**End of last month** **+ gains - losses**
Column 8 (this month) =	Column 8 (last month) + Column 6 (effective rainfall) + Column 7 (irrigation) - Column 3 (ET_c)

For the first row in Column 8 the value for the previous month must be taken from the value at the bottom of the table. For all other rows, the value for the previous month is taken from the row above.

Column 9. Effluent Storage Again, this is calculated from a simple mass balance equation such as that used for Column 8:

Column 9 (this month) = Column 9 (last month)
+ Column 4 (effluent flow)
- Contribution to Column 7

The storage at the end of the previous month is taken from the row above except in March when it is taken from the storage at the end of February at the bottom of the column.

The amount irrigated (Column 7) is drawn from both Column 9 and Column 10. The contribution from Column 9 is entirely a matter of judgement. In the example, preference is given to irrigating with effluent in early stages of crop growth in order to ensure that the crop is well supplied with nitrogen during its vegetative growth phase. The water available from the runoff storage is reserved for use when flowering and grain filling occurs.

Column 10. Runoff storage This is the volume left in the storage which collects runoff from the irrigation area. This volume is calculated using a similar mass balance to that used for Column 9.

Column 10 (this month) = Column 10 (last month)
+ Column 5 (runoff)
- Contribution to Column 7

The data set out in Table B-6.8 is essentially a simple water balance model of how the effluent irrigation system would operate under a given set of conditions. If the table is set up as a computer spreadsheet it can be used to test the effect of management decisions on the operation of the system. For instance:

- How would the system perform in a 90th percentile wet year?
- How much effluent storage would be required if a crop of winter oats was planted as well as maize?

The figures presented in Table B-6.8 represent only one possible solution, of many, in which an effluent irrigation system could be managed. In the example, the maize crop is supplied with 886 mm of water during the growing season. This water comprises effective rainfall (337 mm), effluent (385 mm), runoff (77 mm) and depletion of soil moisture over the growing period (87 mm). The 385 mm of effluent would just meet the requirements for a crop of 14 t/ha dry weight (stalks and grain) if the nitrogen content of the effluent was about 85 mg/L and nitrogen losses amounted to 20% volatilisation, during spray irrigation, and 30% denitrification in a sandy loam soil.

Table B-6.8 ***Water Balance Analysis for Pasture Grown at Warialda NSW for a Median Rainfall Year***

(All values expressed as mm depth of water over the irrigation area)

Month (1)	Total Rainfall (mm) (2)	ET_c (mm) (3)	Effluent Flow (mm) (4)	Runoff (mm) (5)	Effective Rainfall (mm) (6)	Irrigation (mm) (7)	Soil Moisture Store (mm) (8)	Effluent Storage (mm) (9)	Runoff Storage (mm) (10)
Mar	65	10	35	10	55	0	55	35	10
Apr	39	10	35	6	33	0	78	70	16
May	44	10	35	7	37	0	106	105	22
Jun	45	10	35	7	38	0	134	140	29
Jul	45	10	35	7	38	0	162	175	36
Aug	39	10	35	6	33	0	185	210	42
Sep	43	10	35	6	37	80	292	165	48
Oct	59	60	35	9	50	0	282	200	57
Nov	65	140	35	10	55	100	297	135	67
Dec	68	230	35	10	58	80	205	90	77
Jan	84	300	0	13	71	170	147	0	9
Feb	78	170	35	12	66	55	98	0	1

See main text for explanatory notes on calculations.

B-6.3 Soil Salinity and Leaching

B-6.3.1 Soil Salinity

Salinity in the soil can be a serious problem in any irrigation area because of the additional salts added via the irrigation water or brought into the root zone by the upward movement of water from a shallow saline watertable. These problems arise because salt:

- is a common compound which readily dissolves in water.
- tends to accumulate in the root zone unless it is deliberately leached out by drainage.
- can severely reduce crop growth.

The passage of salt through an irrigation area is illustrated in Figure B-6.3. It can be seen that there are a number of possible gains and losses, some of which are trivial and can be ignored for practical purposes including gains from rainfall and losses by surface runoff. Gains from the groundwater can be the major source of salt if the watertable is less than 2 m from the surface and has a salinity greater than about 5,000 μS/cm. There are many practical difficulties with any irrigation on such land and it should only be considered for effluent irrigation if specialist advice is sought - particularly with respect to the management of the watertable and soil salinity.

The important processes of salt movement of concern are:

- salt applied with the irrigation water
- salt lost by drainage from the root zone.

The problem is simply one of achieving an overall mass balance for salt within the root zone, ie:

Salt entering the root zone = Salt leaving the root zone.

If this can be achieved on a year by year basis, then there will be no net accumulation of salt. The salt mass balance equation above can be written in terms of the concentration of salt in the irrigation water (C_I) and drainage water (C_d) together with the volume of water supplied in a year (V_I) and the volume of drainage (V_d). To achieve a salt balance over a year requires that:

$$C_i \times V_i = C_d \times V_d$$

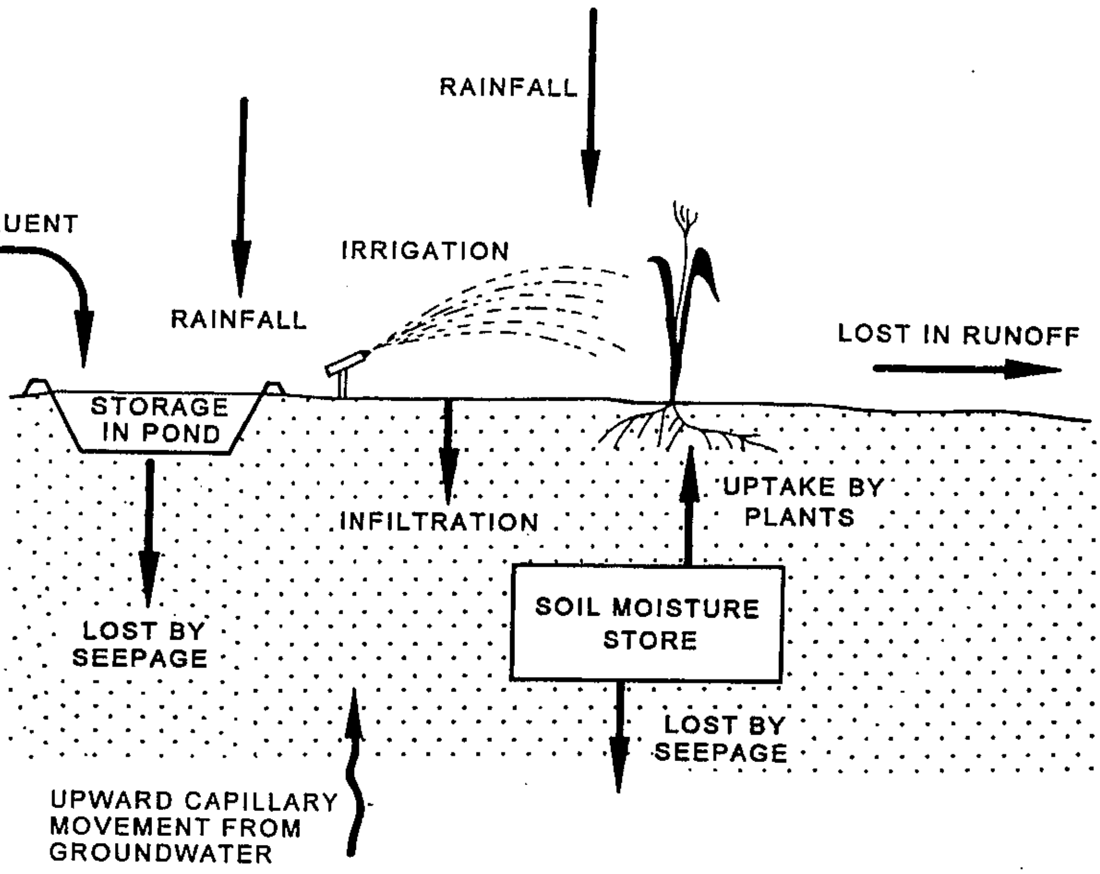


Figure B-6.3 ***Inputs and Losses of Salt in an Irrigation Area***

For our purposes it is convenient to express the salinity in the irrigation and drainage water in terms of the conductivity (EC expressed as μS/cm). The salt balance equation can therefore be written as:

$$EC_i \times V_i = EC_d \times V_d.$$

It is also convenient to work in terms of the depth of water for inflow and drainage so that V_i and V_d are expressed as mm of water applied by irrigation. The terms on the left hand side of the equation may be found by measuring the amount of irrigation effluent or water applied for a whole year and monitoring the salinity of the water. The unknown factors are the drainage volume and salinity.

The permissible salinity of the drainage water is usually related to the salinity in the soil solution which would just start to cause some depression in plant growth. The salinity which will just start to affect plant growth is usually expressed as the salinity of the saturated soil extract (EC_e) which varies for different crops as shown in Table B-6.9. Note that EC_e is usually expressed as dS/m while water salinity is in μS/cm (μS/cm = dS/m x 1,000).

Table B-6.9 ***Salt tolerance of a selected range of pasture/fodder species expressed in terms of the soil salinity threshold causing yield reduction.*** (adapted from Shaw et al, 1987)

Low Salt Tolerance	EC_e (dS/m)	Medium Salt Tolerance	EC_e (dS/m)	High Salt Tolerance	EC_e (dS/m)
White Clover	1.5	Lovegrass	2.0	Wheatgrass	7.5
Forage Maize	1.8	Lucerne	2.0	Kikuyu	8.0
Setaria	2.4	Green Panic	3.0	Barley	6.0
Paspalum	1.8	Pangola	2.0	Buffel	6.9
Townsville Stylo	2.4	Sudangrass	2.8	Couch	6.9
		Oats	5.0	Rhodes	7.0
		Fescue	3.9	Sorghum	8.3

In practice, the soil water salinity at field capacity is about twice that for the saturated extract. Therefore

$EC_d = EC_e \times 2 \times 1{,}000$ (to convert to μS/cm).

The salt balance equation can therefore be re-written as:

$$EC_i \times V_i = 2{,}000 \times EC_e \times V_d$$

Thus $V_d = \dfrac{(EC_i \times V_i)}{(EC_e \times 2{,}000)}$

For example:

Crop = Forage Maize
EC_e = 2.0
V_i = 500 mm
EC_i = 150

$$V_d = \frac{150 \times 500}{2 \times 2000} = 18.75 \text{ mm}$$

It can seen that for this example, a relatively small amount of leaching will be required. A convenient way of expressing the drainage requirement is in terms of the leaching fraction (LF) which is expressed as:

$$LF(\%) = (V_d/V_i) \times 100$$

$$= (EC_i/(EC_e \times 2000)) \times 100$$

$$= EC_i/(EC_e \times 20)$$

The leaching fraction needed can therefore be related directly to the salinity of the supply water and the salinity which the crop can tolerate. A practical range of leaching fractions are given in Table B-6.10.

Table B-6.10 *Required leaching fraction (LF) for different irrigation water salinity (EC_i) assuming maximum soil salinity (EC_e) of 4 dS/m.*

Irrigation Water Salinity, EC_i (μS/cm)	Leaching Fraction (LF) (%)
200	2.5
400	5
600	7.5
800	10
1000	12.5

B-6.3.2 Management of Leaching

The requirement to leach salts from the bottom of the root zone provides some practical problems for areas irrigated with abattoir effluent:

Sub-surface Drainage

The downward movement of effluent past the root zone will eventually contribute to the groundwater unless it is intercepted by sub-surface drains. The first question for an effluent irrigation area is whether any effluent passing the root zone can be safely allowed to drain to the groundwater. The answer to this depends on the consequences of allowing drainage to occur, which is largely a function of the volume of drainage and the quality of the effluent.

In large areas of Australia there is natural drainage to the groundwater from the land surface. The magnitude of this drainage depends largely on the climate and ranges from zero in the arid zone up to a few hundred mm per year in the wet tropics or in parts of Tasmania. In most of the agricultural areas of Australia, the contribution to the groundwater from the surface is of the order of 10 - 20 mm per year on average. However, this figure largely comes about because of pulses of water draining past the root zone as a result of wetter than normal years, rather than steady drainage from year to year. In this context, it should also be noted that one of the major problems facing the dryland agricultural areas of Australia is that there has been an increase in groundwater recharge as a result of the replacement of deep rooted trees with shallow rooted crops and pastures. There are already areas of Australia where the increase in groundwater recharge has brought profound changes to the landscape and particularly led to increased seepage of saline groundwater which is noticeable as dryland salinity and salinisation of waterways. The point of all this is that some drainage to groundwater can be expected under natural conditions in most locations. The best approach for an area which irrigates with abattoir effluent is to control the soil moisture so that leaching is kept to a minimum.

In the case of an area irrigated with abattoir effluent, provided the nitrate levels in the soil water are minimised at the time when leaching occurs, a few millimetres of leachate are unlikely to be a major problem. Problems can be expected to occur, however, if excessive leaching is allowed to occur through poor management of soil moisture. Not only would excessive leaching be likely to lead to transport of nitrates to the groundwater but there would be the possibility of raising the watertable until it became a constraint on agricultural productivity of the land. Just because the groundwater is many meters below the ground, does not mean that it is immune from increased recharge causing the water level to rise. In parts of the Murray Valley, large scale irrigation has caused watertables to rise at between 100 and 500 mm per year. This rate of rise has led to a situation in which large areas of land have watertables within 2 m of the surface. This situation not only requires extra management effort to control watertable levels, but also reduces the opportunity for leaching if required.

Disposal of Drainage Water

One solution is to provide sub-surface drainage to intercept the leachate. If sub-surface drainage is provided, however, how is this water to be disposed of? This problem is common to all irrigation areas. The drainage water is of inferior quality to the normal supply and no-one wants to use it. This problem is clearly manifested in the high salinity in drainage water from some of the irrigation areas in NSW, and Victoria which contribute to the salt load in the Murray River. The ultimate answer in some cases has been to provide an evaporation area into which the drainage water is dumped. More sophisticated disposal systems are available such as serial biological concentration in which drainage water is used to sequentially irrigate a number of areas containing vegetation such as saltbush which has an ever increasing tolerance to salt. Whilst this process transfers the salt to the vegetation, ultimately the vegetation must be harvested and taken away. (In the same way as crops irrigated with effluent should be removed).

Guidelines

Based on the foregoing comments, the following guidelines constitute good practice for management of leaching.

1. Leaching should be a planned and managed activity, not something which happens by accident.

2. Application of irrigation water must be controlled and soil moisture levels monitored to ensure that leaching does not occur as a result of routine operations. The amount of water available in the root zone must not exceed that which can be removed by evapotranspiration.

3. Soil moisture should be monitored below the root zone to check when drainage is occurring. This monitoring should go on throughout the year to ensure that unplanned drainage is not occurring.

4. Irrigation with effluent should be stopped four weeks before it is planned to allow leaching to occur. The purpose of this is to have reduced nitrogen levels in the soil when leaching occurs. This practice should be tied into the practice of allowing the irrigated land to "rest" for two or three months in a year.

5. Leaching should be planned to occur during the wettest part of the year when rainfall can be used to provide the water for leaching to occur.

6. If additional water is required to provide leaching, it should be obtained from a supplementary source such as runoff from another area. Effluent should not be used to carry out leaching.

7. Monitoring of groundwater levels and groundwater quality should be undertaken to ensure that excessive leaching is not occurring and that any leaching does not affect groundwater quality.

B-6.4 Crop and Pasture Management

B-6.4.1 Crop Management

The objective of crop management in an effluent irrigation area must be to maintain vigorous crop growth. In order to match the crop production closely to the effluent production, it will be necessary to have crops growing all year round. A typical cropping regime would be to have a short growing season for forage maize over the summer months followed by a winter crop such as forage oats. The best combination of crops to suit any abattoir will be determined by local climatic conditions and you should seek the advice of a consultant agronomist or the State Department of Agriculture.

Two problems typically arise in planning a cropping regime:

- Time needs to be allowed in the cropping schedule for cultivation of the land prior to sowing each crop. The time necessary for this may mean that a particular crop cannot be fitted into the regime.

- Prior to harvest and during cultivation, effluent cannot be irrigated and must be stored. The requirement for storage must be accounted for in determining the size of the effluent ponds.

It is also good practice to ensure that the cropping regime allows two to three months in the year when effluent is not applied to each particular paddock. In order to maintain continuity of areas capable of being irrigated, different cropping patterns should be prepared for several separate areas. This should be designed so that at any one time at least half the total irrigation area has a growing crop and can irrigated if climatic and soil moisture conditions are right.

B-6.4.2 Weed Control

By providing good growing conditions (adequate water and nutrients) for a pasture or crop on the effluent disposal area, ideal conditions are also being created for weeds to take over. On farms which are irrigating as part of the farming enterprise, weeds can account for 5 - 20% loss in production.

While the economic reasons for producing a high value crop may not be as pressing on an effluent re-use area, there are still a number of good reasons why weeds should be controlled.

- Uncontrolled weed growth severely reduces the value of the area for grazing or cropping and thus reduces the opportunity to minimise the overall cost of effluent re-use.
- Weeds tend to hamper any harvesting operations and damage harvesting equipment such as hay making equipment.
- Weeds tend to harbour pests and diseases which can infect the crop or pasture and reduce the yield.
- Weeds provide a source of unwanted weed seeds which can easily contaminate neighbours crops or pastures (even if you are not concerned).

The cost of purchase and application of herbicide is a major budget item for most irrigated crops. Total reliance on herbicides is rarely economic and integration with various cultural and mechanical control measures is usually necessary.

Mechanical control measures such as inter-row cultivation and hand-weeding are widely used in irrigation cropping. These operations add directly to costs, but when used by experienced operators, should increase yields.

Control of weeds along ditches, channels and headlands can be expensive, especially on poorly designed irrigation systems.

Weed control during a fallow period is usually accomplished by routine cultural operations, but use of a knockdown herbicide in seedbed preparation is a popular alternative to the final cultivation.

B-6.4.3 Effects of Grazing Animals on Irrigated Land

The decision as to whether to graze or harvest an effluent irrigation area must be made early in the planning stages of an irrigation scheme. Although it is easy to change a grazed scheme to a harvested system, changing from a harvested to a grazing regime is much more difficult. Grazing animals have several effects on the operation of an irrigation scheme:

- They tend to destroy the structure of the surface soil, particularly if it is wet. This leads to compaction and reduced infiltration rates. In turn, this will lead to increased runoff and potential for pollution of the local watercourse.
- Animals, particularly cattle, tend trample to destroy irrigation earthworks, especially borders in border-check systems.
- Animals recycle approximately 90% of the nitrogen they consume back to the pasture in the form of urine and dung. A grazed area is far less efficient at removing nitrogen than an area from which the harvested crop is removed.
- About 40% of nitrogen in urine and dung is in the nitrate form and can be rapidly leached to the groundwater if there is an excess of soil moisture.

Calculations suggest that in order to keep the losses of nitrate nitrogen to the groundwater at acceptable levels under a grazing regime, it is necessary to double the land area over that required for a cropped system.

B-6.4.4 Pasture Composition

Nitrate-nitrogen levels in pasture are elevated by irrigation. Nitrate can cause methaemoglobinaemia (which reduces the oxygen uptake of red blood cells) in animals, and animal deaths have been reported when nitrate-nitrogen concentrations in feed exceed 0.2-0.3%. Other reports have suggested that various factors can increase the toxicity of nitrate in feed. For instance, starved animals that have sudden access to abundant pasture are more susceptible to nitrate poisoning. It has also been suggested that the degree of nitrate poisoning depends on the rate at which feed is consumed, and animals can become adapted to nitrate in feed. With regular monitoring of the pasture, from irrigated areas, using suitable management procedures, it should be possible to avoid nitrate toxicity problems.

Levels of other elements in the herbage should not cause any animal health problems.

Studies in New Zealand (Russell and Cooper, 1987) showed that when anaerobic effluent was applied to pasture, the amount of nitrogen recovered in the herbage was similar to that obtained for primary treated effluent irrigation at loadings up to 1,000 kg N/ha/year. In contrast to the results obtained with primary treated effluent irrigation, anaerobic effluent irrigation at loadings higher than 1,000 kg N/ha/year caused the pasture production to decline Levels of nitrate-nitrogen in the herbage were elevated with anaerobic effluent application. At a loading of 1,000 kg/ha/year, the herbage contained 1.6 times the level of nitrate-nitrogen found in pasture irrigated with primary treated effluent at the same nitrogen loading.

Additional care is therefore necessary when feeding animals with fodder from irrigation with anaerobic effluent.

B-6.4.5. Microbiological Aspects

The studies by Russell and Cooper (1987) also showed that microbial die-off occurs rapidly in irrigated pastures and that microbial numbers reduced by 99% 12 days after irrigation. The studies also showed that over 90% of bacteria were found within 30 mm of the ground surface.

The suggested guidelines for management of pastures to minimise microbial disease problems are:

1. Grazing should not occur until 5 days after irrigation.
2. Pastures should not be overgrazed to ensure that livestock are not eating the material nearest the ground.

B-6.5 Odour Management

Odours are not a widespread problem with effluent irrigation systems. However a number of precautions need to be taken to minimise the risk that odours become a source of complaint from neighbours.

B-6.5.1 Set-back Distances

One of the things that can significantly reduce odour impact on neighbours is to ensure that facilities and operations likely to cause odours are isolated from neighbouring houses. Ensure that the:

- Distance from treatment ponds to nearest house - 300 m.
- Distance from areas where effluent is irrigated regularly - 300 m.
- Distance from areas where effluent is irrigated intermittently - 100 m.

B-6.5.2 Irrigation Management

Odours can be minimised by taking account of the effect of wind and of ponding on the soil surface.

Wind

- Fine spray is more susceptible to being carried by the wind. Use a sprinkler which does not create fine droplets.
- Wind speed increases with distance from the ground. Keep the trajectory of the sprays as low as possible.
- If possible, site your irrigation area so that there are no houses located downwind in the direction of the prevailing wind.
- Undertake effluent irrigation in the middle of the day, rather than in the morning or evening.
- A tree belt planted on the edge of the irrigation area will help reduce wind speed.

Irrigation Water

- Avoid spraying effluent which has excessive levels of BOD as this can lead to anaerobic conditions in the soil over a long period. Short periods of anaerobic conditions can assist in increasing denitrification losses but should not be undertaken at the expense of creating odours.
- Apply irrigation at a rate which is less than the infiltration capacity of the soil so that ponding does not occur. Any ponding should last for no more than one hour after irrigation has stopped.

B-6.6 Spray Irrigation

Many spray irrigation systems in the field are performing unsatisfactorily or below their optimum level. Common problems include:

- Insufficient pump capacity or pipe sizes too small so that the pressure at the sprinkler or rain gun gives a dribble rather than a jet.
- Excessive pumping costs because of inadequate pipe size or damage to portable pipes,
- Poor uniformity of water distribution leading to over watering in some areas.

A spray irrigation system that is capable of performing well should have sufficient capacity to meet crop water requirements, especially during periods of peak irrigation demand. In addition the system should be hydraulically efficient to provide uniform water pressure necessary for uniform application.

Monitoring of any irrigation system should include simple routine checks, such as the supply pressure, to ensure that the system is performing as intended. Some other monitoring activities which should be included in a management program are:

B-6.6.1 Quantity and Rate of Water Applied

This basic piece of information should be monitored daily. If an indirect method (such as pump running hours) is used to estimate the volume of daily application, it should be checked at least twice per year to ensure that the system performance has not changed due to wear, blockage or damage. Some of the ways in which the daily volume applied can me monitored include:

Reading the flow meter, if fitted, at the start and end of each day.

Measure pump running time or total power consumption for the pump.

Measuring output of sprinklers with hose, bucket, stopwatch and measuring jug.

Checking operating pressure of sprinklers and determining the output from the manufacturers specifications. Use a drill bit to check the nozzles for wear.

B-6.6.2 Uniformity of Water Application

Uniform water application is essential to minimise the chances of over-watering and causing unintentional drainage to groundwater. Uniformity can be achieved through:

- Using the same sprinkler and jet along a sprayline.
- Keeping pressure variation along sprayline within ± 20% of the design
- Ensuring that the sprinkler spacing and sprayline shifts are as per the original design.
- Laying spraylines perpendicular to prevailing winds.

Methods of checking for uniformity include:

Measuring sprinkler output along a spraylines with a hose, bucket, stopwatch and measuring jug.

Measuring sprayline pressures along a sprayline.

Checking for nozzle wear with a drill bit.

Placing 'catch cans' in a grid covering an rectangular area between four sprinkler positions and measuring the difference in output.

Measuring diameter of sprinkler throw to check for sufficient overlap. The wetted diameter should be 1.3 times the diagonal distance between sprinklers or 1.55 times the longest side of the rectangular spacing, whichever is the longer.

Checking soil moisture at different locations each day after irrigation. (see Section B-7.2 for methods)

B-6.6.3 System Efficiency

To be efficient, a spray irrigation system must be installed and operated according to sound engineering guidelines. Aspects which should be checked periodically include:

Pumping plant performance including checking that flow, pressure and operating speed are in accordance with specifications. (See Section B-6.9 for further information on reviewing pump operation).

Pressure losses between pump and sprinklers have not deviated excessively since installation.

Checking joins, hydrants and hoses for leaks.

Recording details of system operation regularly and comparing the results with previous readings.

B-6.7 Travelling Irrigators

The following guidelines have been compiled from various sources of advice on operation of rain gun and boom irrigators:

1. Maintain the recommended pressure at the nozzle. At low pressures, stream breakup is visually decreased with a resultant increase in droplet size which increases the risk of surface compaction and runoff on clay soils. Low pressures also reduce the wetted diameter. High pressures lead to excessive misting of the stream which increases disturbance by wind.

2. Arrange irrigator laneways to be perpendicular to the prevailing wind.

3. Use the manufacturers recommended lane spacings for windy conditions.

4. Use grassed laneways to reduce hose drag, increase hose life, and reduce soil erosion. Reducing drag helps maintain a constant travel speed.

5. Apply several light applications at frequent intervals rather than fewer heavy applications.

6. Avoid irrigating on windy days when the jet cannot reach 50% of the width of the bay. Night watering is preferable because it is generally less windy. However night watering will reduce ammonia volatilisation losses which may be important in achieving the required nitrogen losses.

7. Use some objective method (see Section B-7.2) of measuring soil moisture in order to schedule irrigation.

B-6.8 Surface Irrigation

The objective of managing a surface irrigation system must be to provide equal infiltration "opportunity time" at all points in the field. As noted in Section B-5.3 this is not easy to achieve because there are complex interactions between the infiltration characteristics of the soil and the hydraulic conditions which control the rate at which the water can flow from the supply channel to the tailwater drain.

Once a system has been designed and constructed, the only factors over which the irrigator has control are:

1. Duration of irrigation, which determines the volume of water being let into the bay or furrow. This "opportunity time" is determined during the design and <u>must by adhered to</u>.

2. The flow rate into the bay or furrow which determines the uniformity of watering. This flow rate must not be altered (unless you really understand what you are doing). Don't assume that water flowing into the tailwater drain is a sign of poor water management.

In many surface irrigation designs, uniform watering can only be achieved by allowing some water to flow from the end of the bay or furrows into the tailwater drain. If this is occurring, check that this is a feature of the design. If it is a part of the design, reducing the total volume of flow from the supply, in the mistaken belief that water is being "wasted", will lead to uneven watering of the field. The main problems with surface irrigation systems are:

- Blockage or damage to siphons which reduces inflow rate.
- Replacement of siphons which are of different length or diameter and therefore alter the flow rate.
- Inadequate control of the time of application of water.

B-6.9 Pumps

All abattoirs have an engineer who is very familiar with pumps and pipelines. Irrigation pumps are no different to the numerous pumps used to circulate water and remove wastewater from the abattoir and are subject to the same common causes of apparent "failure" listed below:

No water delivered - valve closed, pump not primed or suction line air leak.

Not enough water delivered - foot valve partly blocked.

Not enough pressure - air leak in suction or blockage in delivery line.

Pump works for a while then quits - air leak in suction.

Pump leaks excessively at stuffing box - packing worn or not properly lubricated.

Pump is noisy - hydraulic noise (cavitation - suction lift too high) or mechanical defects.

CHAPTER B-7: MONITORING

Monitoring and recording what is happening to all aspects of the effluent irrigation system is vital to its successful operation. Monitoring is required to make day to day decisions about when, and how much to irrigate. In addition, you will need to monitor in order to met your obligations to the environmental regulatory authorities.

Sound monitoring is integral to successful management. Regardless of the capital cost of the irrigation system, management is the key to environmental and economic sustainability

CONTENTS

B-7.1 Record Keeping

Any effluent irrigation system must have a well organised and comprehensive set of data both for day to day management and for reporting to regulatory authorities.

The basis of any record keeping must be:

- An organised system of files (either paper or computer) arranged so that you can find the information when needed
- Routine record keeping on a daily and weekly basis
- Routine summary and review of the data.

Typically you will need sets of records organised for each irrigation paddock which will include:

- daily records of:
  - rainfall
  - irrigation volume
  - soil moisture
  - agronomic activities (cultivation, planting, harvest, animal grazing, etc)
  - evapotranspiration (estimated)
  - water level in the ponds/storage dams (particularly after rainfall)
- Monthly summaries and measurement of:
  - agronomic activities
  - volume of effluent irrigation
  - water level in storage dams and ponds
  - water quality of:
    - effluent
    - local creeks or rivers
- Quarterly summaries and measurement of:
  - Groundwater level
  - Groundwater quality
- Annual summaries and measurement of:
  - Soil nutrients
  - Nitrogen and phosphorus balance
  - Soil salinity
  - Annual water balance
  - Annual crop production
  - Soil structure
  - Groundwater level and quality
  - Local creek water quality

B-7.2 Soil Moisture

There are two aspects concerning soil moisture that need to be considered in the design and management of an irrigation system:

- How much water is stored in the soil profile (Sections B-7.2.1 to B-7.2.8) .
- How moisture moves through the soil (Section B-7.2.9).

B-7.2.1 Field Monitoring Practice

Sampling of soils for soil moisture determination or in-situ assessment of soil moisture must be done in at least 3 places within a paddock or area of similar soil type. Remember that soil moisture needs to be measured down to a point just below the root zone of the crop, which is typically 1 m plus. If you are on sandy soils which are subject to drainage, you may need to measure moisture down to a depth of greater than 2 m in order to check on whether moisture is draining below the root zone.

If you are sampling soils for analysis in a laboratory as described in Section 7.2.3, you will need to:

- take samples at no more than 20 cm intervals down the soil profile
- take at least a 200 g sample at each depth (preferably 500 g)
- place the sample in a clean plastic bag as soon as it is taken out of the soil and seal the bag (using an elastic band)
- clearly mark on the bag:
  - date and time the sample was taken
  - location of sample point
  - the depth of the sample below the surface.

B-7.2.2 Estimation by Feel

The feel of the soil between the fingers is a useful practical guide used widely by farmers to assess the water content of the soil. Table B-6.6 (Chapter B-6) provides guidance on assessing soil moisture content in terms of soil "feel". A soil profile should be inspected down to the base of the root zone. It is usually necessary to inspect a number of sites throughout the area to ensure that sufficient representative samples are taken to describe the overall soil-water content of the profile.

This technique is highly subjective and should be considered as a useful rough guide only.

B-7.2.3 Weight Loss on Drying

The measurement of the moisture content of soils taken in the field does not necessarily require sophisticated equipment costing thousands of dollars. Sufficient accuracy can be achieved with:

- a small electronic balance (eg. kitchen scales) capable of weighing to an accuracy of one gram,
- an ordinary small microwave oven.

Initially you will need to carry out some trials with your oven to see how long it takes to dry the soil you have. (The power of the microwave and the soil type both affect drying time). Weigh a soil sample taken soon after rain (when it is near field capacity). While doing this, leave the sample in the plastic bag, but remove the elastic band. After weighing, transfer the sample to a ceramic or glass bowl suitable for use in a microwave. Place the sample into the oven for a minute and then weigh it. Repeat this process until the sample does not change weight between successive readings. Use this time as the time required to dry any samples you collect on a routine basis. (Typically a sandy soil in a large domestic microwave might take 2 minutes to dry while a clay soil might take 10 minutes in a small microwave).

Note that to get reasonable accuracy you will need a sample of at least 200 g of wet soil - preferably about 500 g.

To calculate the gravimetric moisture content of the soil you need to take account of the weight lost in the oven. Remember to take off the weight of the drying dish from the weight of the dry soil sample. The gravimetric moisture content (W_g), usually expressed as a percentage, is:

$$W_g = \frac{(\text{weight of wet soil - weight of dry soil}) \times 100}{\text{weight of dry soil}}$$

To calculate the volumetric moisture content of the soil you need to take account of the density of the dry soil as well as the weight lost in the oven. The volumetric moisture content (W_v) is given by:

$$W_v = \frac{(\text{weight of wet soil - weight of dry soil}) \times 100 \times \rho}{\text{weight of dry soil}}$$

The factor ρ in the equation is the dry density of the soil (t/m^3). In agricultural situations, the soil density will vary in the range of:

- 1.1 t/m^3 for loose ploughed soil
- 1.7+ t/m^3 for a dense compacted sub-soil.

The dry density of a soil can be measured by taking a soil sample of a known volume (V) which is then dried to obtain the dry weight of the soil. The dry density is then:

$$\rho = \frac{\text{Weight of dry soil (g)}}{\text{Volume of sample (mL)}}$$

Note: density in t/m^3 is numerically the same as g/mL.

The simplest way to obtain a sample of a known volume is to obtain a cylinder of known length and diameter with a sharp edge at one end. (An old food tin or a length of pipe - say 100 mm - with one sharp edge). Push (or gently hammer) the cylinder into the soil until the top edge is level with the surface. Dig around the cylinder so that it can be removed without disturbing the soil inside. If the soil is very dry, it might be necessary to dig out an area around the cylinder so that a sheet of metal can be slid under the base to prevent the sample falling out.

During this process do not forget to write down everything to do with the sampling and weighing:

- date and time sample taken
- location of sample in the paddock
- depth of sample
- wet weight in the plastic bag
- dry weight in the bowl
- weight of the bowl
- calculated volumetric moisture content.

B-7.2.4 Neutron Probe

The neutron probe is an established technique for objective monitoring of soil moisture that has been adopted widely throughout Australia including effluent disposal sites. The soil moisture is measured at different depths in the soil profile by lowering a source of fast neutrons down an aluminium tube placed in the ground. The proportion of slow neutrons that are reflected in the soil and detected are recorded. The reflection of the neutrons by the soil depends on the amount of hydrogen present. Hydrogen ions are found in soil water, the soil organic matter and clay content. Only soil water (and associated hydrogen atoms) will vary from day to day and thus the variation of soil water content can be determined.

Measurements are taken two to three times a week and information is down loaded to a personal computer (or hand written onto paper) for interpretation. Daily water use, compaction layers, through drainage and water stress can be observed and correlation with plant growth considered.

From continual measurements, an irrigation scheduling regime, with paddocks ranked according to watering needs, can be determined with the Neutron Probe.

The instrument costs in the order of $10,000 but does not require a high level of technical skill to operate correctly. For field use it requires that a series of aluminium tubes be placed in the ground to allow the probe to be lowered to take readings at the required interval down the soil profile.

B-7.2.5 Time Domain Reflectometry

Time domain reflectometry (TDR) is a new technique that operates in a way that is analogous to closed loop radar in order to determine the volumetric soil moisture content of the soil. An electromagnetic wave is propagated through the soil and the time of travel of the wave is measured. The velocity of the wave is a measure of the di-electric constant of the soil. Dry soil has a di-electric constant of 3-5 while that of free water is 80. Higher moisture content of the soil will correspond to an increase in the total di-electric and a faster travel time for the electromagnetic wave. Because the di-electric constant for soil is very different from that of water, measurement of the di-electric properties of a field soil can be used to determine the moisture content.

The method uses a metal prong, called a waveguide, which is inserted into the soil at the measurement location. The method is quick, is relatively independent of soil type, non-destructible and allows repeatable in-situ measurements. The TDR is a portable unit allowing individual soil moisture measurement by pushing the waveguides into the soil. Alternatively, a number of sensors can be buried in the soil at different depths and connected to a set of cables in a terminal box (multiplexer) on the surface. The multiplexer can then be used to continually measure up to 256 buried sensors in an array.

The TDR measures the average moisture content along the length of the rods (ranging from 15 cm to 70 cm in length). Sensors are available in two configurations. For portable measurement, two stainless steel guides are pushed into the soil, or alternatively, three prong waveguides may be placed permanently in the soil and connected to the TDR. In the latter mode, the TDR system operates in a similar method to the Neutron Probe measuring the moisture content down the soil profile.

B-7.2.6 Tensiometers

Portable and stationary tensiometers are available for measuring the soil moisture on a tension basis. A unique relationship (called a soil moisture characteristic) relates a tension reading to the widely used volumetric moisture readings. Tensiometers act in a similar principle to a plant root, measuring the force that plants have to exert to obtain moisture from the soil. As the soil dries, the water is lost from the tensiometer via a ceramic cup. The loss of water creates a vacuum in the tensiometer and this is recorded as a suction reading. The drier the soil, the higher the suction reading. (Note that 10 kPa is considered field capacity and 1500 kPa to be wilting point).

Tensiometers may be placed permanently in the soil giving an analogue or digital output. Logging of tensiometers is possible via transducers and cable back to a computer or datalogger. Portable tensiometers allow greater freedom of sampling, giving relatively quick readings of soil moisture tension. Tensiometers will take time to equilibrate, especially in heavier soil types and this should be accounted for in determining an irrigation scheduling regime.

For the suction range in which water is available for plant use, ie. from about 10 kPa (field capacity) to 1500 kPa (permanent wilting point), tensiometers operate at the moist end of the range, ie. from 0 to 90 kPa. In most irrigated situations, water is applied before the 90 kPa suction is reached. Above 90 kPa, air is drawn through the ceramic cup and the vacuum in the tensiometer is broken. Because of their greater sensitivity at low suctions, tensiometers are better suited to medium to coarse textured soils, so that a greater part of the available water range is covered. Although a tensiometer has limited water potential range and requires frequent servicing, it is accurate, easily installed and relatively inexpensive.

B-7.2.7 Capacitance Probe

The capacitance probe is a relatively new technique for field based soil moisture determination. A sensor can be lowered down a PVC tube and a frequency output is noted and converted to volumetric soil moisture content. The capacitance technique is similar to that of the TDR in that the di-electric constant of the soil will determine the moisture content reading. A high frequency transistor oscillator (150 MHz) operates with the soil di-electric, between a pair of cylindrical electrodes, and measures the frequency. The measured frequency is related to the soil moisture content via a non-linear universal calibration. Measurement of moisture content is influenced by soil type and bulk density.

B-7.2.8 Electrical Resistance Blocks

Electrical resistance blocks consist of a set of electrodes set in a small porous calcium sulphate block. The block is placed in the soil and absorbs water until equilibrium is reached with the surrounding soil. The electrical resistance of the block can be used to infer the moisture content of the soil surrounding the block. Typically, resistance blocks are buried in the soil profile at several depths and then regularly monitored throughout the year.

The limits of useful measurement are dictated by the breaking of the water film in the block at the dry end of the range (up to 600 kPa) and by decreased sensitivity at the wet end (60 kPa). The electrical resistance sensors are inexpensive and easily installed, however, they are sensitive to changes in soil solute (ion) concentrations and will dissolve with time (up to 4 years) in the soil, thus requiring replacement.

Both tensiometers and resistance blocks require intelligent use and placement in order to derive useful information on soil suction. Readings should be taken daily, usually early in the morning to avoid temperature effects.

B-7.2.9 Permeameters

Permeameters (in various shapes and designs) are instruments that are used to measure how fast the water can infiltrate into the soil surface and how fast the water will move through the soil profile. These properties of a soil are a function of the hydraulic conductivity (or permeability) of the soil. For example, results from permeameter tests may indicate that the long term steady state infiltration rate (after initial wetting of the soil surface layer) is 15 mm/h. The spray irrigation application rate must be less than this in order to ensure that surface ponding and runoff do not occur. The infiltration rate is also one of the factors which is taken into account in the design of the "opportunity time" for a surface irrigation system (see Section B-5.3).

Generally, soils with high clay content will have lower hydraulic conductivity. Improvements in soil structure (see Section B-1.4.3) will generally increase the conductivity.

Permeameters are also used to check clay linings of dams and channels. A permeameter can be used to indicate the leakage rate from the site of a proposed effluent storage dam, and whether any special clay liner is needed to minimise leakage and protect an underlying aquifer.

B-7.3 Climate

B-7.3.1 Rainfall

In order to schedule irrigation with any accuracy, you will need at least one rain gauge which should be read every day by the person responsible for the day to day management of the irrigation area.

B-7.3.2 Irrigation

The volume of effluent pumped from the final pond must be recorded daily, together with which part of the irrigation area the effluent was being applied to.

In addition to recording daily volume of effluent pumped, a daily log should be kept of the general performance of the irrigation system. This log should note such things as:

- Where the irrigator was positioned in the paddock,
- Pressure at the supply point,
- Wind conditions,
- Time of starting irrigation,
- Time of ending irrigation,
- Any abnormal aspects in the operation (eg mis-alignment of a centre pivot machine),
- Any signs of ponding or runoff.

A range of things to look out for in different irrigation systems are set out in the relevant sections of Chapter B-6. In particular there are suggestions for how to check for equipment wear, and how to measure irrigation uniformity and application rates.

B-7.3.3 Evapotranspiration

Estimates of evapotranspiration can usually be obtained from your nearest office of the Bureau of Meteorology or State Department of Agriculture. Make an effort to get these and start working out an estimated daily water balance for each paddock so that you can anticipate which areas are going to need irrigating first.

Do not forget to check which measurement of evaporation you are being given by the source of data (pan, open water, reference crop or a particular crop). Section B-2.2 contains some notes on the different measures of evaporation and evapotranspiration and how to convert between them.

Modern recording weather stations are available which record the necessary variables to calculate the reference crop evapotranspiration within the electronic logic of the datalogger. These instruments are available from a variety of suppliers and range in cost from $4000 - $5,000. A device of this type is almost an essential item of equipment for a well managed effluent irrigation system.

B-7.3.4 Other Climatic Factors

In addition to rainfall, it is also a good idea to keep a daily record of wind run, temperature and relative humidity. Records of these meteorological elements are taken at stations operated by the Bureau of Meteorology in most major towns and are usually available daily.

Alternatively, as noted above, there are a variety of relatively inexpensive automatic weather stations available which can automatically record a full range of climatic variables such as wind speed, wind direction, humidity, solar radiation and rainfall for several months. Most of these systems come with the necessary software to download and analyse the data in a portable computer. However, for management decisions about when to irrigate and how much water to apply, the data needs to be available each day. It is therefore advisable to obtain a system which can be connected to the office computer by telephone line or special purpose cable and from which daily summaries can be obtained for checking and making management decisions, as well as keeping a full record.

B-7.4 Effluent Quality

Most abattoirs have very few records of the quality of the effluent produced. Without any measurements of effluent quality, it is impossible to assess what the nitrogen, phosphorus and salt loadings are. It is therefore not possible to assess whether the loading rate exceeds the capacity of the land.

A recommended minimum monitoring of the effluent, at the point where it is pumped from the final pond, is to sample monthly and have the effluent tested for:

- TKN, ammonia, nitrate,
- Total phosphorus and orthophosphate,
- BOD,
- Salinity (either EC or TDS).

There are a variety of test kits on the market which allow routine testing to be carried out much cheaper than sending samples to a commercial laboratory. Whilst these kits are relatively cheap and quick to use, the results obtained are only likely to be useful for internal monitoring and management purposes. For regulatory purposes, most State Environmental Agencies insist on samples being tested by a NATA registered laboratory.

B-7.5 Soil Nutrients, Salt and Structure

B-7.5.1 Annual Soil Testing

Soils in the effluent irrigation area should be monitored annually. Sampling procedure should involve the collection of 50 cm cores which can be bulked for analysis. Three samples should be taken per 100 ha or within each paddock or separate soil type. The following chemical and physical tests should be carried out:

***Chemical*:**
pH
salinity as $EC_{1:5}$
total nitrogen, nitrate
available phosphorus and phosphorus sorption
total potassium
organic carbon
sodium adsorption ratio
sodium
calcium
magnesium
chloride
exchangeable cations

***Physical*:**
bulk density
colour
texture
surface characteristics

In addition to the bulk core sampling every year, each three years a full profile analysis should be carried out at the intervals 0-15 cm, 15-30 cm, 30-60 cm and 60-90 cm.

- quantity added in the effluent
- quantity removed by the crop
- quantity removed and returned by grazing
- net gain or loss at the end of the year.

As with nitrogen, it is important to keep a year to year check on the total phosphorus in the soil. Because the phosphorus load from abattoir effluent is likely to be greater than the ability of any crop to remove it, it can be expected that the phosphorus levels will increase over time. Most Australian soils are thought to be capable of storing at least 2,000 kg/ha of P before there would be any problem with the storage capacity being leached. However, by using the soil as a "sink", the soil itself can become a pollutant and additional safeguards against soil erosion might need to be implemented.

B-7.5.4 Organic Matter Content

The organic matter content of the soil is a good indicator of the general fertility and moisture holding capacity of a soil. As mentioned in Chapter B-2, organic matter content of at least 15 t/ha should be a target for a well managed effluent irrigation area.

B-7.5.5 Soil Structure

The annual monitoring of the soil should be used to keep track of the soil bulk density and the ESP. Any significant trend should be treated as a sign of changing structural conditions. In particular a trend of increasing bulk density is a sign that structural decline is occurring. This probably means that the area is being subject to one of the following:

- Cultivated too much.
- Cultivated when the soil is wet.
- Stock trampling is occurring.
- The soil is being maintained at near saturation for too long.

B-7.5.6 Salinity

Soil salinity should be monitored at least once per year at representative sites throughout the irrigation area (see Section B-7.5.1). It should be measured in a 1:5 soil solution and expressed as $EC_{1:5}$.

At least once every three years samples should be taken down the soil profile to check if there is any accumulation of salts in the lower root zone. The measurement of soil salinity, as $EC_{1:5}$, must be converted to the saturated extract soil salinity (EC_e) which is more representative of how a plant will react to salinity.

EC_e (dS/m) ≊ $EC_{1:5}$ (dS/m) x multiplier factor.

The multiplier factor depends on soil texture, so all $EC_{1:5}$ results should be accompanied by an estimate of texture.

Analyses should include:

***Chemical*:**	pH salinity as $EC_{1:5}$ total nitrogen, nitrate available phosphorus and phosphorus sorption total potassium exchangeable cations
***Physical*:**	percentage dispersion

B-7.5.2 Nitrogen Balance

A full nitrogen balance should be made for each paddock or separate management area. This nitrogen balance should be calculated from all the known inputs and outputs of nitrogen to the soil. The main items which must be measured are:

- Daily irrigation volume pumped to each area
- Monthly (at a minimum) sampling of effluent quality to determine TKN, NH_4^+ and NO_3^-.
- Crop removed from the area
- Estimated crop nitrogen content
- Animals grazed and the duration of grazing

The full nitrogen balance should be computed annually for each paddock or management area using a form similar to Form B-7.1. Note that the calculation of the nitrogen balance also includes a check on the total remaining nitrogen at the end of each year. These check measurements are essential to correct the estimated inputs and outputs. After a few years of record keeping you will be able to check the accuracy of the estimated inputs and outputs. If your estimates are showing that there should be a nitrogen balance, but the soil testing indicates that nitrogen levels are continuing to increase, then your estimates are probably wrong.

If nitrogen levels in the soil show a continuing upward trend over several years, then you will need to reduce the nitrogen loading or change the cropping pattern in order to restore the balance.

B-7.5.3 Phosphorus Balance

Phosphorus needs to be monitored and checked in a similar way to that recommended for nitrogen. Form B-7.2 contains the components which need to be determined in order to establish the phosphorus balance. These include:

Form B-7.1 Nitrogen History and Balance

YEAR	N FROM LAST YEAR		FERTIL-IZER	EFFLUENT			CROP			GRAZING				NITROGEN BALANCE		
	Estimated (kg/ha)	Tested (kg/ha)	Applied (kg/ha)	Volume applied (kL/ha)	N conc. (mg/L)	Total N applied (kg/ha)	Type	N credits (kg/ha)	N removed (kg/ha)	Animal type	Stocking rate (no./ha)	N removed (kg/ha)	N returned (kg/ha)	Total gains (kg/ha)	Total losses (kg/ha)	NET (kg/ha)

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Form B-7.2 Phosphorus History and Balance

YEAR	P FROM LAST YEAR		FERTIL-IZER	EFFLUENT			CROP		GRAZING				PHOSPHORUS BALANCE		
	Estimated (kg/ha)	Tested (kg/ha)	Applied (kg/ha)	Volume applied (kL/ha)	P conc. (mg/L)	Total P applied (kg/ha)	Type	P removed (kg/ha)	Animal type	Stocking rate (no./ha)	P removed (kg/ha)	P returned (kg/ha)	Total gains (kg/ha)	Total losses (kg/ha)	NET (kg/ha)

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Multiplier factors for converting $EC_{1:5}$ (dS/m) to an approximate value of EC_e (dS/m) are given in Table B-7.1. The broad classification of soil salinity and its effects on crop growth are set out in Table B-7.2.

Table B-7.1 ***Soil Salinity Conversion Factors***
(after Pope and Abbott, 1989)

Soil Texture	Multiplier factor
Sandy loam, fine sandy loam, light sandy clay loam	11
Loam, loam fine sandy, silt loam, sandy clay loam	10
Clay loam, silty clay loam, sandy clay, light clay	9
Light medium clay	8
Medium clay	7
Heavy clay	6

Table B-7.2 ***Broad Classification of Soil Salinity***
(adapted from SCS of NSW, 1991)

Rating	EC_e (dS/m)	Effect on Plants
Non-saline	<2	Salinity effects mostly negligible
Slightly saline	2-4	Yields of sensitive crops affected
Moderately saline	4-8	Yields of many crops affected
Highly saline	8-16	Only tolerant crops yield satisfactorily
Extremely saline	>16	Only very tolerant crops yield satisfactorily

The salt tolerance of a range of crops likely to be used for effluent irrigation are set out in Table B-7.3.

Table B-7.3 ***Salt Tolerance of Some Agricultural Crops, Showing Maximum EC_e Values for no Yield Reduction***
(adapted from Doorenbos and Pruitt, 1977)

	Sensitive (EC_e 0-1.9 dS/m)		Moderately tolerant (EC_e 2.0-3.8 dS/m)		Tolerant (EC_e > 3.9 dS/m)	
Field Crops	Maize Sugarcane	1.7 1.7	Rice	3.0	Barley Safflower Sorghum Soybean Wheat	8.0 5.3 4.0 5.0 6.0
Forage Crops	Bent grass Orchard grass	1.7 1.5	Lucerne Soudan grass Trefoil, big Vetch	2.0 2.8 2.3 3.0	Barley (hay) Bermuda grass Perennial rye Phalaris Trefoil Wheat grass	6.0 6.9 5.6 4.6 5.0 7.5

The following indicators of salinity have been formulated by the Soil Conservation Service of NSW (Hazelton and Murphy, 1992):

1. Trees dying for no apparent reason.
2. Productive annual and perennial species thin and die out. They are replaced by more salt tolerant plants.
3. Soil becoming waterlogged. This is one of the first signs of a potential salinity problem. However, not all waterlogging will result in the development of salinity.
4. Bare patches of soil appearing which become progressively larger and readily erode.
5. Stock congregating on an area and licking the surface.
6. Salt crystals visible when the soil surface is dry.
7. Surface of the bare soil is "puffy" to walk on when dry.
8. Excess quantities of runoff flowing from the area causing erosion of the site and the area downstream.
9. Very clear water in a dam, because the salt settles the sediment.
10. Smell of salt.

B-7.5.7 Soil Water Quality

An alternative to monitoring groundwater quality (see Section B-7.6.1), which indicates if any pollution has already occurred, is to monitor water quality at the bottom of, or just below, the root zone. Suction lysimeters can be used to obtain a sample of water from the unsaturated soil above the watertable. The sample is obtained by using a vacuum pump to create a suction inside a sampling device which has a ceramic tip through which soil water is sucked. The sampling cup with the ceramic tip is usually left in the soil at the required depth and connected to the surface by a rigid tube. At the surface, a valve arrangement allows a vacuum pump to be connected to create a vacuum in the sampling cup. The device is then left for a few days to suck in a soil water sample. The valve at the surface is then opened to allow a fine sample tube to be inserted into the cup to extract the water sample for analysis.

The advantage of using a suction lysimeter is the ability to monitor the quality of the soil water before it reaches the watertable. If, for example, nitrogen levels were found to be high at the base of the root zone, then it would be possible to reduce nitrogen loading and/or reduce the amount of irrigation in order to minimise nitrogen leaching below the root zone.

B-7.6 Surface and Groundwater

B-7.6.1 Groundwater Level

The amount of groundwater monitoring needed will be dependant on the risk of contamination of groundwater. The main determining factor will be the depth to any watertable under the irrigation area. If any significant watertable is present and the water is not saline, then you can expect to have to install a number of monitoring bores around the perimeter and within the irrigation area.

Table B-7.4 gives an indication of the number of bores which might be required. The actual number will need to be negotiated with the environmental regulating agency.

Monitoring of the bores should be undertaken preferably every three months, but the following schedule may be adopted as a minimum:

Water Level - every 6 months
Water Quality - every year

Table B-7.4 ***Number of Test Bores Required per 100 ha***

Depth to Watertable (m)	Salinity of Groundwater (μS/cm)		
	0-2,000	2,000-5,000	>5,000
0-5	5	3	1
5-15	3	2	1
>15	2	1	1

Each test bore should be installed using the following criteria:

- Identify an area which is representative of the surrounding land use. Ensure test wells are more than 30 m from the following:

  - permanent or semi-permanent water bodies (ie. dams, reuse system, supply or local channels, blocked roadside table drains)
  - dairy or other buildings
  - mature tree(s)
  - the spears of a spear point pump

  Avoid locations near farm drains and channels, as they tend to produce high local watertables when they are holding water. However, when these are dry, the test well readings will return to a representative watertable level.

- Try to install the test wells in areas of easy access (fence lines or roadsides are ideal) and where stock will cause minimal damage. The test well may need to be fenced from stock.

- Watertables are generally closest to the surface in topographically low areas associated with heavy soils. These areas will normally show the first signs of salinity. When installing test wells, work from areas of low topography up.
- If a range of soil types and cropping/grazing patterns exist, it is a good idea to install a test well in each of these areas.

B-7.6.2 Groundwater Quality

When sampling groundwater it is important to get a sample which is representative of the surrounding groundwater. The water standing in the test well may well be unrepresentative because it has been standing for several months. If possible, the well should first be emptied using the sampling bailer. Then allow the well to fill again before taking a sample for analysis.

The analyses which should be undertaken includes:

- pH
- EC
- Total nitrogen

B-7.6.3 Surface Water Monitoring

Where there is a defined creek or river running adjacent to the effluent area, surface water should be collected one site upstream and one site downstream of the effluent irrigation area.

Samples should be taken preferably four times (at least twice) per year and analysed for:

- TKN
- Total phosphorus
- EC

The most sensitive time for sampling would be when the flow is low.

CHAPTER B-8: BIBLIOGRAPHY AND REFERENCES

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CHAPTER B-9: GLOSSARY

B-9.1 Abbreviations and Acronyms

ANZECC	-	Australian and New Zealand Environment and Conservation Council
BOD	-	Biochemical Oxygen Demand
CEC	-	Cation Exchange Capacity
COD	-	Chemical Oxygen Demand
CSIRO	-	Commonwealth Scientific and Industrial Research Organisation
EC	-	Electrical Conductivity
EPA	-	Environmental Protection Authority, NSW or Victoria
ESP	-	Exchangeable Sodium Percentage
LWK	-	Liveweight Killed
NATA	-	National Association of Testing Authorities
NHMRC	-	National Health & Medical Research Council
NOX	-	Nitrite plus nitrate
pH	-	Term describing the hydrogen ion activity (acidity/alkalinity) of a system
SAR	-	Sodium Adsorption Ratio
SEPP	-	State Environment Protection Policy, Victoria
SS	-	Suspended Solids
TDS	-	Total Dissolved Salts
TKN	-	Total Kjeldahl Nitrogen

B-9.2 Terms

A HORIZON: The horizon formed at or near the surface, but within the mineral soil, having properties that reflect the influence of accumulating organic matter or eluviation, alone or in combination.

ABSORPTION: The process by which one substance is taken into and included within another substance, as the absorption of water by soil or nutrients by plants.

ACT (Statute): The laws as passed by Parliament.

ADSORPTION: The increased concentration of molecules or ions at a surface, including exchangeable cations and anions on soil particles.

AEROBIC: Describes conditions in which oxygen is plentiful and chemically, oxidising processes prevail. Such conditions are usually found in well-drained soils with good soil structure.

ALGAE: Primitive plants, one or many-celled, usually aquatic and capable of synthesising cell material by photosynthesis.

ALKALINITY: The capacity of water to neutralise acids, a property imparted by the water's content of carbonates, bicarbonates, hydroxides, and occasionally, borates, silicates, and phosphates. It is expressed in milligrams per litre of equivalent calcium carbonate.

ANAEROBIC: Describes conditions in which oxygen is absent and chemically, reducing processes prevail. Such conditions are usually found in waterlogged or poorly drained soils in which water has replaced soil air.

ANION: Negatively charged ion.

ANOXIC: Describes soil conditions in which there is a gross deficiency of oxygen.

AQUIFERS: Sizeable body of groundwater which can flow and yield water. They are usually classed as confined or unconfined.

AVAILABLE WATER CAPACITY (AWC): The moisture holding capacity of the soil, generally expressed as the depth of available water per metre depth of soil.

AVAILABLE WATER, PLANT (W_p): That part of the total available water within the soil that is able to be used by the plant. It is generally considered to be about 50% of the total available water.

AVAILABLE WATER, TOTAL (W): Storage capacity of the soil moisture store.

AVERAGE: A value equal to the total score of individual values divided by the number of values.

B HORIZON: The horizon immediately beneath the A horizon characterised by a higher colloid (clay or humus) content, or by a darker or brighter colour than the soil immediately above or below, the colour usually being associated with the colloidal materials. The colloids may be of alluvial origin, as clay or humus; they may have been formed in place (clay, including sesquioxides); or they may have been derived from a texturally layered parent material.

BACTERIA: Single celled organisms that have no nucleus.

BIOCHEMICAL OXYGEN DEMAND (BOD): The quantity of oxygen used by micro-organisms in the biological oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions. A standard test used in assessing wastewater strength. BOD usually refers to the demand after 5 days and at 20^{0}C i.e. the 5 day BOD, often shown as BOD_5.

BULK DENSITY, SOIL: The mass of dry soil per unit volume. The volume is determined before drying to constant weight at 105^{O}C.

C HORIZON: The horizon that normally lies beneath the B horizon but may lie beneath the A horizon, where the only significant change caused by soil development is an increase in organic matter, which produces an A horizon. In concept, the C horizon is unaltered or slightly altered parent material.

CARBON-NITROGEN RATIO (C:N): The weight ratio of carbon to nitrogen in a waste material.

CATION-EXCHANGE CAPACITY (CEC): The sum total of exchangeable cations that a soil can adsorb; sometimes called total-exchange, base-exchange capacity, or cation-adsorption capacity. Expressed in milliequivalents per 100 grams or per gram or soil (or of other exchanges, such as clay).

CATION: Positively charged ion.

CHEMICAL OXYGEN DEMAND (COD): A measure of the oxygen-consuming capacity of inorganic and organic matter present in water or wastewater. It is expressed as the amount of oxygen consumed from a chemical oxidant in a specified test. It does not differentiate between stable and unstable organic matter and thus does not necessarily correlate with biochemical oxygen demand. Also known as OC and DOC, oxygen consumed and dichromate oxygen consumed, respectively.

CODES OF PRACTICE: Guidelines published to assist industry meet or exceed its legal obligations. Generally do not have the same force and effect as an Act.

COLIFORM BACTERIA: A group of bacteria used as indicators. They predominantly inhabit the intestines of man or animals, but are also present in soil and vegetation. They are gram-negative, aerobic and facultatively anaerobic, nonspore-forming bacilli that ferment lactose with production of gas. Also included are all bacteria that produce a dark, purplish-green colony with metallic sheen by the membrane-filter technique used for coliform identification. The two groups are not always identical, but they are generally of equal sanitary significance. Tests are available to assess total coliforms or faecal coliforms. See ESCHERICHIA COLI.

COMMON LAW: That part of law of England administered by the old common law courts.

CONDUCTIVITY, HYDRAULIC: As applied to soils, the ability of the soil to transmit water in liquid form through pores.

CONTAMINATION: Effluent contamination refers to the corruption, either chemically or biologically, of effluent standards.

CROP ROTATION: A beneficial agricultural practice involving the cultivation of a succession of different crops. By doing this it allows the land to be rested between crops, pests and diseases can be prevented and soil and climate characteristics can be best utilised.

CULTIVATE: To prepare the ground in readiness for planting crops.

DEFICIT IRRIGATION: An irrigation technique where the prime aim is to maximise crop yield with limited water supply.

DENITRIFICATION: The biochemical reduction of nitrate or nitrite (by microbial or other means) to gaseous molecular nitrogen or an oxide of nitrogen.

DEOXYGENATION: The depletion of the dissolved oxygen in a liquid under natural conditions associated with the biochemical oxidation of organic matter present.

DISSOLVED OXYGEN (DO): The free oxygen dissolved in water, wastewater, or other liquid, usually expressed in milligrams per litre (mg/L), parts per million (ppm), or percent of saturation.

DISSOLVED SOLIDS: Solids present in solution.

$EC_{1:5}$: Electrical conductivity or salt content as measured in a 1:5 soil solution, expressed as dS/m.

ECe: Electrical conductivity or measure of salt content in the extracted soil water when the soil is saturated with water, expressed as dS/m.

EFFLUENT: The water discharged following a wastewater treatment process, usually to be irrigated.

ENVIRONMENT: Includes ecosystems; all natural and physical resources; the qualities and characteristics of locations, places and areas that contribute to their biological diversity and integrity, intrinsic scientific value or interest, amenity, harmony, and sense of community; and the social, economic, aesthetic and cultural conditions that affect or are affected by the foregoing.

ENVIRONMENTAL IMPACT ASSESSMENT: The critical appraisal of the likely effects of a proposed project, activity, or policy on the environment.

ENVIRONMENTAL IMPACT STATEMENT: A document prepared after careful studies describing a proposed development or activity and disclosing the possible, probable or certain effects of the proposal on the environment.

Epan: Pan evaporation or rate of water loss from an unscreened class A pan, expressed as mm/day.

ESCHERICHIA COLI (E.COLI): One of the species of bacteria in the coliform group. Its presence is considered indicative of fresh faecal contamination.

ETa: Actual crop evapotranspiration rate (ETa ≤ ETm) taking account of any moisture stress which might occur, expressed as mm/day.

ETm: Maximum evapotranspiration rate of the crop when soil water is not limited; also called maximum crop water requirements, expressed as mm/day.

ETo: Reference crop evapotranspiration rate for a short green grass and given climate when soil water is not limited, expressed as mm/day.

EVAPORATION RATE (of water): The loss of water, expressed in terms of depth, evaporated from a given surface per unit of time. It is usually expressed in mm per day, month or year.

EVAPOTRANSPIRATION: The combined loss of water from a given area, and during a specified period of time, by evaporation from the soil surface and by transpiration from plants.

EXCHANGEABLE SODIUM CONCENTRATION: The total cation capacity occupied by sodium ions.

EXCHANGEABLE SODIUM PERCENTAGE (ESP): The proportion of the cation exchange capacity occupied by sodium ions, expressed as a percentage.

FAECAL COLIFORMS: Faecal coliforms are bacteria of the coliform type that can only exist within the guts of warm blooded animals. It is for this reason that the presence of faecal coliforms is an indicator of sewage pollution. *E. coli* is a bacterium that comes from the faecal coliform group.

FIELD CAPACITY: The maximum amount of water that a soil can hold once free drainage (due to gravity) has ceased.

FLOODPLAIN: Flat or nearly flat land on the floor of a river valley that is covered by water during floods.

FULL POINT: The total depth of water available to the plant when the soil is at field capacity.

GRAZE: The feeding of cattle on growing grass/pasture.

GROUNDWATER: The water which reaches the saturated zone below the watertable and eventually flows laterally into streams.

HARVEST: Reaping and gathering in of the season's yield of grain or other crops.

IMMOBILISATION/MINERALISATION: Is the process where plant available nitrogen is converted into an unavailable organic form by the soils microbial population.

IN-SITU: Relates to the general location out in the field, and usually refers to 'on-the-spot' soil testing.

INFILTRATION RATE: (1) The rate at which water enters the soil or other porous material under a given condition. (2) The rate at which infiltration takes place, expressed as depth of water per unit time, usually in millimetres per hour.

INFILTRATION: The process whereby water enters the soil through the immediate surface.

ION: A charged atom, molecule, or radical, the migration of which affects the transport of electricity through an electrolyte or, to a certain extent, through a gas. An atom or molecule that has lost or gained one or more electrons; by such ionisation it becomes electrically charged. An example is the alpha particle.

IRRIGATION: Irrigation refers to the surface distribution of effluent water. Associated with irrigation is an appropriate irrigation area which is dependent on local evapotranspiration conditions. In Sydney, domestic AWTA units are required to have 100 m^2 of land set aside purely for effluent irrigation.

kc: Crop coefficient (or crop factor) relating reference evapotranspiration rate (ETo) to the potential evapotranspiration rate (ETc), or ETc = kc . ETo, expressed as a fraction.

kpan: Pan coefficient (or pan factor) relating the pan evaporation rate (Epan) to the reference evapotranspiration rate (ETo), or ETo = kpan . Epan, expressed as a fraction.

LEACHING FRACTION (LF): The volume of drainage required as a percentage of the volume of irrigation water applied, say on a yearly basis, expressed as a percentage.

LEACHING: (1) The removal of soluble constituents from soils or other material by water. (2) The removal of salts and alkali from soils by abundant irrigation combined with drainage. (3) The disposal of a liquid through a non-water-tight artificial structure, conduit, or porous material by downward or lateral drainage, or both, into the surrounding permeable soil.

LIABILITY: A legal obligation.

LOADING, EFFLUENT: The rate at which effluent and its nutrients is applied to an irrigation area. Commonly measured as m^3/yr.

LOADING, HYDRAULIC: The rate at which simply the volume of effluent (water) is applied to an irrigation area. Commonly measured as m^3/yr.

LYSIMETER: A device for measuring percolation and leaching losses from a column of soil under control conditions.

MEAN: See AVERAGE.

MEDIAN: The value which has 50% of values above it and 50% below.

MICRO-ORGANISMS: Microscopic organisms such as bacteria, viruses, yeasts, algae, fungi and protozoa. Micro-organisms appear in all habitats, including soil, water, skin, hair, intestines, etc.

MINERALISATION: See immobilisation/mineralisation.

MOISTURE CONTENT, GRAVIMETRIC (G): The mass of water (g) per unit mass of oven dry soil (g), expressed as a percentage.

MOISTURE CONTENT, VOLUMETRIC (W): For a unit area, this is the depth of water (mm) per unit depth of soil (m), expressed as a percentage. It is the same as the volume of water per unit volume of soil.

NEGLIGENCE: An omission to do something which a reasonable person would do or doing something a reasonable person would not do.

NITRATE-NITROGEN: Nitrate is a major nutrient. In surface waters, it is generally present in trace quantities and expressed in milligrams per litre (mg/L).

NITRIFICATION: The bacterial conversion (biochemical oxidation) of ammonia to nitrate-nitrogen and nitrite-nitrogen.

NITRITE-NITROGEN: Is an intermediate chemical state between ammonia and nitrate-nitrogen. It persists only briefly in surface waters before oxidising into nitrate-nitrogen. Nitrite is associated with a number of health risks. It is usually expressed in milligrams per litre (mg/L).

NUTRIENTS: Nutrients are those chemical elements that are essential for sustained plant or animal growth. The most important of these elements include nitrogen and phosphorus and many of their compound derivatives. Nitrogen compounds include ammonia, nitrate and nitrite. Phosphorus compounds include phosphates and long-chain (large molecule) polyphosphates. Nutrients are prevalent in the majority of wastewaters. Phosphates are commonly used in many detergents.

ORGANIC CARBON: That part of organic matter which is composed of organic carbon.

ORGANIC MATTER: Chemical substances of animal or vegetable origin, or more correctly, of basically carbon structures, comprising compounds consisting of hydrocarbons and their derivatives.

ORGANIC NITROGEN: Nitrogen combined in organic molecules such as proteins, amino acids.

ORGANIC PHOSPHORUS: A part of all living things and the principal form of phosphorus in waste.

PATHOGENIC: Causing disease. "Pathogenic" is also used to designate microbes which commonly cause infectious diseases, as opposed to those which do so uncommonly or never.

PATHOGENS: Micro-organisms which are parasitic on, cause disease in, or otherwise affect other organisms (such as animals and human beings).

PED: A unit of soil structure such as an aggregate, crumb, prism, block, or granule, formed by natural processes (in contrast with a clod, which is formed artificially).

PENALTY: A punishment particularly a fine or money payment.

PERCOLATION RATE: The rate of movement of water under hydrostatic pressure through the interstices of a contact or filtering medium.

PERCOLATION: The flow or trickling of a liquid downward through a contact or filtering medium. The liquid may or may not fill the pores of the medium.

PERMANENT WILTING POINT: The moisture content of the soil where water is no longer available to the plant, causing it to permanently wilt.

PERMEABILITY, SOIL: The property of a soil which determines the ease with which gases, liquids, or plant roots penetrate or pass through soil.

pH: The negative of the logarithm of the hydrogen-ion concentration. The concentration is the weight of hydrogen-ions, in grams per litre of solution. Neutral water, for example, has a pH value of 7 and a hydrogen-ion concentration of 10^{-7}.

POLLUTION: The presence in a body of water (or soil or air) of material in such quantities that it impairs the water's usefulness or renders it offensive to the senses of sight, taste or smell. Contamination may accompany pollution. In general a public hazard is created but in some instances only economy or aesthetics are involved, as when waste salt brines contaminate surface waters or when foul odours pollute the air.

POROSITY, SOIL: Is a measure of the amount of pores in the soil.

POTENTIAL CROP EVAPOTRANSPIRATION RATE (ET_c): The potential evapotranspiration rate from a crop when soil water is not limited, expressed as mm/day.

PRIMARY TREATMENT: Sewage treatment by screening, grit removal, sedimentation with sludge digestion to remove gross and settleable solids.

REFILL POINT: The depth of available water at the point where the plant starts to suffer moisture stress or a loss in potential production because of a lower soil water content.

REGULATION: A legally enforceable rule passed by bodies or persons so authorised by Parliament.

ROOTING DEPTH (d): The depth to which the roots of a plant penetrate and extract water.

RUNOFF: Occurs when soil cannot absorb all of the precipitation falling on it. The surplus water flows in sheets over plane surfaces.

SECONDARY TREATMENT: Treatment of primary effluent by biological aerobic processes to remove organic matter.

SETTLEABLE SOLIDS: That matter in wastewater which will not stay in suspension during a preselected settling period, such as one hour, but either settles to the bottom or floats to the top.

SINK: Storage of nutrients or chemicals in the soil in a form which is unavailable for plant use or transport by water.

SODIC SOIL: A soil containing sufficient exchangeable sodium to adversely affect soil stability, plant growth, and/or land use. In Australia, soils with an ESP greater than 5 are called sodic soils.

SODIUM ADSORPTION RATIO (SAR): Indicates the exchangeable sodium status (or sodium hazard) of the soil.

SOIL HORIZON: A layer of soil or soil material approximately parallel to the land surface and differing from adjacent genetically related layers in physical, chemical, and biological properties or characteristics such as colour, structure, texture, consistence, pH, etc.

SOIL MAP: A map showing the distribution of soil types or other soil mapping units in relation to the prominent physical and cultural features of the earth's surface.

SOIL SALINITY: The characteristic of soils relating to their content of water soluble salts. A soil high in salinity (greater than 4µS/cm) will adversely affect plant growth and/or land use.

SOIL SEPARATES: Groups of mineral particles separated on the basis of a range in size. The principal separates are sand, silt, and clay.

SOIL STRUCTURE: The combination or arrangement of individual soil particles into definable aggregates, or peds, which are characterised and classified on the basis of size, shape, and degree of distinctness.

SOIL SURVEY: The systematic examination , description, classification, and mapping of soils in an area.

SOIL TEXTURE: The relative proportions of the various soil separates in a soil.

SOIL TYPE: In mapping soils, a subdivision of a soil series based on differences in the texture of the A horizon.

SOIL WATER: A general term emphasising the physical rather than the chemical properties and behaviour of the soil solution.

STATUE LAW: Law laid down in acts of parliament.

STRESS (of a plant): Conditions in which there is a deficiency of water to meet the evapotranspiration needs of the plant.

SUSPENDED SOLIDS: This is also known as non-filtrable residue (NFR). Solids physically suspended in water, wastewater, or other liquids. The quantity of material deposited when a quantity of water, wastewater, or liquid is passed through a filter. Expressed as mg/L.

TAILWATER: Drainage water at the lower end of an irrigation bay or furrow.

TENSIOMETER: A device for measuring the negative hydraulic pressure (or tension) of water in soil in-situ; a porous, permeable ceramic cup connected through a tube to a manometer or vacuum gauge.

TENSION, SOIL WATER: The expression, in positive terms, of the negative hydraulic pressure of soil water.

TERTIARY TREATMENT: Tertiary treatment follows primary and secondary treatment and is used to reduce the BOD_5 or suspended solids concentration, remove bacteria or pathogens or remove nutrients.

THROUGH DRAINAGE: Drainage of water downwards past the root zone.

TOPSOIL: (1) The layer of soil moved in cultivation. (2) The A horizon. (3) The A1 horizon. (4) Presumably fertile soil material used to topdress roadbanks, gardens, and lawns.

TOTAL KJELDAHL NITROGEN (TKN): An analytical method for determining total organic nitrogen and ammonia.

TOTAL NITROGEN: Comprises all forms of nitrogen which exists as either organic, soluble, attached (nitrate) or ammonium nitrogen.

TOTAL PHOSPHORUS: Comprises all forms of phosphorus which exists as either organic, soluble or attached phosphorus.

TOTAL SOLIDS: The solids in water, wastewater, or other liquids; includes suspended (non-filtrable) and dissolved (filtrable) solids; all material remaining as residue after water has evaporated. Expressed as mg/L.

TRANSECT: An arbitrary line or cross-section along which a soil is tested, at various intervals, to determine soil properties along that line.

VIRUS: A microscopic, noncellular particle that is composed of only genetic coding material (ie DNA). It is parasitic and reproduces only within a host cell. Viruses are more difficult to deactivate than bacteria.

VOLATILISATION: A complex process involving chemical and biological reactions in the soil and physical transport of nitrogen out of the soil. Nitrogen is lost to the atmosphere as ammonia (NH_3).

WASTE: Includes any matter whether liquid, solid, gaseous or radioactive, which is discharged, emitted or deposited in the environment in such volume, constituency or manner as to cause alteration to the environment.

WASTEWATER: Water which is collected and transported to a treatment plant (often by the sewer). Wastewater normally includes water from both domestic and industrial sources.

WATER HOLDING CAPACITY: The difference between the field capacity and the permanent wilting point.

WATERTABLE: That level in saturated soil where the hydraulic pressure is zero.

Ym: Maximum harvested yield for a high producing variety adapted to the given environment with growth factors not limited, expressed as kg or tonne/ha

B-9.3 Chemical Symbols

B	-	Boron
Be	-	Beryllium
C	-	Carbon
Ca	-	Calcium
Cd	-	Cadmium
Cl	-	Chlorine
Cr	-	Chromium
Cu	-	Copper
Fe	-	Iron
K	-	Potassium
Li	-	Lithium
Mg	-	Magnesium
Mn	-	Manganese
Mo	-	Molybdenum
N	-	Nitrogen
Ni	-	Nickel
Na	-	Sodium
NH_3	-	Ammonia
NH_4^+	-	Ammonium
NO_3-	-	Nitrate
NOX	-	Nitrite + nitrate
N_2	-	Di-nitrogen
N_2O	-	Nitrous Oxide
P	-	Phosphorus
Pb	-	Lead
S	-	Sulphur
Se	-	Selenium
Zn	-	Zinc

SECTION C:

APPENDICES

CONTENTS

APPENDIX C-1

ENVIRONMENTAL REGULATIONS AND GUIDELINES

CONTENTS

C-1.1 Principles

C-1.1.1 Introduction

Wastewater reuse offers substantial benefits and enjoys considerable community support as a "good thing". However wastewater reuse is not without risks to the environment as well as public health. In the case of abattoir effluent reuse, the major risks arise from the threat of:

- soil degradation from increased salinity,
- soil structure decline,
- change to the watertable,
- contamination of groundwater and/or surface water from phosphorus and nitrogen,
- public health risks from pathogens,
- unacceptable odours,
- concentration of residues in food and animals.

The environmental and public health risks associated with wastewater re-use raises a variety of legal issues for the **producers** of the wastewater and the **owners** and **occupiers** on whose land wastewater is reused. In many situations the abattoir does not own the land on which the effluent is being reused. In those circumstances it is essential that the abattoir manager has a clear understanding of which parties have what responsibility relating to environmental and public health matters. **The fact that a contract has been entered into with a landholder to take the effluent does not mean that the abattoir has no residual responsibility.**

This chapter sets out the general principles which have a bearing on management of abattoir effluent. It summarises the range of:

- legal and administrative measures that regulate wastewater re-use,
- the approvals which need to be held in order to operate or establish a wastewater reuse scheme,
- the potential legal liability of owners and occupiers of land for environmental and public health problems associated with wastewater re-use.

The purpose of this chapter is to set out the general principles. Subsequent chapters deal with the detailed requirements in each State.

C-1.1.2 Legal Instruments

The re-use of wastewater is regulated by a complex set of rules and requirements put forward by State Parliaments, statutory authorities, local authorities and the Courts. These rules consist of:

- decisions by Courts (the so called "common law") which set precedents that must be followed,
- legislation comprising statutes enacted by the Parliament, regulations and policies approved by the government and local laws adopted by local authorities,
- non-binding guidelines, policies and codes of practice adopted by decision makers to assist in the application of legislative requirements.

C-1.1.2.1 The Common Law

The common law recognises a number of civil wrongs (as opposed to criminal wrongs), other than a breach of contract, which the law will address with damages or by the granting of an injunction.

The common law now recognises 4 types of "wrongs" - negligence, nuisance, trespass, and breach of statutory duty.

Negligence - where a person has suffered damage as a result of a breach of a duty of care owed to that person. The duty of care may arise from generally accepted community standards, not just through a specific direct contractual obligation.

Nuisance - where the use of land causes an unreasonable and substantial interference with a person's use or enjoyment of the land (private nuisance) or the right of the public at large to health, safety, property and quality of environment (public nuisance).

Trespass - where there has been direct interference with a person, their land or goods by any person, object or substance under the control of the defendant. For example it has been found by the Courts that sewage deposited on a person's land, as a result of the natural flow of a river, constitutes a trespass.

Breach of Statutory Duty - where the plaintiff has suffered damage as a result of the breach of a statutory obligation imposed on the defendant and which was intended by the Parliament to give rise to a civil action for damages.

It can be seen that the common law is very much concerned with the maintenance of private property or interests. Apart from the doctrine of public nuisance, the common law does not take into account the wider public interest of fostering principles such as environmental protection or ecologically sustainable development. The application of the common law doctrine to so called "toxic tort disputes", that is cases involving the release of toxic chemicals into the environment, is also limited by the distinctive characteristics which distinguish a "toxic tort" from other types of injury associated with the law's traditional experience in the field of torts. For example:

- injury resulting from genetic or biochemical disruption may develop without identifiable prior traumatic events,
- the time between exposure to a toxic chemical and the expression of the injury may be long, sometimes up to 20 years or more, thereby giving rise to problems of commencing proceedings within time limits imposed by the various State's Limitation of Actions Acts as well as the problem of tracing the source of the disease to exposure to a specific toxic chemical,
- injury resulting from chronic and repeated exposure to a chemical rather than acute exposure can only be established through epidemiological studies, the success of which is dependent on the nature of the available data,
- proof that a chemical is harmful often requires scientific evidence associated with biological causation which is on the frontiers of science and which, in many cases, may only show that exposure to the chemical increases the risk that the plaintiff would contract the disease.

As a result of these difficulties, governments have played a major role in formulating policies and programs in respect of wastewater and implementing these through legislative activity.

C-1.1.2.2. Legislation

Commonwealth, State and Local governments have all introduced legislation to control the reuse of wastewater. Unfortunately, no one piece of legislation deals specifically with wastewater reuse. Consequently, regard must be had to the myriad of statutes, regulations and local laws which regulate, amongst other things, various aspects of wastewater reuse.

Commonwealth legislation is generally of no practical significance as its application is limited to land or water over which the Commonwealth has jurisdiction. This will be the case where an approval is required from the Commonwealth, such as an export or foreign investment approval or where the wastewater scheme is to be established on land or water owned or under the control of the Commonwealth.

Laws adopted by local authorities are of greater practical significance as they are generally applicable to all developments involving the reuse of wastewater. In all cases, it is necessary to consult the laws adopted by the local authority in which a wastewater reuse scheme is being proposed.

Of greater practical significance for reuse of abattoir effluent is State legislation which imposes regulations in respect of the establishment and operation of wastewater reuse schemes. This legislation can be divided into the following general categories:

- **Development** - various instruments which control development of building, sewerage and water supply matters,
- **Pollution** - controls on water pollution, odour, hazard chemicals and land contamination,
- **Conservation** - various acts which control soil degradation and environmental harm,
- **Public Health** - controls on the sale of food, limits on pesticide residues in foodstuffs, chemical residues in stock and the public health risks associated with sewage.

C-1.1.2.3 Policies

The application of legislation is generally supported by various non-binding policies, codes of practice and guidelines. Details of such policies and guidelines for each State are listed in later chapters.

Relevant guidelines prepared at the national level include:

- Guidelines for Drinking Water Quality in Australia, National Health and Medical Research Council, 1987,
- Guidelines for the Re-use of Reclaimed Water in Australia, National Health and Medical Research Council, 1987,
- Australian Guidelines for Recreational Use of Water, National Health and Medical Research Council, 1989,
- Draft National Water Quality Guidelines, Australian and New Zealand Environment Council, 1990,
- Draft Guidelines for Sewerage Systems and Effluent Management, Australian and New Zealand Environment and Conservation Council, and Australian Water Resources Council, 1992,
- Australian Water Quality Guidelines for Fresh and Marine Waters, Australian and New Zealand Environment and Conservation Council, 1992.

C-1.1.3 Approvals Process

The establishment and operation of wastewater reuse schemes is not regulated by one piece of legislation in any State or Territory. Rather, the approvals process involves the application of a large number of statutes and decision making bodies. In simple terms, a wastewater reuse scheme may require the approval of the relevant local authorities, State Departments and State Agencies responsible for:

- Environmental Protection
- Agriculture
- Public Health
- Health and Safety
- Land Management

C-1.1.4 Potential Legal Liability

Land owners and public authorities may be exposed to potential legal liability as a result of the implementation of wastewater reuse schemes. This liability may arise under both legislation and the common law.

The legislation generally imposes strict legal liabilities on land owners and occupiers in relation to:

- **land contamination**, by persistent chemicals such as heavy metals or pesticides, may require the occupier to undertake remedial action,
- **soil degradation**, which might take the form of erosion of a degraded soil structure, may require remedial action by the user of the land,
- **water pollution**, which may take the form of nitrogen in groundwater or phosphorus in surface water,
- **odour**, which might by prohibited under clean air or public health regulations,
- **chemical residue** build-up in plants and animals,
- **public health** matters associated with pathogens,
- general **environmental harm**,
- **breach** of conditions set down in approvals and licences.

Generally speaking, this liability is of a **criminal nature** with legislation imposing various offences and penalties in respect of various environmental and public health risks associated with wastewater re-use schemes.

C-1.2 New South Wales

C-1.2.1 Environmental Protection Authority

The NSW Environmental Protection Authority has prime responsibility for environmental legislation which may affect the operation of systems which reuse abattoir effluent. The requirement to obtain the approval of the Environment Protection Authority will arise in a number of ways:

- premises to which waste (solid and liquid) is transported for treatment, storage and disposal must be registered pursuant to the Waste Disposal Act 1970 (Section 22(1)),
- the installation, construction or modification of any apparatus, equipment or works required for the storage, treatment or disposal of wastewater other than from a single household must be authorised by a pollution control approval under the Clean Waters Act, 1970, and the Pollution Control Act, 1970, (Section 19),
- a re-use scheme which is, or is likely to pollute any waters, must be licensed pursuant to the Clean Waters Act, 1970 (Section 16).

The requirement to obtain a licence under the Clean Waters Act, 1970, in respect of water pollution is very wide. Pollution is defined to include anything providing a change in the physical, chemical or geological composition of waters (Chapter B-5). Moreover, the pollutant does not have to be discharged directly into the waters. It is sufficient for the pollutant to be put into a position from which it ends up in the water or is likely to do so (Section 16(2)). The Land and Environment Court has held that pollution is likely to end up in the waters if there is a real possibility that this will occur (*State Pollution Control Commission v Blayney Abattoirs Pty Ltd*, 1991) (72 LGRA 221). The environmental risks normally associated with re-use schemes, such as infiltration of nutrients to groundwater or runoff of phosphorus to surface waters, means that almost all reuse schemes will have to be licensed under the Clean Waters Act, 1970.

C-1.2.1.1 Pollution Control Act, 1970

This Act coordinates the issuing of licences and approvals by the Environment Protection Authority. The Act also provides for other purposes including requirements such as power of entry, furnishing and disclosure of information.

Pollution Control Approval

It is necessary for approval under section 17K of the Pollution Control Act, 1970, to construct or install:

- an abattoir (required by section 19 of the Clean Waters Act, 1970), or
- fuel burning equipment that is scheduled under the Clean Air Act, 1961 (required by Section 16 of the Clean Air Act, 1961).

The EPA in considering the application for pollution control approval makes an assessment of the adequacy of the controls proposed, including:

- the comprehensiveness of pollution controls and environment protection,
- the performance claims of equipment/controls against limits set by Act, regulation or guideline limits set for specific development,
- ability of proposed controls to meet performance claims.

For major developments that may take several years to construct, the EPA may give a staged approval, covering the initial construction phase, and requiring further approvals as the project proceeds.

Pollution Control Licences

The EPA, under section 17D of the Pollution Control Act, 1970, licences abattoirs (where required by Section 10 of the Clean Air Act, 1961) and on application will licence abattoirs for the application of wastes to land (in relation to Section 16 of the Clean Waters Act, 1970).

C-1.2.1.2 Clean Waters Act, 1970

The Clean Waters Act and its regulations are designed to control pollution in rivers, streams, lakes, lagoons, natural and artificial watercourses (including swamps and wetlands), dams, tidal waters (including estuaries, oceans, beaches, saltwater drains and the sea) and underground waters.

Its principal control provisions are:

- to require any person who is responsible for land, on which there is a drain, to hold a licence issued by the Authority if the drain discharges or is likely to be used for discharging pollutants into waters,

- to prohibit any person from discharging wastes to waters other than in accordance with the conditions contained in such a licence issued by the EPA,
- to prohibit any person from installing or constructing any apparatus, equipment or works, for the treatment or storage of certain wastes, from discharging pollutants into waters, unless that person has the approval, in writing, of the EPA and complies with any conditions to the approval.

Section 16 makes it an offence to pollute waters unless the polluter holds a licence and does not breach any licence condition. Any person may apply for a licence. In practice, anyone who irrigates effluent or constructs effluent holding ponds needs a licence unless they happen to be in a flood free location, devoid of groundwater strata, and kilometres from permanent surface water.

Section 19 requires that approval, in writing, must be sought for the installation, construction or modification of any apparatus, equipment or works for discharging of pollutants into any waters; the treatment of pollutants prior to, and for the discharge of pollutants into waters; or the storage, treatment or disposal in a prescribed manner or in prescribed circumstances of matter in a prescribed class or description.

Regulation 11A prescribes, for the purposes of Section 19, any process or operation carried on in connection with any trade or industry. This would include abattoirs.

C-1.2.1.3 Environmental Offences and Penalties Act, 1989

The Act strengthens existing legislation by providing for much higher penalties where environmental harm has been caused.

The Act also provides for the issuing of Penalty Notices for various minor offences, and for clean-up and cost recovery.

C-1.2.1.4 Notices and Orders

If, in the course of investigation of pollution or inspection of premises, EPA officers uncover problems, they may issue a notice of order under the pollution control acts (for example, Regulation 21 of the Clean Waters Act, 1970, and Section 20 of the Clean Air Act, 1961) to install equipment, take certain preventative measures or undertake measurements.

C-1.2.2 Health Department

The approval of the Health Department will be required where crops are being grown on land subject to wastewater re-use. The Food Standards (Adoption) Regulation, 1989 (made under the Food Act, 1989), adopts the food standards code which provides for maximum pesticide residue limits at the point of sale.

C-1.2.3 NSW Agriculture

The approval of the NSW Agriculture will be required in certain circumstances:

- where stock are to be grazed on land subject to wastewater re-use, the Stock (Chemical Residues) Act, 1975, empowers the Minister to restrict or absolutely prohibit the grazing of residue affected land by stock; and
- where crops are being grown on land subject to wastewater re-use, the Pesticides Act, 1978, provides that certain food items containing prohibited residues can be prevented from becoming available for sale.

C-1.2.4 Workcover Authority

As with all other workplaces, the approval of the Workcover Authority will also have to be obtained. The Occupational Health & Safety Act requires employers to maintain, as far as reasonably practical, the place of work in a condition which is safe and without risk to health. There is also a general duty on employers to protect the health and safety of the general public who may be affected by work activities.

C-1.2.5 Local Authority Approvals

The need for local authority approval may arise in one of three ways:

- the relevant local environmental plan, development control plan or regional environmental plan may require a development consent to be obtained or modified, pursuant to the Environmental Planning and Assessment Act, 1979,
- building, sewerage and water supply works will have to be approved pursuant to the Local Government Act, 1993,

- a licence may also have to be obtained in respect of the scheme pursuant to the applicable local law.

Where the wastewater re-use scheme is itself the primary purpose of the proposed development, the scheme will be a designated development. Under Schedule 3 of the Environmental Planning and Assessment Regulation, 1980, waste works processing, recovering or disposing of liquid chemical, oil or petroleum waste products is a designated development. As a result, an environmental impact statement must accompany the application for development consent for this type of development. Public notice is required to be given and members of the public are entitled to object and appeal to the Land and Environment Court if the public authority grants consent.

C-1.2.6 Policies

A number of guidelines have been prepared in New South Wales in respect to wastewater reuse and disposal. Many of these focus primarily on the reuse of domestic wastewater and therefore deal with public health issues which are not necessarily of concern to abattoirs. However, many of the guidelines contain reference to issues such as pollution control, soil degradation and groundwater quality which are common to reuse of effluent from any source. These guidelines include:

- Water Conservation by Reuse - Guidelines for the Use of Recycled Water in New South Wales (Environmental Design Guide WP - 7), State Pollution Control Commission, 1987,
- Reuse of Treated Wastewater by Land Application (Environmental Design Guide WP - 8), State Pollution Control Commission, 1988,
- Landfill Disposal of Industrial Wastes (Environmental Guideline), State Pollution Control Commission, 1989,
- Guidelines for the Use of Sewage Sludge on Agricultural Land, New South Wales Agriculture, 1989,
- Guidelines for the Utilisation of Treated Wastewater on Land (Draft), Environment Protection Authority, 1992,
- Environmental Guidelines for the Discharge of Wastewater to Ocean Waters, Environment Protection Authority, 1993,
- New South Wales Guidelines for Urban and

Residential Use of Reclaimed Water, New South Wales Recycled Water Co-ordination Committee, 1993.

These guidelines are of particular relevance in the licensing of wastewater reuse schemes by State government bodies. However, of greater relevance at the local authority level, are the various policies and codes of practice which support each local authority's local environmental plan, development control plans and other local laws. Matters such as land contamination and sewage disposal may be the subject of such policies.

C-1.2.7 References

Clean Air Act, 1961

Clean Waters Act, 1970

Environmental Offences and Penalties Act, 1989

Environmental Planning and Assessment Act, 1979

Environmental Planning and Assessment Regulation, 1980

Food Act, 1989

Food Standards (Adoption) Regulation, 1989

Local Government Act, 1993

Occupational Health & Safely Act

Pesticides Act, 1978

Pollution Control Act, 1970

SPCC v Blayney Abattoirs Pty Ltd, 1991

Stock (Chemical Residues) Act, 1975

Waste Disposal Act, 1970

C-1.3. Northern Territory

The legislative environment in the Northern Territory is quite complex, with several agencies all being closely involved in project development. The complexity appears to have arisen from the combined and superimposed historic influences of Commonwealth and State Legislation. The current legislation is, however, controlled at State Government level. The first point of contact for any abattoir development or expansion in the Northern Territory is the Department of Lands and Housing.

C-1.3.1 Permits and Licences

The agencies involved, the Acts under which they operate, relevant subsidiary regulations, the controls they impose, and their monitoring and reporting requirements are summarised in Table C-1.1.

In the Northern Territory, environmental issues relating to an abattoir site are determined primarily by the location of the operation. Thus, the Department of Lands and Housing is the key agency as it determines regional land zoning, appropriate local land-uses, etc. Only after siting issues, in the broad sense, have been considered are the environmental and health aspects considered.

A new operation or a major expansion of an existing operation would require an Environmental Impact Statement which would include commitments by the Proponent. These commitments would be incorporated into Licence Conditions, together with any additional special conditions which might be required by other government agencies. A Licence to Discharge may also be required, as might some special licences required by Local Government Authorities.

Reports on environmental monitoring (mainly water-related issues) are required on a monthly basis by the Power and Water Authority. There are no other formal monitoring or reporting requirements although, as mentioned above, there may be special conditions set on a site-by-site basis. The Conservation Commission, for example, may require special monitoring. If this is so, the requirement would be imposed through a condition set by the Power and Water Authority. The Power and Water Authority carries out independent monitoring to audit the operator, and the Local Government Authorities may also monitor in some cases.

C-1.3.2 Pollution Control Requirements

Discharge into any surface water body is prohibited in the Northern Territory unless special permits are issued. As a general rule, all effluent water must be retained on site. Groundwater contamination is monitored on an as-required basis by the Power and Water Authority and special requirements and conditions may be imposed. Odour is dealt with on a complaints basis. Public health issues are managed by means of the normal hygiene requirements set by the Department of Health and Community Services.

C-1.3.3 Planning New or Enlarged Facilities

Any new facility or major enlargement of an existing facility would require an Environmental Impact Assessment to be prepared. This would be scrutinised by all relevant government agencies and would be available for public review.

C-1.3.4 Trends and Initiatives

The Abattoirs and Slaughtering Act, 1955, is out of date and is to be replaced by a "Meat Industries Act" which is expected to come into operation in 1994 or 1995. A Codes of Practice Manual will also be released at that time. It is believed the new Act will not include any significant legislative changes for sheep and cattle abattoirs, but the revision is primarily to include some special situations such as crocodile slaughter-houses.

The Planning Act, Northern Territory of Australia (1990) is also under review, but no changes are foreseen which will affect abattoirs .

C-1.3.5 References

Abattoirs and Slaughtering Act, 1955

Environmental Assessment Act, 1982 (under the Conservation Commission Act, 1980)

Planning Act, Northern Territory of Australia, 1990

Public Health Act, 1955

Water Act, 1992

Water Supply and Sewage Act (Trade Waste)

TABLE C-1.1
LEGISLATION AFFECTING ABATTOIR EFFLUENT DISPOSAL: NORTHERN TERRITORY - Page 1

AGENCY	OPERATIONAL ACT	RELEVANT SUBSIDIARY REGULATIONS	CONTROLS IMPOSED	MONITORING AND REPORTING REQUIREMENTS
Department of Health and Community Services	Public Health Act 1955	Public Health Nuisance Regulations Noxious Trades Regulations	The site of waste disposal and any public health and safety issues are key considerations. Also examines odour management and water quality of both surface and ground water.	No formal requirements but conditions may be imposed by Chief Medical Officer in some circumstances.
Power and Water Authority (PWA)	Water Act 1992	Trade Waste Regulations	If area of impact is outside the sewer catchment then it comes directly under the Water Act 1992; Conservation Commission, Lands and Housing, etc. then become involved. General condition is that all water must be retained on-site. Trade Waste Regulations only apply in Water and Sewage Districts where waste is to enter sewer. A licence to discharge is required, and, with new operations, an Environmental Impact Statement.	Monitoring of sewers is carried out by PWA under a program agreed with the plant operator. If no problems then there is no cost to the operator. If there is a problem then the operator pays for all further monitoring until problem is fixed. Reporting frequency usually monthly by PWA and/or operator. PWA tests groundwater quality periodically.
Department of Lands and Housing	Planning Act, Northern Territory of Australia 1990 (as Amended)	None. Entire Act is presently under review (probable release 1994) but no changes affecting abattoirs are foreseen.	Land zoning and abattoir siting requirements. Abattoirs are only permitted in areas designated as "Industrial 3: Offensive and Hazardous Industries". This Department is first point of contact for all abattoir developments.	There are no monitoring or reporting requirements, but the Department would refer applications for new abattoirs or extensions to the other agencies listed here and they may set monitoring requirements.

TABLE C-1.1
LEGISLATION AFFECTING ABATTOIR EFFLUENT DISPOSAL: NORTHERN TERRITORY - Page 2

AGENCY	OPERATIONAL ACT	RELEVANT SUBSIDIARY REGULATIONS	CONTROLS IMPOSED	MONITORING AND REPORTING REQUIREMENTS
Department of Primary Industry and Fisheries	Abattoirs and Slaughtering Act 1955	Current Act and Regulations is completely out of date and does not cover new activities such as crocodile abattoirs. A new Act, to be called the Meat Industries Act, is in preparation and will be ready late 1994 or early 1995. A Codes of Practice manual is also in preparation.	Conditions on new or expanded plants may be imposed, if required. The Department has considerable input to newly proposed abattoirs, especially in respect to offal disposal and to a lesser extent liquid waste disposal. Small abattoirs can dispose of water by spray irrigation; large ones must have holding evaporation ponds.	None, but conditions could be imposed. This situation is not expected to change under the new Act.
Conservation Commission of the Northern Territory (Environmental Unit).	Environmental Assessment Act 1982 applied under the Conservation Commission Act 1980	None, but Acts apply primarily to the impact of new plants or major extensions to existing plants. The Conservation Commission would make recommendations to other government agencies such as Department of Lands and Housing, Primary Industry and Fisheries and Department of Public Health. These agencies would then apply the conditions. Specific legislation on pollution and waste disposal is presently being drafted by the Commission.	Controls would be imposed through conditions imposed by other Decision Making Authorities, not directly by the Conservation Commission.	None, but conditions could be requested by the Conservation Commission and imposed through the other Decision Making Authorities. An Environmental Approval may have separate conditions applied in the case of a new or expanded plant.
Local Government Authorities (LGAs)	Numerous LGA Regulations and local By-laws	By-laws in some cases	Regulations affecting pipelines, ponds, methods of disposal, etc. All vary according to local environmental conditions, land zoning and LGA requirements.	Generally none, but may be imposed as licence or approval conditions.

C-1.4. Queensland

C-1.4.1 Overview

The licences, permits or approvals for land disposal of abattoir effluent can vary from, only approval by local government to several licences depending upon the location, scale of the project and degree of pre-treatment of effluent. A study of environmental impacts may be called for before licences are issued.

The requirements to hold licences to restrict release of substances into the environment is about to change in Queensland. The proposed Environmental Protection Bill will allow a single licence to be issued to premises to replace multiple licences that may be required under different current legislation. Meatworks are listed on the draft schedule as an activity requiring a licence from the Department of Environment and Heritage. The Bill was scheduled to be gazetted in mid 1994.

The current legislation that may relate to land disposal of abattoir effluent is listed below (Table C-1.2) and is followed by more detailed comments.

TABLE C-1.2
LEGISLATION AFFECTING ABATTOIR EFFLUENT DISPOSAL: QUEENSLAND

LEGISLATION*	RESPONSIBLE AUTHORITY	REQUIREMENTS	COMMENTS
Clean Waters Act 1990	Department of Environment and Heritage	Licence to discharge or overflow into waterways	Requirement for a licence is determined on site specific grounds; should not be required for a well managed site
Water Resources Act 1989	Department of Primary Industries	Licence to construct referrable water storages	A licence is required if a storage is large or contains a referrable substance; should be required for a well managed site
Clean Air Act 1963	Department of Environment and Heritage	No legal requirements	Odour guidelines to be released imminently
Local Government (Planning & Environment) Act 1990	Department of Housing & Local Government	Impact assessment report may be called	Impact assessment report may be called
Contaminated Land Act 1991	Department of Environment and Heritage	Duty of disclosure; duty not to intentionally contaminate	Holder to be held responsible for contamination even after sale
Environmental Protection Bill	Department of Environment and Heritage	Licence to be held as per draft schedule of relevant activities	New legislation to supersede existing environmental legislation;
Health Act 1937	Department of Health	No legal requirements	Wish to be advised for public health
Local Authority by-laws	Local Government	Various	Approval required; conditions will vary from council to council

*Great Barrier Reef Marine Park Act 1975 would apply where the possibility of effluent discharge to the waters of the reef existed.

C-1.4.2 Local Government

The statutory requirements for abattoir effluent disposal begin with the local government. The land must be zoned appropriately for such use and approval held from the local government. Compliance with by-laws and regulations covering the development will be required. Approvals for such a land use may include further site specific conditions, but more commonly the land use will be approved subject to complying with other Acts (the Clean Waters Act, 1990, for example).

Buffer zones should exist between the disposal site and future development areas. This will be considered by the local government as part of the approvals process.

Where storages are to be constructed, control of mosquito larvae may be required where mosquito-borne diseases are prevalent and control of weeds (for example hyacinth and salvinia) would be required.

The local authority should be contacted first to discuss requirements for land disposal of effluent.

C-1.4.3 State Legislation

Environmental Protection Bill - Draft
(Department of Environment and Heritage)

This Bill will replace several pieces of environmental legislation and may be gazetted mid 1994. Scheduled "environmentally relevant activities" will require either a licence or approval from the proposed administering authority. Meatworks are listed on the draft schedule as an activity requiring a licence from the Department of Environment and Heritage. Land disposal of effluent on land, other than that owned by the abattoir, is not listed. However, at this time, it may be considered that an approval from the local government will be required, and, in some instances, a licence may be required.

The Bill is in draft form at the moment and the following description may change. Licences will need to be applied for by the person or business proposing to undertake any environmentally relevant activity. Standard licences will be developed for consistency across all local authority areas. Three grades of licences will be offered with fees increasing depending upon the environmental performance. A single licence relating to all relevant environmental impacts will be offered. Licence conditions will be publicly available.

Clean Waters Act, 1990
(Department of Environment and Heritage)

Where discharge to any waters as defined in the Clean Waters Act is proposed, a licence for such a discharge must be obtained from the Department of Environment and Heritage. This is prescribed under Section 23 of the Clean Waters Act. This licence will set out the conditions which are to apply to the discharge. Applications should be addressed to the Manager, Operations Branch, Division of Environment for your local area.

Where land disposal is proposed, it is necessary to formally advise the Department of Environment and Heritage of the proposal and obtain confirmation that land disposal complies with the requirements of the Clean Waters Act. An application may need to be supported by a full impact assessment study. If so, the Department of Environment and Heritage will direct accordingly. Impact studies have been increasingly required by Department of Environment and Heritage for the determination of licence requirements.

In general, a well managed scheme should not require a licence i.e. discharge should not be planned to occur. However, it is unlikely that land disposal can remove the total effluent volume unless storage facilities are constructed for total containment through rain periods. If these dams are managed such that overflow is contained for a design storm of at least a 1 in 10 year, 72 hour storm event or greater, as determined for each specific location, an overflow licence would not be required. The design storm volume is the total runoff expected from the design storm assuming any diversions are operating.

In the event that a licence is required, the Department of Environment and Heritage will advise on the data required to evaluate licence conditions. In general, effluent standards for discharge to natural waters give consideration to:

- the quality and dilution available in the receiving waters,
- possible effects on the receiving environment,
- current and future requirements for effluent disposal to these waters, and the uses made of the receiving waters.

Standards adopted by the Department of Environment and Heritage are that the biochemical oxygen demand determined over 5 days (BOD_5) is not to exceed 20 mg/L, and suspended solids (SS) is not to exceed 30 mg/L. More stringent conditions may apply depending upon location.

Sampling points and monitoring requirements will be contained within the licence.

Conjugate methods of disposal may be recommended where effluent is applied to land during dry conditions, stored in a designed pond during rain, and discharged to a stream when heavy rain occurs.

Water Resources Act, 1989
(Department of Primary Industries)

Storages constructed to contain effluent are not normally of sufficient size to warrant licensing under the Water Resources Act, that is, a dam wall that is 10 metres or more in height and creates a reservoir capacity of more than 20,000 m^3, or a dam wall that is 5 metres or more in height and creates a reservoir capacity of more than 50,000 m^3, or works that contain a hazardous substance. In general, effluent deemed hazardous would not be considered appropriate for irrigation disposal.

Land disposal of effluent can proceed in a designated groundwater recharge area if subsurface drainage is controlled. The Department of Primary Industries should be advised.

Great Barrier Reef Marine Park Act, 1975
(Great Barrier Reef Marine Park Authority)

The Authority is concerned about the long-term build-up of nitrogen and phosphorus from discharges. The Authority recommends land disposal of nutrient rich waters, however discharges from storages may require treatments for nutrient removal if the waters discharge into or can move into the Marine Park.

Clean Air Act, 1963
(Department of Environment and Heritage)

There are no statutory standards for odour in Queensland. Guidelines are currently being formulated and may be publicly available by May 1994. Irrigation waters should not contain untreated blood or organic residue that can lead to purification.

Local Government (Planning & Environment) Act, 1990
(Department of Housing & Local Government & Planning)

An impact assessment report may be called for depending upon the location and size of the project.

Contaminated Land Act, 1991
(Department of Environment and Heritage)

The Contaminated Land Act cannot prohibit an activity nor is a licence required. The Act carries a duty of disclosure of activities that contaminate land with hazardous material. There is also a duty not to intentionally contaminate land. A site evaluation may be required upon decommissioning of the site depending upon the quality of water used and the duration of operations. The consequences of contamination remain the responsibility of the organisation or individual who caused the contamination even after sale of the land.

It is recommended that a site evaluation be conducted before irrigation use commences to provide a comparative baseline for the impact of irrigation.

Health Act, 1937
(Department of Health)

There are no legal approvals which the Department of Health would require for land disposal of effluent. Nevertheless, the Department would wish to be advised of such uses. The Department may require control of mosquitoes in areas where mosquito-borne diseases are prevalent.

C-1.4.4 Guidelines

Guidelines specifically for land disposal of abattoir effluent are not available in Queensland. Section 18 of "Guidelines for the Planning and Design of Sewerage Schemes", Volume 2, Department of Primary Industries, Water Resources Commission, discusses land disposal of sewerage effluent. These guidelines can be used for other effluent when differences in quality are taken into account.

Guidelines for assessing storm allowances of storages are addressed in "Guidelines on Prevention of Water Pollution from Cyanide Use in Gold Ore Processing", Department of Environment and Heritage. Although the risk factors are **not** relevant, the method of calculating design allowances for different areas of Queensland are relevant.

Simplified methods to assess irrigation usage and volumes of effluent are addressed in "Queensland Government Guidelines for Establishment and Operation of Cattle Feedlots", Queensland Department of Primary Industries, and "Guidelines for the Use of Treated Sewerage for Agricultural Irrigation and Recreational Areas and Impoundment", Water Quality Committee Queensland, 1977.

C-1.4.5 Standards

The minimum compulsory standards, adopted by the Department of Environment and Heritage, for water discharging into Queensland waterways, are that the biochemical oxygen demand determined over 5 days (BOD_5) is not to exceed 20 mg/L, and suspended solids (SS) is not to exceed 30 mg/L.

More stringent conditions may apply depending upon location and these will be reflected in licence conditions.

General standards appropriate for a range of downstream water uses may be found in "Australian Water Quality Guidelines for Fresh and Marine Waters", Australian and New Zealand Environment and Conservation Council, 1992.

C-1.4.6 Monitoring

Sampling methods should comply with Department of Environment and Heritage publication "Recommended Sampling / Preservation Techniques of Waters and Wastewaters", 1992.

Required sampling sites for water will be identified in any discharge licence issued by the Department of Environment and Heritage.

Recommended sampling should consist of simultaneous sampling of waters upstream and downstream of any discharge when any discharge occurs by either pumping or overland flow from the irrigation area.

Table C-1.3 shows additional recommended parameters for monitoring:

TABLE C-1.3
RECOMMENDED MONITORING OF PARAMETERS

PARAMETER	EFFLUENT	SURFACE WATER	GROUND WATER
pH	R	R	R
Salinity	R	R	R
Nitrate	-	-	R
Microbiological	R	-	R
SAR	R	-	-
Residual alkalinity	R	-	-
Parasite and virus	P	-	-
Organics	L	-	L
Heavy metals	L	-	-

R routine
P periodic
L long term

Dissolved oxygen and pH parameters are normally met if BOD and SS are met. Chemical Oxygen Demand may be used routinely for BOD, with care, as it is cheaper and quicker, especially to diagnose a problem.

Soil sampling should occur annually. Complete soil analysis for pH, salinity, and available levels of N, P, K, Ca, Mg and micronutrients should be conducted by a soils laboratory.

An assessment of parameters for contamination is presented in Table C-1.4 (Guidelines for the Assessment of Contaminated Land in Queensland issued by the Bureau of Emergency Services, 1992). Although there are various documented contaminant guideline values, it is recommended that the indicative guideline levels for contaminants reported in Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites issued by ANZECC and NHMRC (1992) be adopted.

TABLE C-1.4
SUBSTANCES SUBJECT TO CONTAMINATION

CONTAMINANT GROUP	SUBSTANCE
Metals	Cadmium
	Cobalt
	Chromium (Cr III)
	Chromium (Cr VI)
	Copper
	Mercury
	Nickel
	Lead
	Zinc
Inorganic Non-Metals	Arsenic
	Total Cyanide (free)
	Sulphur
	Sulphides
	Sulphates
Organics	Total Hydrocarbons
	Benzene, Ethyl benzene, Toluene, Xylene
	Total polycyclic aromatic hydrocarbons
Others	pH
	Polychlorinated biphenyls

C-1.4.7 Procedures for New Sites

The following general procedures should be followed when proposing to establish a new effluent disposal facility:

- Formally apply to the local government for approval for land disposal of effluent at the nominated site. An impact assessment study may be called at this time,
- Where the land is not owned by the abattoir, it is advised to reach a legal agreement with the receiver of the effluent,
- Formally advise the Department of Environment and Heritage of the proposal for an assessment of the requirement for a discharge licence. An impact assessment study may be called at this time,
- Advise the Department of Primary Industries Water Resources if the proposal is in a designated catchment recharge area or if large storages are to be constructed.
- Advise the Department of Health of the proposal.

C-1.4.8 Effectiveness in Queensland

Land disposal of effluent should not be relied upon as the sole method of disposal in regions of high summer rainfall, in particular, south-east Queensland south of Bundaberg and north Queensland east of the Great Dividing Range. Western regions may also require occasional flushing of the soil with fresh water to remove salts.

General problems identified in the Guidelines for the Planning and Design of Sewerage Schemes were:

a) areas characterised by high summer rainfall may not allow irrigation disposal all year round and additional effluent storage may be required,

b) salinity and other soil chemical problems may be created where regular flushing of the soil by rain does not occur,

c) application rates depend upon nutrient uptake rates by plants and native vegetation is characterised by low uptake rates,

d) over-watering and nutrient enrichment may occur more easily in western Queensland.

C-1.4.9 References

Australian and New Zealand Guidelines for the Assessment and Management of Contamination Sites

Australian Water Quality Guidelines for Fresh and Marine Waters, 1992

Clear Air Act, 1963

Clean Waters Act, 1990

Contaminated Land Act, 1991

Environmental Protection Bill

Great Barrier Reef Marine Park Act, 1975

Guidelines for the Assessment of Contaminated Land in Queensland, 1992

Guidelines for the Planning and Design of Sewerage Schemes, Volume 2

Guidelines for the Use of Treated Sewerage for Agricultural Irrigation and Recreational Areas and Impoundment, 1977

Guidelines on Prevention of Water Pollution from Cyanide Use in Gold Ore Processing

Health Act, 1937

Local Government (Planning & Environment) Act, 1990

Queensland Government Guidelines for Establishment and Operation of Cattle Feedlots

Recommended Sampling/Preservation Techniques of Waters and Wastewaters, 1992

Water Resources Act, 1989

C-1.5 South Australia

C-1.5.1 Background

Environmental management and regulation in South Australia has been undertaken under a number of different Acts. Hence pollution control has been enforced by a range of government authorities with responsibilities for a range of issues relating to land disposal of abattoir effluent (such as pollution discharge, odour, noise, nuisance, etc). A new *Environment Protection Act*, 1993, removes the majority of these duplications, however, it is not yet formally in operation. The Act will be administered by the South Australian Environmental Protection Authority.

The Act provides a range of measures to ensure the protection of the environment, including:

- works approval - required prior to building or modifying works at which an activity of environmental significance is carried out,
- orders - mandatory standards, limits or prohibitions,
- policies - including guidelines and codes of practice,
- a licensing system - for activities of environmental significance,
- general duty - for the bulk of activities that are not licensed, where a person is required to take all reasonable and practical measures to minimise harm.

Other government authorities such as the Health Department and local councils have responsibility for dealing with nuisance and public health.

C-1.5.2 Pollution Control Requirements

Being an industry that produces prescribed waste, an abattoir must obtain a licence under the *Waste Management Act*, 1987. The licence may include conditions requiring the licensee to store, treat or dispose of wastes produced in a specified manner. The Act also specifies that any person who collects or transports prescribed waste produced in the course of carrying out an industrial or commercial process, requires a licence to do so. The licence may include conditions which regulate the kinds of waste that are permitted or not permitted to be collected and transported by the holder of the licence. The licence may also regulate the kinds of receptacles and vehicles to be used by the licensee and the standards with which they must comply.

An abattoir is also considered a noxious trade and, therefore, requires a licence under the *Noxious Trades Act*, 1943-1965. The Act provides for the preparation of regulations in respect to the disposal of offal, garbage and effluent from premises licensed under the Act, the means to be taken to prevent or limit the emanation of offensive smells caused by the carrying out of any noxious trade and the sanitary rules to be observed in the carrying out of any noxious trade.

The Regulations under the *Noxious Trades Act*, 1943 -1965 further specify that any person carrying out a noxious trade shall, to the satisfaction of the Responsible Authority, effectively control or destroy all offensive vapour, gas, dust or effluvium arising from such trade or from any material residue or other substance. Any effluent fluids should be prevented from flowing into any watertable, creek, river or water supply unless it has been purified to the satisfaction of the local Water Board. Another requirement is that all waste matter is to be removed or disposed of at the end of each day.

The *Clean Air Act*, 1984, deals mainly with the regulation of air pollution caused from the carrying out of various activities, rather than odour or air pollution issues occurring in the transport or disposal of wastes. However, some general pollution control requirements should be mentioned. Occupiers of premises are not to cause or permit air pollution from their premises through the failure to maintain or operate equipment in a proper and efficient manner. Also, excessive odours must not be emitted from any premises. Odours are considered to be offensive if a complaint is made by a member of the public alleging that the odour is offensive or causes discomfort and if, in the opinion of an authorised officer, the odour is offensive or causes discomfort to a greater degree than members of the public would be reasonably expected to tolerate.

C-1.5.3 Planning Approvals for New or Enlarged Facilities

In relation to State and local planning regulations, the appropriate legislation is the *Development Approvals Act (SA)*, 1993. This Act came into effect on January 15, 1994. Prior to this Act , the *Planning Act (SA)*, 1982 was the relevant legislation. Under the new Act, all proposals for establishing abattoir operations require planning approval as there are no zones across the State in which abattoirs are as-of-right and where no consent is necessary. An application for planning approval is made to the local council.

In making an application for a permit to operate an abattoir, the following information would need to be provided:

- the size of the premises,
- the layout of the site,

- the intensity of the use eg. number of employees, car parking and scale of operation,
- a detailed explanation of the exact activities that will occur on site,
- methods of waste disposal,
- hours of operation.

Should an application to establish an abattoir be successful, a permit will be issued, allowing the user to commence. The permit may have conditions attached to it, specifying that all buildings and works require the consent of the planning authority. In most instances, the planning authority will be the local municipal council. Like Victoria and Tasmania, the extent and significance of the buildings and works will determine whether they can be treated as amended plans to the existing permit or whether a fresh application will need to be made.

The *Environment Protection Act*, 1993, when it comes into effect, will require that all proposed abattoirs obtain a licence before commencing operation. Similarly, all buildings and works will require a works approval. Therefore, both opening new abattoirs and enlarging existing premises will require approval under this Act, as well as under the *Development Approvals Act,* 1993.

C-1.5.4 Trends and Initiatives

A major regulatory change is currently underway in South Australia. New legislation titled the ***Environment Protection Act,* 1993** is anticipated to come into effect in May/June 1994. It will replace and consolidate many existing Acts including the *Noise Control Act*, the *Marine Environment Protection Act*, the *Waste Management Act* and parts of the *Water Resources Act*.

The legislation requires that no person undertake any activity that pollutes, or might pollute, the environment without firstly taking all reasonable and practicable measures to prevent or minimise the environmental damage.

It also contains a licensing and works approval system for activities of environmental significance. As is the case in Victoria presently, works approvals will be required prior to buildings or works being carried out for an activity which negatively affects the natural environment. Activities which will pollute the environment need to obtain a licence before they are permitted to operate. Conditions may be attached to licences which require some form of pollution monitoring and/or development of environmental improvement plans. The Act contains the provision to devise environment protection policies for various segments of the environment which may include particular controls or requirements (mandatory provisions) and policies that may be given effect to by the issuing of environment protection orders.

Also contained in the *Environment Protection Act* 1993 are special environment protection provisions. One of these provisions relates to water quality in water protection areas. The Act gives the Minister the authority to exercise certain powers necessary for the protection of the quality of surface or underground water within a water protection area.

Table C-1.5 summaries the legislation affecting abattoir effluent disposal. The table shows the agencies involved, the Acts under which they operate, the controls they impose, and their monitoring and reporting requirements.

C-1.5.5 References

Clean Air Act, 1984

Development Approvals Act, 1993

Environment Protection Act (S.A.), 1993

Marine Environment Protection Act

Noise Control Act

Noxious Trades Act Regulations

Noxious Trades Act (S.A.), 1943 - 1965

Planning Act, 1992

Waste Management Act Regulations, 1988

Waste Management Act (S.A.) 1987

Water Resources Act (S.A.), 1990

TABLE C-1.5
LEGISLATION AFFECTING ABATTOIR EFFLUENT DISPOSAL: SOUTH AUSTRALIA

AGENCY	OPERATIONAL ACT	CONTROLS	MONITORING AND REPORTING REQUIREMENTS
Environment Protection Authority Ph: (08) 204 2000	*Water Resources Act* 1990	A licence must be obtained to dispose of wastes. Information that must be provided includes the types of wastes to be disposed, the proposed quantities and the methods of disposal.	Monitoring and reporting requirements may be imposed as part of the licence.
Environment Protection Authority Ph: (08) 204 2000	*Waste Management Act* 1987 and Waste Management Act Regulations 1988	Being an industry in which prescribed wastes are produced, an abattoir must obtain a licence to operate under this Act. A licence is also required to collect or transport waste. Conditions may be attached to licences regarding the kinds of waste that are or are not to be transported and the vehicles or receptacles to be used and the standards with which they must comply. A person must not, without lawful authority, deposit waste so that it results or is likely to result in a nuisance or offensive condition, a risk to health or safety or damage to the environment.	It is an offence to contravene or fail to comply with any condition of a licence, the penalty being a $20,000 fine. Unlawful depositing of waste is an offence and is punishable by a $20,000 fine.
Department of Health Ph: (08) 226 6000	*Noxious Trades Act* 1943-1965 Noxious Trades Act Regulations	Being a noxious trade, a licence must be obtained under this Act to commence operation of an abattoir. All waste matter must be removed or disposed of at the end of each working day.	Operating a noxious trade without a licence constitutes an offence, incurring a penalty not exceeding $50 per day during which the trade is carried out. An officer of the local council given power to do so under the Act may, at any time, inspect the premises, and if necessary, require the premises to be kept in a sanitary condition.
Environment Protection Authority Ph: (08) 204 2000	*Environment Protection Act* 1993	**This Act is expected to come into operation in May/June 1994.** The Act will supersede many of the current pieces of legislation.	

C-1.6. Tasmania

C-1.6.1 Background

Tasmania, as with Victoria, has operated under an *Environment Protection Act* since 1973. This Act regulates noise emissions and waste discharges to land, water or air. It is enforced by the Department of Environment and Land Management in conjunction with the Environment Protection Advisory Council. In addition, local councils, the Inland Fisheries Commission, the Department of Health Services and the Rivers and Water Supply Commission all have varying responsibilities for enforcing other legislation relevant to waste management and pollution.

The regulations associated with the *Environment Protection Act*, relate to limits for the discharge of wastes to water, land and air, as well as noise, although they are not as comprehensive as the Victorian State Environment Protection Policy (SEPP) and regulations in setting specific standards for ambient criteria.

The Tasmanian government has, since 1973, allowed a number of companies to discharge and dispose of waste, or emit noise in excess of standards, by granting them a Ministerial exemption. These exemptions have been closely monitored and reviewed, with the aim, over time, of all industry achieving compliance with legislation through improvements in their processes and waste minimisation initiatives. All Ministerial exemptions are to cease on 30 June 1994. New environmental legislation will be promulgated at or around that time.

C-1.6.2 Pollution Control Requirements

Should a licence to operate an abattoir be granted under the *Environment Protection Act*, 1973, the following conditions may be attached which require the licensee to:

- do specified things to prevent, minimise or control pollution and noise,
- comply with specified standards for the emission of pollutants or noise,
- carry out a specified routine of monitoring emissions and supplying information about the results,
- do specified things for the restoration of the surface of the land and the vegetation of the premises.

The Meat Hygiene Regulations, 1986, pursuant to the *Meat Hygiene Act*, 1985, specify pollution control requirements that must be adhered to. These include:

- the operator must provide a suitable facility to process or dispose of solid waste of animal origin on a daily basis, or shall remove daily such waste to a processing plant of facility,

- where burial is used as a means of disposal of solid waste, it shall be done on an area of land at least 50 m from the premises and shall be carried out in such a manner as to prevent the transmission of disease from the waste and so as to prevent the creation of obnoxious odours,
- if the matter is spread over land, it is to be spread evenly and thinly,
- all solid waste not of animal origin at licensed meat premises shall be deposited in conveniently located containers. These containers shall be frequently emptied and the contents disposed of daily by incineration or by removal from the premises.

The Environment Protection (Water Pollution) Regulations, 1974, contain requirements that must be adhered to with respect to the protection of Tasmania's watercourses. For the purposes of these regulations, Tasmania's watercourses are separated into three segments, these being bays or estuarine waters, coastal waters and inland waters. Different emission standards apply depending on the nature of the watercourse.

C-1.6.3 Planning Approvals for New or Enlarged Facilities

The *Environment Protection Act*, 1973, specifies that all scheduled premises require a licence to operate. As an abattoir is classed as a scheduled premises, a licence must be obtained. In making an application, the following information must be provided:

- the nature of the premises for which a licence is sought,
- the location of those premises,
- plans, specifications and description of emissions and other information upon request of the Department of Environment and Land Management.

The *Environment Protection Act*, 1973, also states that approval must be obtained to:

- change any process used on the premises which will cause or substantially increase the emission of a pollutant of noise from the premises,
- construct, install, alter or remove any structure on the premises or any furnace or other device that produces a pollutant on the premises,
- change the nature of materials used on the premises so as to cause or substantially increase the emission of pollutants or noise from the premises,
- increase the quantity of materials dealt with or used

on the premises by more than the amount specified on the licence.

Therefore, as in Victoria, proposals for new abattoirs need approval under State environmental legislation, as do extensions, enlargements or alterations to existing premises.

In regard to local planning legislation, it is assumed that an abattoir would need a planning permit to operate, no matter where it is located in Tasmania. This permit is obtained from the local council who has the discretion to permit or refuse the application under the Land Use Planning and Approvals Act, 1993. Should the application be approved, conditions may be attached to the licence.

If existing premises are to be altered in any way, the Land Use Planning and Approvals Act, 1993, requires the holder of the permit to submit amended plans to the planning authority detailing the proposed alterations. The planning authority may amend the permit if it is satisfied that the proposed changes do not cause any increased detriment to any person and do not effectively change the use or development for which the permit was issued. Therefore, depending on the size, scale and consequences of the proposed enlargements or alterations, they would be dealt with as either amended plans to an existing permit or a new permit application.

C-1.6.4 Trends and Initiatives

New legislation to replace the *Environment Protection Act*, 1973, is planned to be enacted by the end of June 1994. From review of the Bill, the *Environmental Management and Pollution Control Act* will focus more on ambient environmental values and beneficial uses than on "end-of-pipe" point source emissions. The tools of management will include:

- State Policies, similar to the Victorian SEPP's, which will specify environmental values and beneficial uses and set ambient standards to protect these,
- Ambient Environmental Quality Requirements (AEQR's), which are to be based on the State Policies, will set specific requirements for industry discharges into particular local environments,
- Environmental Improvement Plans (EIP's), which will require companies which do not meet regulations at June 30, 1994, to specify how they intend to work toward compliance. These EIP's have a three-year time restriction.

In the area of sustainable land management, the *State Policies and Projects Act (Tas)*, 1993, is new legislation that provides for the development of Tasmanian Sustainable Development Policies, projects of State significance and State of the Environment Reports.

The development of State Policies is to be consistent with the following objectives:

- to promote the sustainable development of natural and physical resources and the maintenance of ecological processes and genetic diversity,
- to provide for the fair, orderly and sustainable use and development of air, land and water,
- to encourage public involvement in resource management and planning,
- to facilitate economic development in accordance with the above objectives,
- to promote the sharing of responsibility for resource management and planning between the different spheres of Government, the community and industry in the State.

The Act sets up a Sustainable Development Advisory Council to prepare State of the Environment Reports. These reports, produced at 5 yearly intervals, will relate to:

- the condition of the environment,
- trends and changes in the environment,
- the achievement of resource management objectives,
- recommendations for future action to be taken in relation to the management of the environment.

C-1.6.5 Guidelines and Policies

A document titled **"Environmental Guidelines for Meat Premises and Associated Waste Disposal Facilities, 1991"** outlines environmentally sound practices for the disposal of wastes from abattoirs. While it is not a legally binding document, the guidelines are useful in setting goals and detailing methods that could be employed to achieve those goals, so that the end result is an abattoir that is environmentally responsible in its waste disposal. Following is a summary of the main points that relate to waste disposal onto land.

Facilities and disposal sites require planning approval by the local municipality. In selecting a suitable location for a waste disposal site:

- the site should not be upwind of residential areas as this may result in odour problems for residents,
- as solid waste sites may attract birds, and

secondary treatment ponds may attract waterfowl, any proposed siting near airfields should be reported to aviation transport authorities,
- the site should not be subject to flooding,
- the site should not be within a defined distance of a watercourse, being 75 m from rivers and lakes, 50 m from creeks and streams, and 20 m from any other watercourse,
- the site should not be within 200 m of a bore or well that is used for domestic purposes or stock watering, or within 100 m of a bore used solely for irrigation purposes,
- the site should not be within 50 m of the abattoir or any other processing facility,
- the site should not be within 20 m of any property boundary, or within 50 m of a public road,
- the site should not be within 500 m of any residence in other ownership or occupation,
- the site should permit all-weather access to the trenches.

In terms of site management:

- materials should be rendered within 12 hours of slaughter,
- the stream of gases from rendering plants should be subject to some form of odour reduction treatment before being exhausted into the atmosphere, such as some form of scrubbing/condensing system and high temperature incinerators. Incinerators should be capable of maintaining the gases at 750 degrees Celsius for at least 0.5 seconds,
- paunch manure and manure from animal holding areas, can be used as fertiliser to be spread onto suitable land,
- wastes such as bones, blood, fat and offal should be made available to rendering facilities rather than be disposed of by burial,
- blood from slaughtering is not to be mixed with other liquid emissions such as washwater. It should be collected in steel trays and transported to an external drying area or bloodpit. Only where blood cannot be utilised for secondary processing should it be disposed of by burial with solid wastes,
- burial of solid wastes should only be used as a last resort.

In instances where the selected method is trench disposal:

- adequate access by vehicles and excavation equipment should be planned,
- trenches should be dug across the slope and the fill deposited on the uphill side of the trench. This minimises surface runoff entering the trench,
- trenches should begin at the top of the slope,

- each load of waste should be immediately covered by 150 mm of fill. Lime can be added to maintain pH levels and reduce odour generation,
- the final cover should consist of 600 mm of compacted material, of a slowly permeable nature, mounded above the trench to prevent water accumulating,
- a revegetation program should be devised to revegetate the area as soon as possible.

Table C-1.6 summarises the legislation affecting abattoir effluent disposal. The table shows the agencies involved, the Acts under which they operate, the controls they impose, and their monitoring and reporting requirements.

C-1.6.6 References

"Environmental Guidelines for Meat Premises and Associated Waste Disposal Facilities". Tasmanian Department of Environment and Land Management, 1991

Environmental Management and Pollution Control Act

Environment Protection Act (Tas), 1973

Environment Protection Regulations, 1974

Land Use Planning and Approvals Act (Tas), 1993

Local Government Act (Tas), 1993

Meat Hygiene Act (Tas), 1985

Meat Hygiene Regulations, 1986

State Policies and Projects Act, 1993

TABLE C-1.6
LEGISLATION AFFECTING ABATTOIR EFFLUENT DISPOSAL: TASMANIA

AGENCY	OPERATIONAL ACT	CONTROLS	MONITORING AND REPORTING REQUIREMENTS
Department of Environment and Land Management Ph: (002) 33 8011	*Environment Protection Act* 1973 •Environment Protection (Waste Disposal) Regulations 1974 •Environment Protection (Atmospheric Pollution) Regulations 1974 •Environment Protection (Water Pollution) Regulations 1974	Abattoirs need a licence to operate. Pollution conditions can be attached to licences. Licences are effective for 12 months and must be renewed annually.	Causing or permitting pollution is an offence, the penalty being $5000 and a daily penalty of $1000 for every day the offence continues.
Department of Environment and Land Management Ph: (002) 33 8011	Environmental Guidelines for Meat Premises and Associated Waste Disposal Facilities 1991	**This document is not legally binding.** It provides advice on the responsible environmental siting and management of specific industries and their associated waste disposal facilities. The guidelines also intend to assist industry to operate premises with minimal adverse environmental impact.	
Local authorities	*Local Government Act* 1993	"Nuisance" includes a nuisance which relates to excessive or unreasonable levels of pollution. Council may serve an abatement notice on those who it believes are committing a nuisance.	The penalty for failing to comply with the abatement notice is a fine not exceeding 20 units.
Department of Primary Industry and Fisheries Ph: (002) 33 8011	*Meat Hygiene Act* 1985 • Meat Hygiene Regulations 1986	A licence must be obtained to operate an abattoir. All solid waste of animal origin must be processed or disposed of on a daily basis. Burial of solid waste shall be on an area of land at least 50 metres from the premises and shall be carried out in such a way as to prevent transmission of disease, the creation of obnoxious odours and so as not to create a nuisance. Materials such as manure shall be disposed of in a manner so as not to create obnoxious odours and, if they are spread over paddocks, should be spread evenly and thinly. Liquid waste should be finally disposed of by pondage, ground absorption, irrigation or other approved means.	Failure to obtain a licence incurs a penalty of $5000 and a daily penalty of $500. Failure to comply with the regulations is considered an offence and liable to a penalty not exceeding $1000 and in the case of a continuing offence, a penalty not exceeding $100 for each day during which the offence continues.

C-1.7 Victoria

C-1.7.1 Background

The *Environment Protection Act*, 1970, sets a framework for the protection of the environment in Victoria. In order to protect particular segments of the environment, set standards, and control certain types of industries, the Act allows for the creation of State Environment Protection Policies (SEPP's) and Industrial Waste Management Policies. Each policy sets standards for waste emissions and for the receiving environment.

The Environment Protection Authority (EPA) in Victoria is responsible for enforcement of the Act and has the responsibility of co-ordinating all activities relating to the discharge of wastes into the environment and the generation, storage, treatment, transport and disposal of industrial wastes.

Other government authorities such as the Health Department and local councils have responsibility for dealing with nuisance and public health issues.

Table C-1.7 specifies which authorities have responsibility for enforcing legislation relating to waste disposal of abattoir effluent, and what the requirements under the legislation are.

C-1.7.2 Pollution Control Requirements

Under the Environmental Protection (Scheduled Premises and Exemptions) Regulations, 1984, an abattoir with a processing capacity of more than 200 tonnes annually is determined to be a Schedule 2 and Schedule 3 premises, which relate to control and licensing of premises which discharge waste to water and land.

Enforcement tools available to the EPA to control pollution include:

- Works approval - ensuring that appropriate controls are in place for all new works on scheduled premises,
- Licences - these set out strict operating standards for scheduled premises (including monitoring requirements),
- Pollution Abatement Notices - served on the occupier of a premises from which contaminated runoff or other pollution is discharged. They can require the supply of plans, specifications, etc for pollution control, the measures to be undertaken, and the maximum allowable concentrations of the

pollutants to be discharged,

- Clean-up Notices - served on the occupier of a premises where pollution has occurred or is likely to occur, and can require the owner to remediate the site or allow the EPA to initiate clean-up with costs being imposed on the occupier,
- Prosecutions - there are a range of offences in the *Environment Protection Act* (eg. causing pollution, breach of licence/notice and causing an environmental hazard) which can incur a fine or jail sentence.

The *Environment Protection Act*, 1970, requires that disposal of wastes comply with the requirements outlined in the State Environmental Protection Policies (SEPP's).

In relation to SEPP's for Victoria's watercourses, specific pollution control requirements differ depending on the particular watercourse. There are currently eleven SEPP's for watercourses across the State. Water quality indicators used to achieve set objectives include levels of dissolved oxygen, bacteria, pH, temperature, salinity, light penetration, toxicants, nutrients and biostimulants, aesthetic appearance and settleable matter. The SEPP (Waters of Victoria) specifies a preference for wastes to be discharged to land rather than water and indicates that facilities for effluent disposal on land should be in accordance with the *Guidelines for Wastewater Irrigation* produced by the EPA, (1983), (see below).

One SEPP for the air environment applies across the whole of the State. The policy defines three classes of air pollutants. Class 1 indicators are substances which are widespread in the urban air environment and are used as indicators of general air quality (carbon monoxide, sulphur dioxide, nitrogen dioxide, ozone, lead and particulates). Class 2 indicators are pollutants which are generally source-specific and are not Class 1 or Class 3 indicators. Class 3 indicators are pollutants which, because of their recognised carcinogenic, mutagenic, teratogenic, highly toxic or highly persistent nature, are subject to particularly stringent emission controls.

The EPA has promulgated an Industrial Waste Management Policy (Waste Minimisation), 1990, which covers any aspect of industrial waste in Victoria, and requires a licence or works approval application to include a waste minimisation plan which details waste minimisation options. The EPA can also require a company, through an amendment to an existing licence, to undertake a waste audit or prepare a waste minimisation plan for existing facilities.

C-1.7.3 Planning Approvals for New or Enlarged Facilities

The *Environment Protection Act* specifies that alterations, modifications or additions which are likely to increase waste discharges from a scheduled premises, require works approvals. Enlarging existing facilities or establishing new facilities would fall into this category and, therefore, a works approval would need to be obtained before works could commence.

In relation to local planning regulation, it is assumed that the use of land for an abattoir would either be discretionary or prohibited in every land use zone across the State. Therefore, all proposals for new abattoirs would need to obtain a permit to operate under the Planning and Environment Act, 1987. This permit is obtained from the local municipal council. One of the permit conditions may require that all further buildings and works gain the approval of Council. Therefore, if an abattoir was to be enlarged or altered in any way, amended plans to the original permit would need to be submitted to Council. If the enlargement or alteration significantly altered the operation of the plant, a new permit application may have to be made. Because of the nature of abattoir operations, the EPA would be a referral authority for any application made to a local council for building, extending or modifying an abattoir facility.

C-1.7.4 Trends and Initiatives

The Victorian *Industrial Waste Strategy*, adopted by the State Government in 1986, advocates the need for a "cradle to grave" approach to waste management. The Strategy encompasses all aspects of waste management, including waste generation, storage, treatment, transport and disposal.

Included in the Strategy is the concept of waste minimisation. The policy targets four options for waste management. They are:

- waste avoidance/reduction,
- waste reclamation/recycling,
- waste treatment,
- waste disposal.

The policy advocates the need to consider waste minimisation very early in the design of plants. Proposals for new works to existing plants are expected to contain a plan for the management of all wastes before approval will be given. The Policy permits the EPA to require occupiers of premises to undertake waste audits on their site to identify the nature and volumes of wastes generated on site. Waste management plans which detail the strategy for management of wastes may be required.

The *Industrial Waste Management Policy (Waste Minimisation)*, 1990, referred to in Section C-1.7.2, is a legally enforceable policy which focuses on minimising waste generation.

Legislation requiring **Environment Improvement Plans** (EIP's) was introduced in 1990. EIP's consist of a public commitment from a company to the community to be environmentally responsible. An EIP is prepared with community consultation and then approved by the EPA. Companies not willing to partake in this activity may be required to submit themselves to public scrutiny, by publication of the results of statutory environmental audits and monitoring in the local newspapers.

Another initiative of the EPA in encouraging and assisting industry to clean up the natural environment, is the introduction of a **Clean Technology Incentive Scheme** in which low interest loans are provided to companies wanting to include waste minimisation or recycling processes in their operations. These processes must be innovative or widely applicable to other industry to qualify for the incentive loans.

The **Guidelines for Wastewater Irrigation** were prepared by the EPA in 1983 and revised in 1991. They provide specific information relating to site selection and suitability, irrigation techniques, wastewater quality monitoring and management, land use planning and management, and legislative requirements.

The EPA has proposed a change to existing environmental regulations, which involves the concept of an accredited licence system designed to allow the accreditation of companies which meet certain prerequisites in order to give those companies greater operational freedom and reduce costs. The system requires that companies demonstrate an effective environmental management system in order to be accredited. It is not likely that this new system will apply to abattoirs, but further changes could be possible in the future.

C-1.7.5 References

Environment Protection Act (Vic), 1970

Environment Protection (Industrial Waste) Regulations (Vic), 1985

Environment Protection (Scheduled Premises and Exemptions) Regulations, 1984

Guidelines for Wastewater Irrigation, 1983 (rev. 1991)

Industrial Waste Management Policy (Vic), 1990

Industrial Waste Strategy, 1986

Planning and Environment Act (Vic), 1987

TABLE C-1.7
LEGISLATION AFFECTING ABATTOIR EFFLUENT DISPOSAL: VICTORIA

AGENCY	OPERATIONAL ACT	CONTROLS	MONITORING AND REPORTING REQUIREMENTS
Environment Protection Authority Ph: (03) 628 5111	*Environment Protection Act 1970*	Any alteration, modification or addition which is likely to increase waste discharge from scheduled premises or any proposed scheduled premises requires a works approval. On completion of works in accordance with a works approval, an application for a licence is then submitted.	Stringent monitoring and reporting requirements must be undertaken in accordance with licences.
Environment Protection Authority Ph: (03) 628 5111	State Environment Protection Policies (under the Environment Protection Act 1970)	SEPPs specify environmental indicators to be measured to define environmental quality, environmental quality objectives and programs by which the objectives can be attained and maintained.	SEPPS are legally binding documents and failure to comply with SEPP requirements result in penalties of 100 units.
Environment Protection Authority Ph: (03) 628 5111	Environment Protection (Industrial Waste) Regulations 1985	Any vehicles used to transport prescribed wastes must be individually permitted. Any transportation of prescribed waste on a highway must be accompanied by a transport certificate.	Annual returns must be provided detailing any waste produced, treated, reprocessed, stored or disposed of. "Notifiable chemicals" must be identified as they may be subject to regulation at all stages of their life cycle.
Environment Protection Authority Ph: (03) 628 5111	Industrial Waste (Waste Minimisation) Policy 1990	This policy has statutory status under the Environment Protection Act and its rules are enforceable. It requires a 'cradle-to-grave' approach to the management of industrial wastes.	Owners of premises may be required to undertake waste audits in order to identify nature, source and volumes of wastes generated. Technological standards are set for processes which generate wastes. For most wastes, commonly available technology will be the minimum acceptable standard. For wastes that have the potential to seriously damage the environment, more stringent technological standards are set.

C-1.8. Western Australia

In Western Australia, the legislative environment is relatively simple, with the Department of Environmental Protection (DEP - formerly the Environmental Protection Authority) being the primary point of contact.

C-1.8.1 Permits and Licences

The agencies involved, the Acts under which they operate, relevant subsidiary regulations, the controls they impose, and their monitoring and reporting requirements are summarised in Table C-1.8.

In Western Australia, issues relating to an abattoir site are determined primarily by their potential environmental impacts. Thus, the Department of Environmental Protection is the key agency. A new operation or a major expansion of an existing operation would require an Environmental Impact Statement style of document which would include commitments by the Proponent. These commitments would be incorporated into Licence Conditions and Works Approvals, together with any special conditions which might be required by other government agencies. In particular, the Water Authority of Western Australia would be heavily involved in water management aspects, and would determine the special conditions relevant to this aspect. A Licence to Discharge may also be required, as might some special licences required by Local Government Authorities.

Reports on environmental monitoring (especially water-related issues) are required initially on a monthly basis and later, when operations have been shown to be well managed, on a 3 monthly basis. These reports go to Department of Environmental Protection and the Water Authority and are scrutinised by both agencies. There are no other formal monitoring or reporting requirements although there may be special conditions set on a site-by-site basis, especially if the site is in an environmentally sensitive area. The Water Authority carries out independent monitoring on a 3, 6 or 12 monthly basis to audit the operator, and the Department of Environmental Protection may also audit periodically. The Health Department monitors waste disposal as part of its regular hygiene monitoring program. The Local Government Authorities also monitor periodically, mainly in respect to health issues.

C-1.8.2 Pollution Control Requirements

Discharge into any surface water body is prohibited unless special permits are issued. As a general rule, all effluent water must be retained on site. Groundwater contamination is monitored by the Water Authority and special requirements and conditions may be imposed. Odour is dealt with on a complaints basis. Public health issues are managed by means of the normal hygiene requirements set by the Health Department.

C-1.8.3 Planning New or Enlarged Facilities

Any new facility or major enlargement of an existing facility would require an Environmental Impact Assessment to be prepared. In Western Australia, the size and complexity of the project determines the detail of the Environmental Impact Statement and the period of time it is reviewed by the public. It would, however, regardless of project size, be scrutinised by all relevant Government agencies.

C-1.8.4 Trends and Initiatives

The Health Act, 1911, is now undergoing a complete review. So far only a Discussion Paper has been prepared and is undergoing review within the Department of Health. It will probably be released for external review by other government agencies in the next year or so, then for public review sometime thereafter. It cannot be expected to change any abattoir management practices for at least 3-4 years.

C-1.8.5 References

Environmental Protection Act, 1986

Health Act, 1911

Metropolitan Water Authority Act, 1982

Water Authority Act, 1984

TABLE C-1.8
LEGISLATION AFFECTING ABATTOIR EFFLUENT DISPOSAL: WESTERN AUSTRALIA - Page 1

AGENCY	OPERATIONAL ACT	RELEVANT SUBSIDIARY REGULATIONS	CONTROLS IMPOSED	MONITORING AND REPORTING REQUIREMENTS
Health Department of Western Australia	Health Act 1911 and Amendments	Country Slaughterhouse Regulations Septic Tank Regulations (all wastewater systems involving a holding structure are Septic Tanks as defined under the Act)	Wastewater Management Section of the Health Department assesses capability of the disposal system and is involved in assessing hygiene aspects of water disposal if it is to be used for plant washdown or pasture irrigation. There are no direct formal controls but conditions on Works Approvals are imposed via the Department of Environmental Protection.	No formal requirements of the operator, but Meat Hygiene Section of Health Department includes wastewater disposal mechanisms in its usual hygiene monitoring. There are no monitoring or reporting requirements on the operator.
Department of Environmental Protection (DEP - formerly Environmental Protection Authority)	Environmental Protection Act 1986	None	Size, location, sensitivity of receiving environment, plant technology and method of disposal are prime determinants of conditions set by DEP. A licence to discharge is required, and, with new operations, an Environmental Impact Statement. Conditions are set by the Water Authority and incorporated into DEP's Licence Conditions	Monitoring of nutrients and (sometimes) bacteriological quality. Reporting frequency usually monthly for abattoirs just starting, but later extended to 3 monthly. Operator must do monitoring, but Water Authority audits on a 3, 6 or 12 monthly basis. Operator must send summary reports to the DEP on a 6 or 12 month basis.

TABLE C-1.8
LEGISLATION AFFECTING ABATTOIR EFFLUENT DISPOSAL: WESTERN AUSTRALIA - Page 2

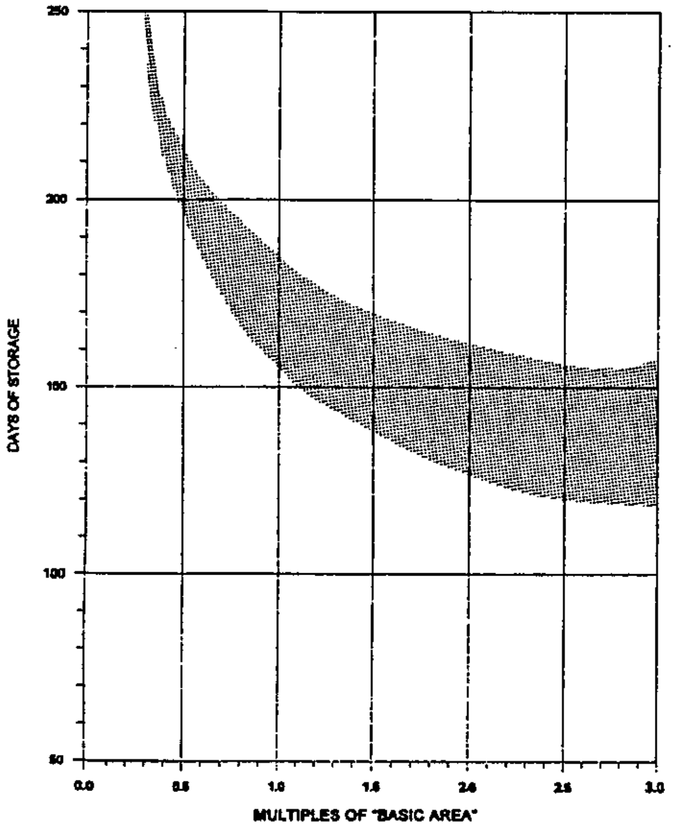
AGENCY	OPERATIONAL ACT	RELEVANT SUBSIDIARY REGULATIONS	CONTROLS IMPOSED	MONITORING AND REPORTING REQUIREMENTS
Water Authority of Western Australia	Metropolitan Water Authority Act 1982 Water Authority Act 1984	Metropolitan Water Supply Sewerage and Drainage Act 1909 and Amendments and By-laws Country Towns Sewage Act 1948 and Amendments and By-laws.	Water Authority audits monitoring undertaken by operator. Audit is on a three, six or 12 monthly basis. Operator must send summary reports to the Water Authority as well as DEP on a six or 12 month basis.	Specific monitoring or reporting requirements set via DEP and are effectively those issued with the operating licences.
Waterways Commission, Department of Primary Industry, Conservation and Land Management, etc.	Various	Various.	Conditions may be set by these agencies depending on the precise location of the abattoir and the condition of the receiving environment. These conditions would be specific and only applied as required.	None but conditions could be imposed as required and incorporated into the Works Approvals or other licences.
Local Government Authorities (LGAs)	Numerous LGA Regulations and local By-laws		Regulations affecting pipelines, ponds, methods of disposal, etc. All vary according to local environmental conditions, land zoning and LGA requirements.	Generally none, but may be imposed as licence or approval conditions. Some LGAs specifically require bacteriological monitoring.

APPENDIX C-2

IRRIGATION AREA AND WET WEATHER STORAGE

CONTENTS

C-2.1 System Performance Diagrams for the Median Year



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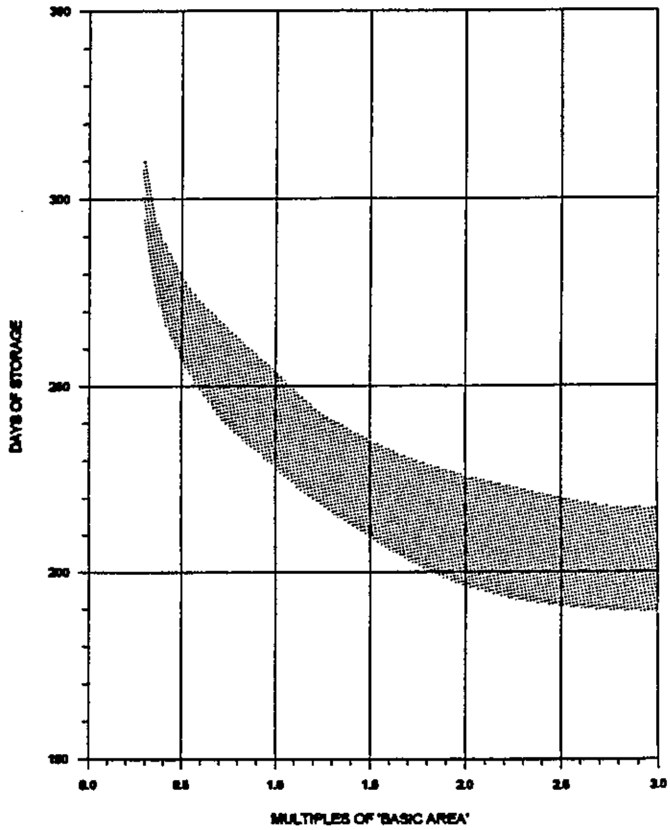

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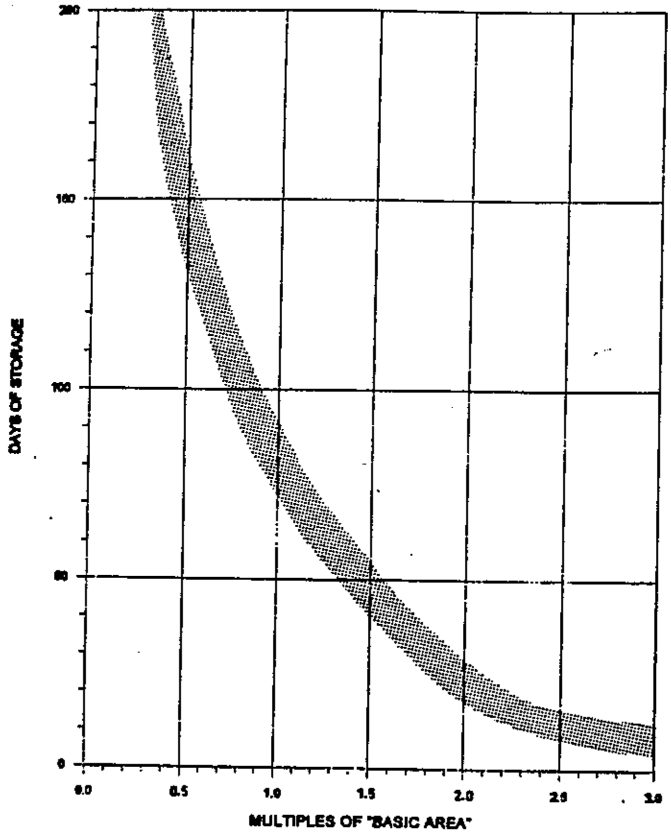

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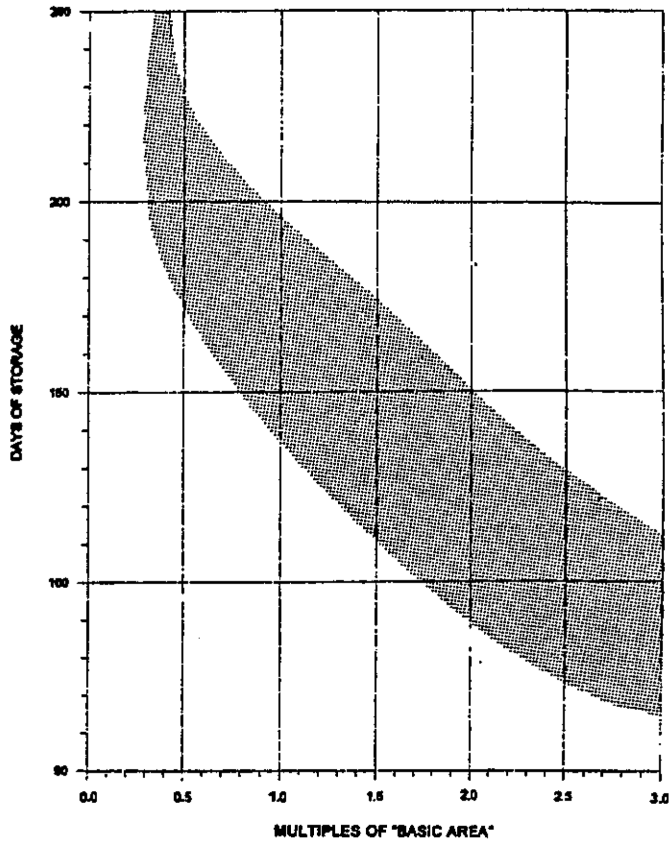

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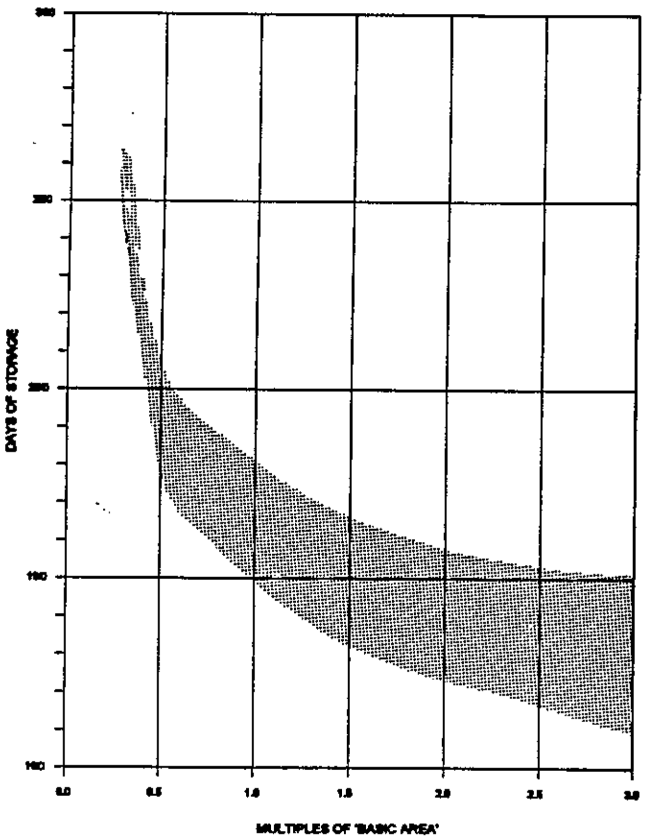

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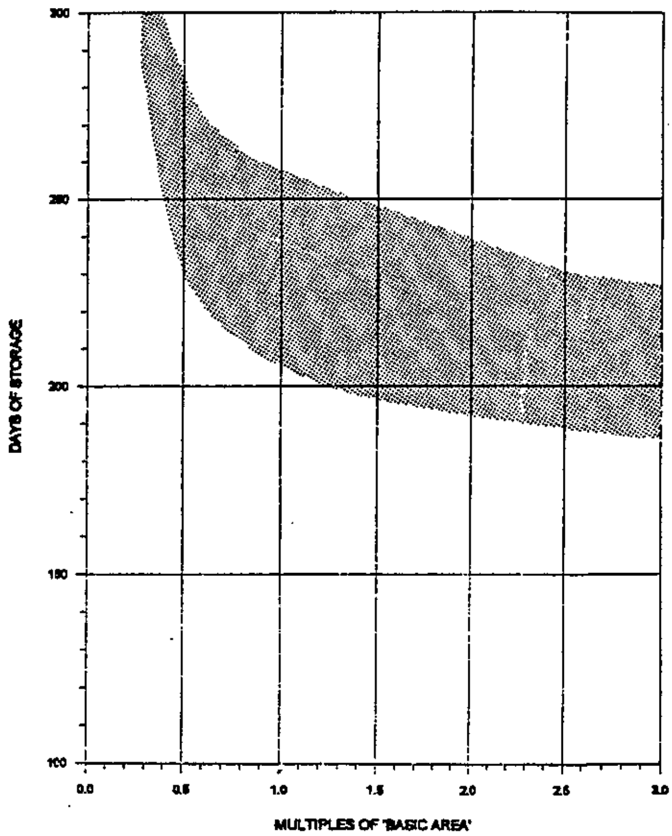

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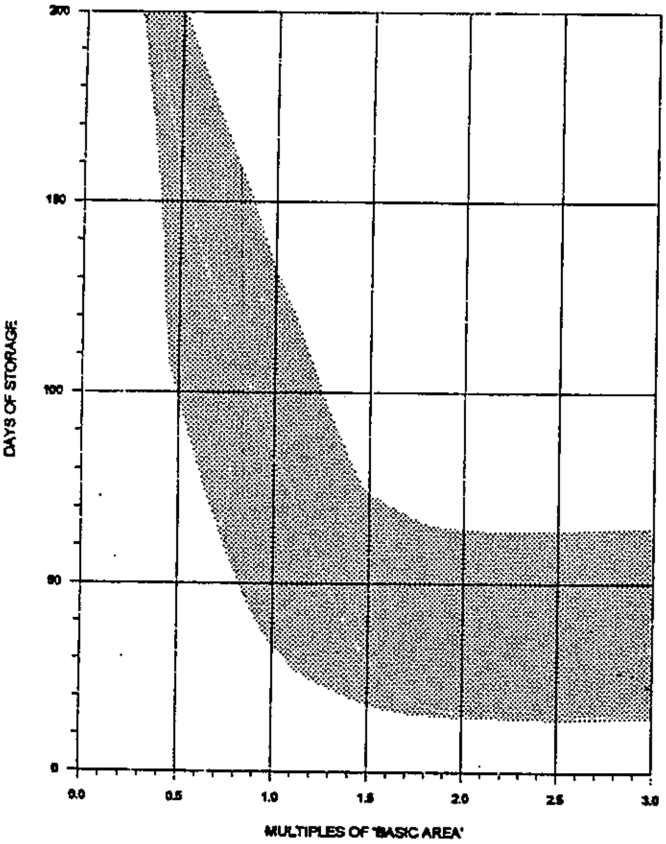

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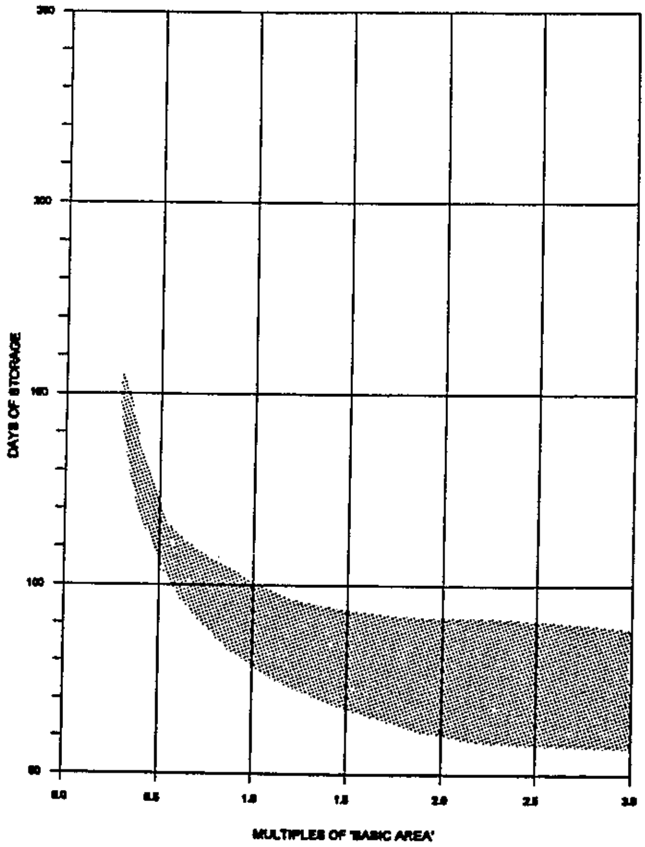

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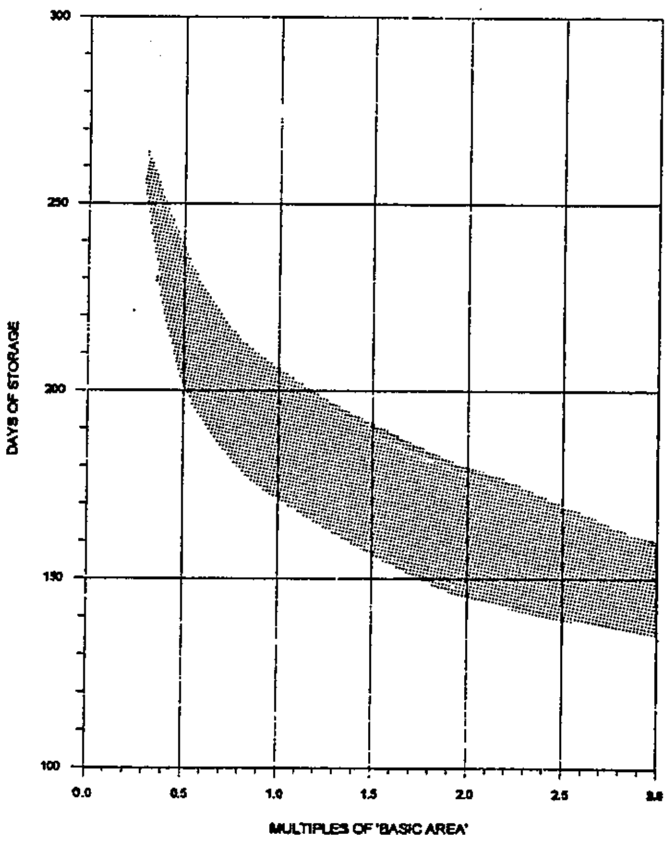

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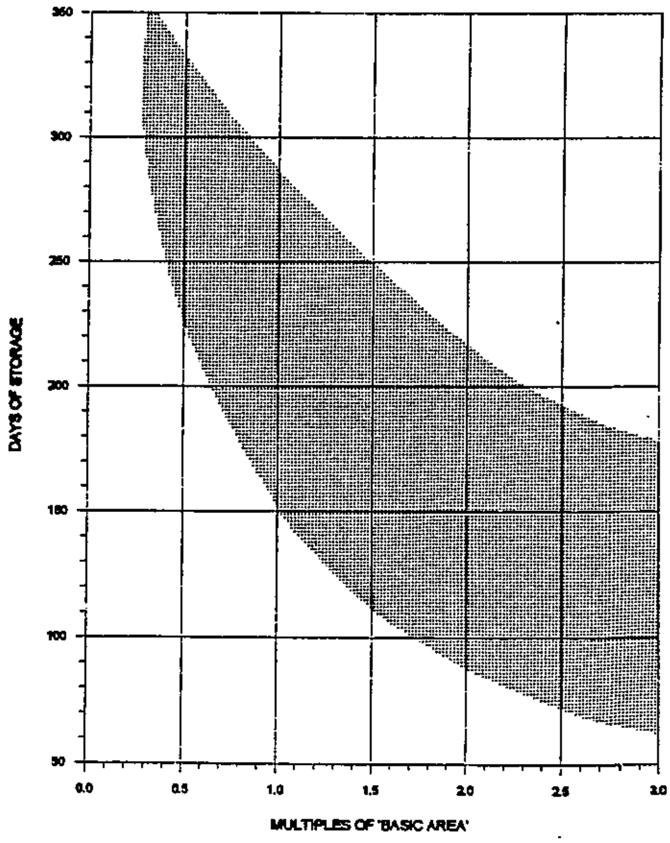
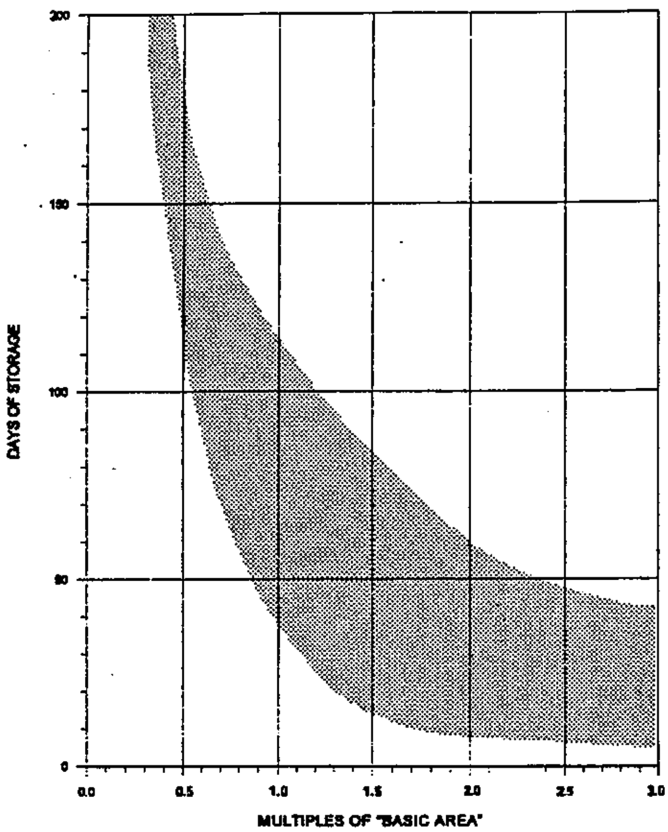


SCONE



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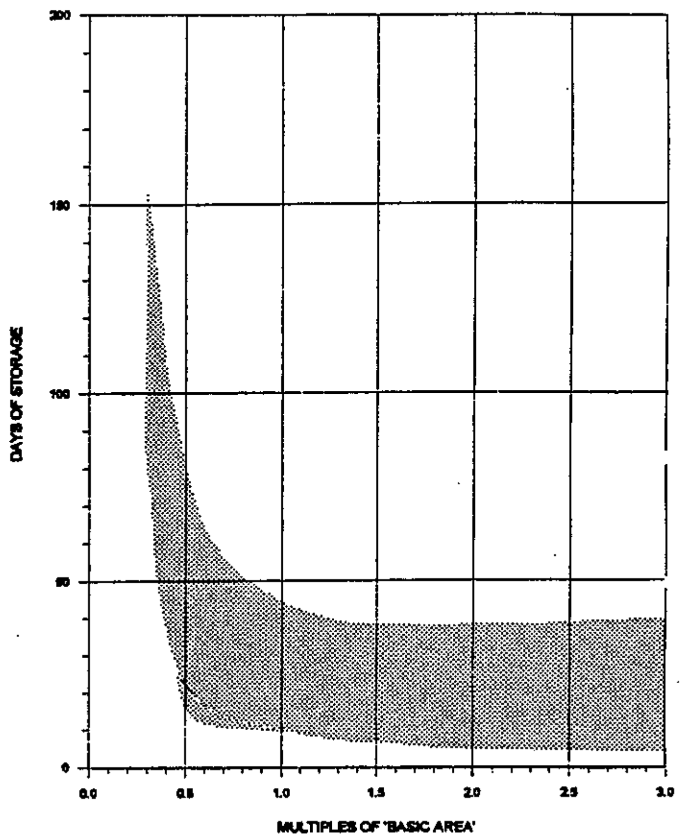

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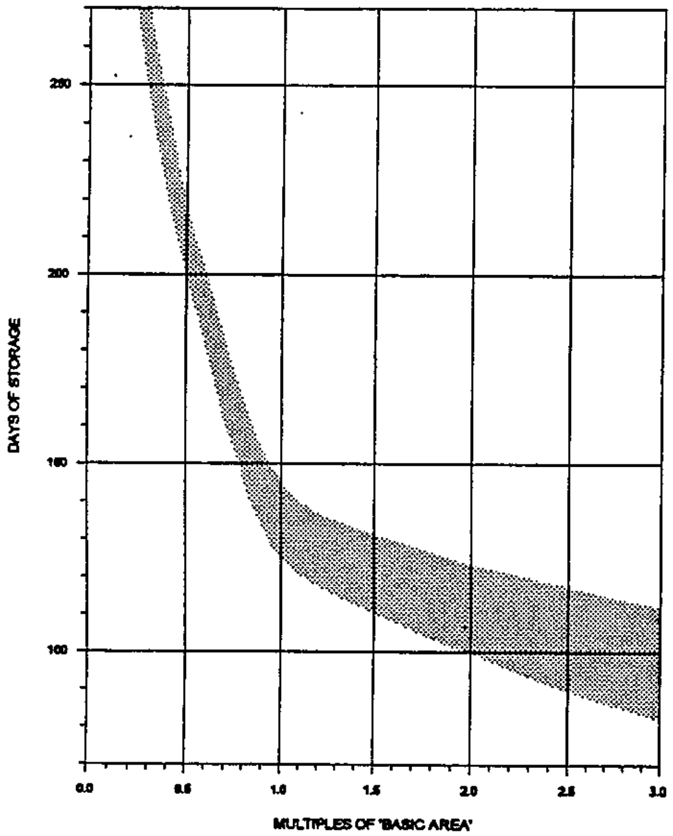

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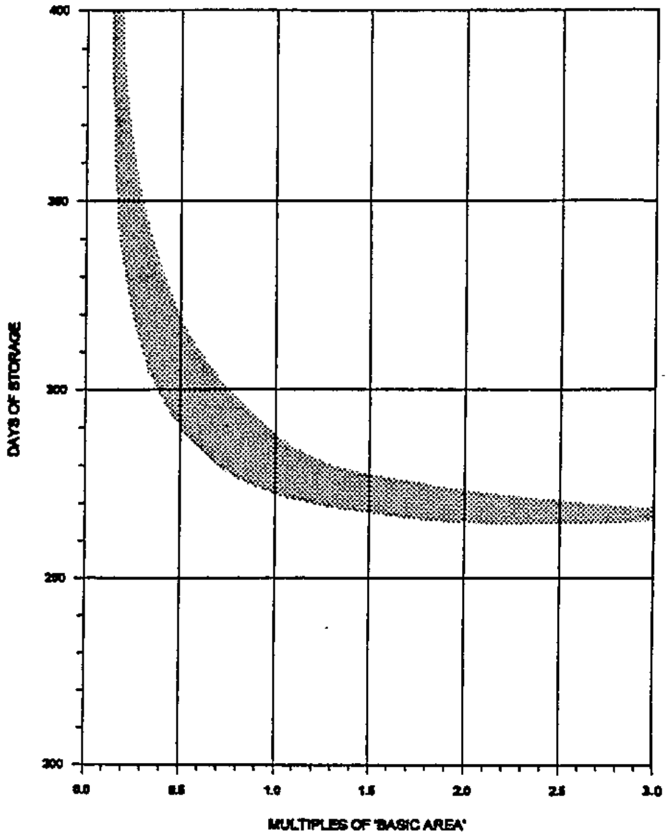
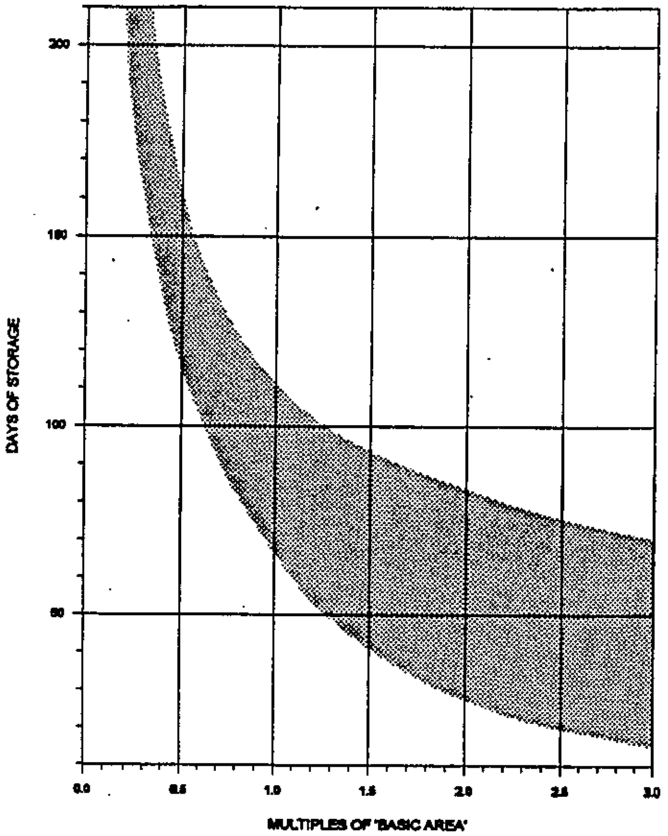
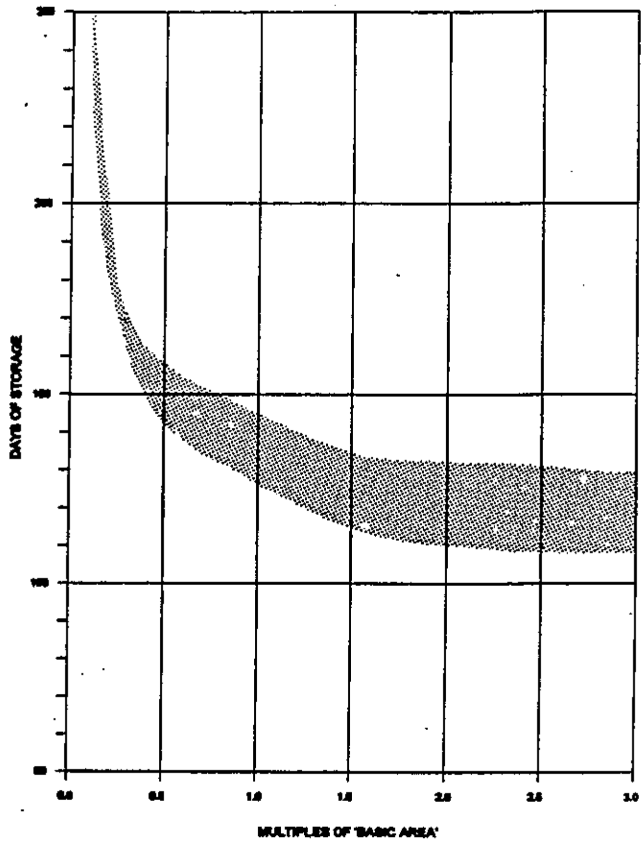


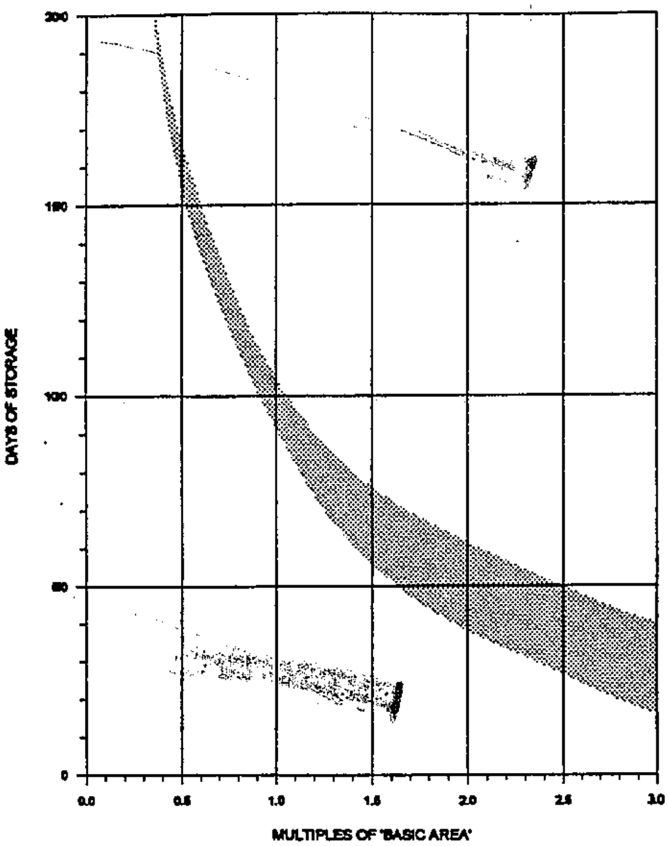
ALBURY


DAYS OF STORAGE
200
150
100
50
0.0
0.5
1.0
1.5
2.0
2.5
3.0
MULTIPLES OF 'BASIC AREA'

NOWRA


DAYS OF STORAGE
MULTIPLES OF 'BASIC AREA'

PERTH



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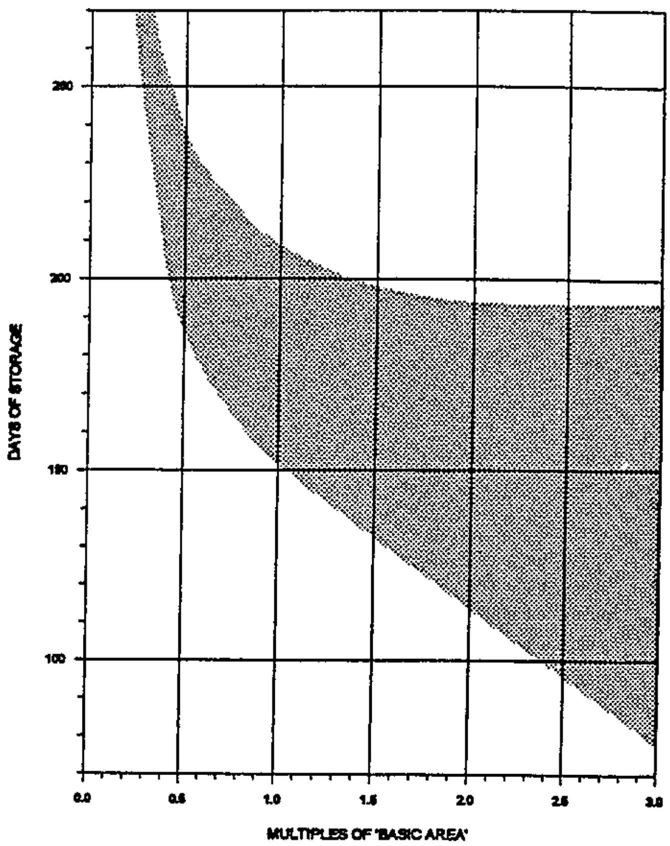
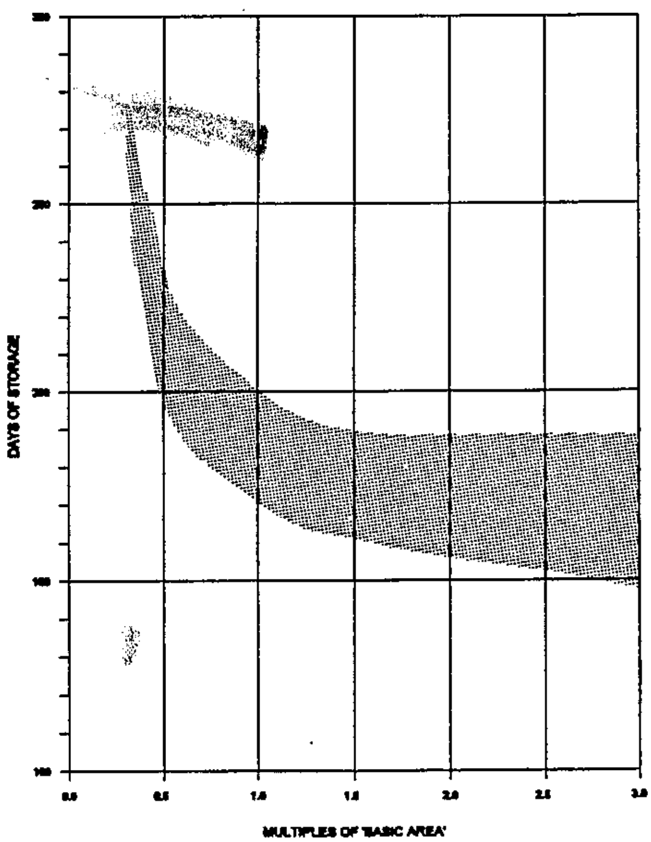
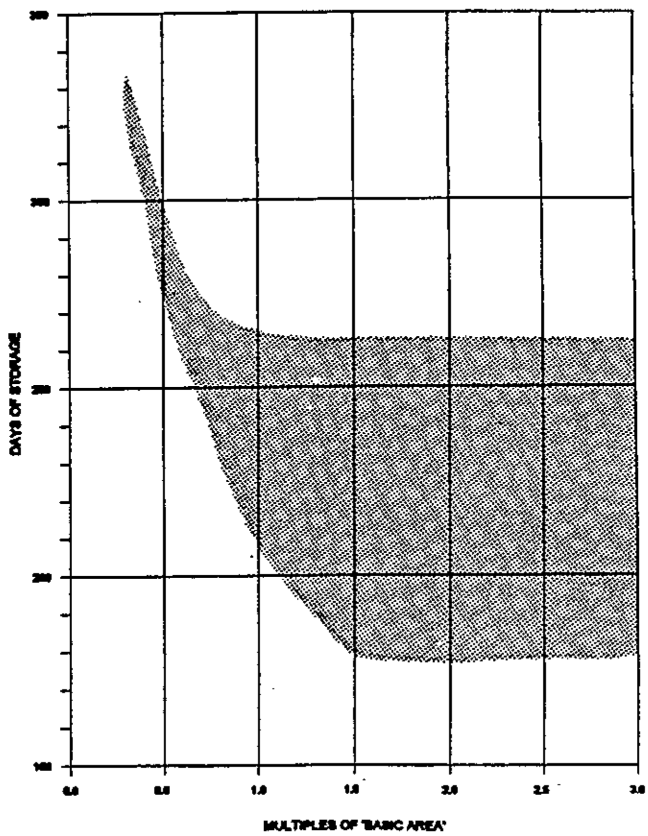


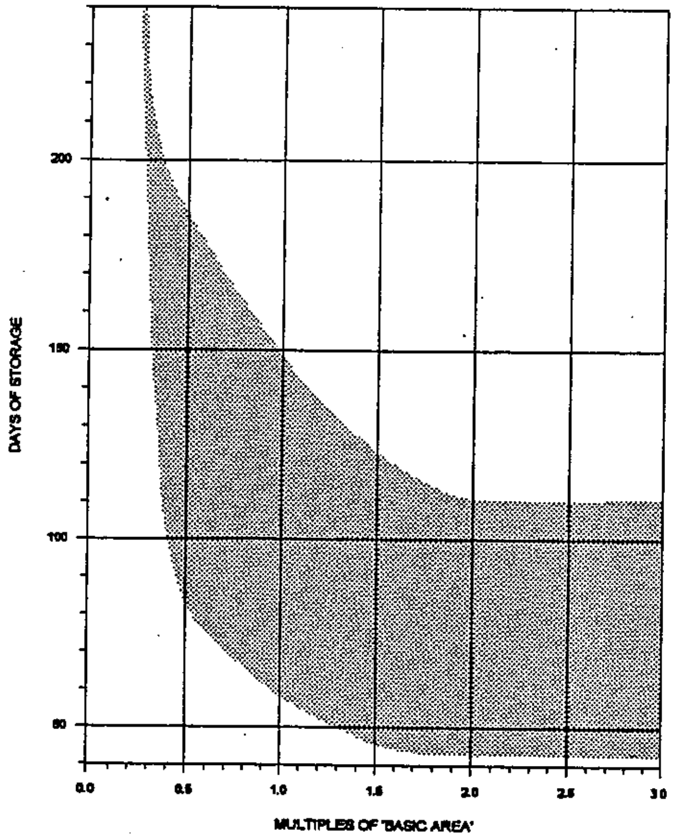
DARWIN



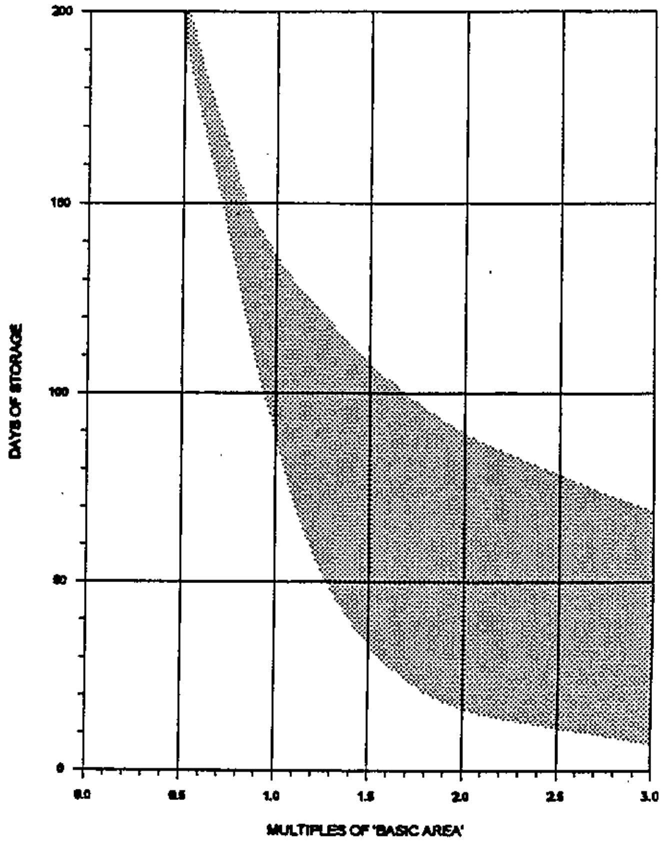
ECHUCA



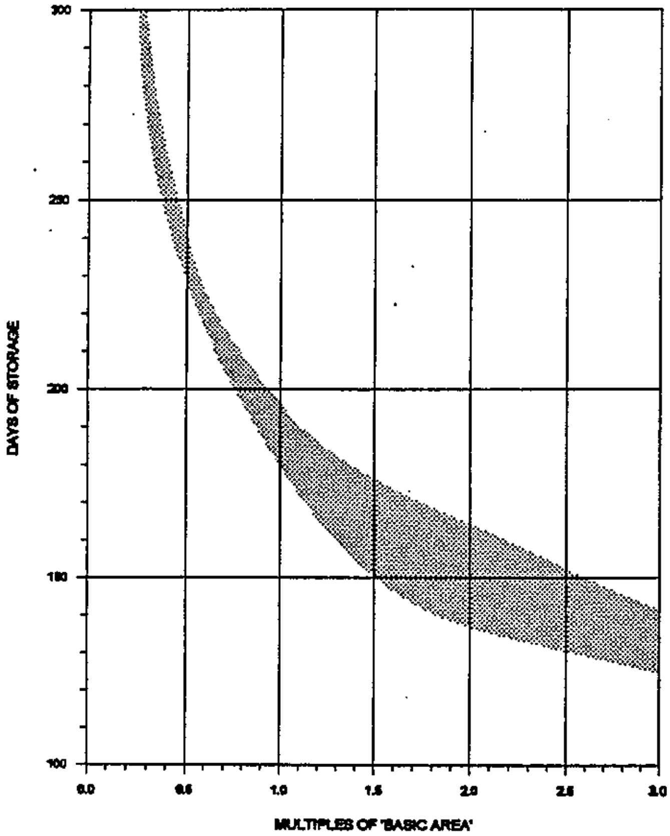
HOBART



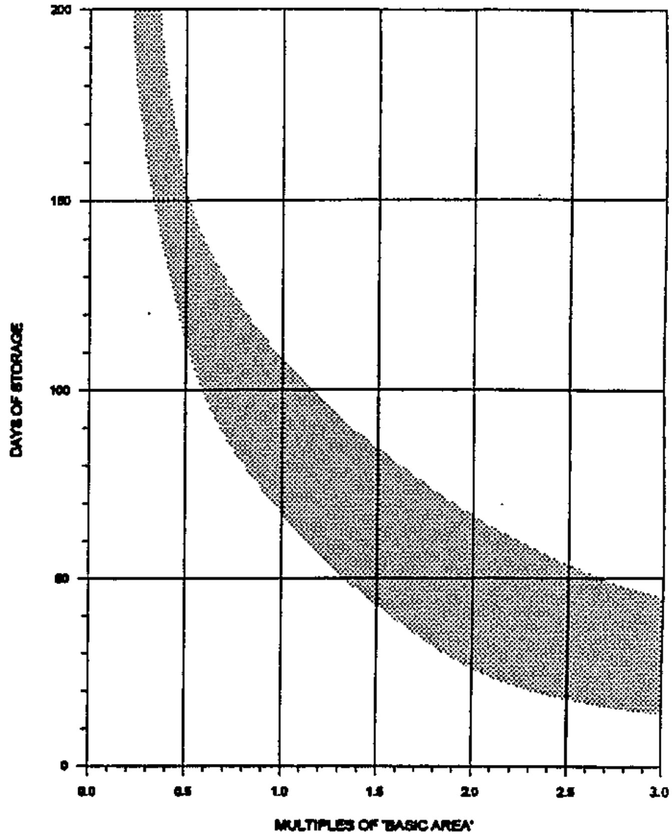
TOWNSVILLE



TOOWOOMBA


DAYS OF STORAGE
MULTIPLES OF 'BASIC AREA'

SALE


DAYS OF STORAGE
MULTIPLES OF 'BASIC AREA'

SCONE

APPENDIX C-3

FORMS AND RECORDS

CONTENTS

C-3.1 FORMS

CONTENTS

FORM A-1 EFFLUENT IRRIGATION REVIEW SUMMARY

Abattoir :	
Review compiled by:	**Date:**

ISSUE	CHAPTER	POSSIBLE SCORE	YOUR SCORE
Licences and Records	A-3	20	
Nutrient and Chemical Management	A-4	45	
Irrigation Area and Wet Weather Storage	A-5	30	
Soil Moisture Management	A-6	40	
Groundwater Pollution	A-7	20	
Surface Runoff	A-8	20	
Emergency Preparedness	A-9	25	
TOTAL SCORE		200	

1. This summary table provides an overview of the main factors which govern the level of risk associated with the operation of an effluent irrigation system.

2. The column labelled "Chapter" tells you where to find information on each particular issue and where to find the detailed table from which to get your score.

3. Check your score against the table on page A-6 and decide where to start your performance improvement program.

FORM A-2.1 INFORMATION SUMMARY (1)

Checklist of data and information you will need to build up a dossier and complete the review

1.	**General Data**
1.1	***Maps, Plans and General Data*** Abattoir site plan showing effluent drains and pumps ☐ Plans of effluent treatment system showing pipelines and valves ☐ Irrigation area site contour map showing channels, pipelines, valves, drains and fences ☐ Recent aerial photograph of effluent irrigation area ☐ Soils map of the irrigation area and soil descriptions ☐ Local topographic map showing creeks, waterways and wetlands ☐ Dimensions, depths and capacities of all ponds ☐ Geological map of the area ☐ Map showing groundwater bores in the locality ☐
1.2	***Licences, Permits and Records*** Copies of all operating licences required for effluent irrigation ☐ Copies of monitoring data for the last 12 months ☐ Copies of monitoring summary reports for past 5 years ☐ Copy of complaints register ☐ Names and contact details of all neighbours ☐ Names and contact details of all environmental authorities ☐ Irrigation system procedures manual ☐ Irrigation system emergency procedures ☐ Irrigation operation daily log ☐

FORM A-2.2 INFORMATION SUMMARY (2)

2.0	Abattoir Production and Effluent Quality
2.1	***Production*** Annual head killed: Cattle ..... ☐ Sheep ..... ☐ Pigs ..... ☐ Other ..... ☐ Total annual dressed weight of product (tonnes) ..... ☐
2.2	***Water Supply and Use*** Total water supplied to abattoir from all sources - preferably daily totals (kL) ..... ☐ Salinity of water supply (mg/L) ..... ☐ Volume irrigated - preferably daily volume (kL) ..... ☐
2.3	***Effluent Processing and Storage Facilities*** Details of: Solids (paunch and sludge) de-watering facilities ..... ☐ Screens and save alls ..... ☐ Dissolved air flotation (DAF) units ..... ☐ Nutrient reduction facilities: - activated sludge ..... ☐ - sequenced batch reactor ..... ☐ - chemical dosing ..... ☐ Aerated ponds ..... ☐ Anaerobic lagoons/ponds ..... ☐ Aerobic/facultative (oxidation) ponds ..... ☐ Aerated ponds ..... ☐ Wet weather storage ponds ..... ☐
2.4	***Effluent Quality*** Plan showing location of routine effluent sampling points ..... ☐ Laboratory analysis reports for all samples taken during last 12 months ..... ☐

FORM A-2.3 INFORMATION SUMMARY (3)

3.0	Irrigation System
3.1	***Irrigation System and Operations***
	Plan of irrigation layout .... ☐
	Irrigation records for each field or block .... ☐
	Operating manuals for irrigation equipment .... ☐
	Crop history in each paddock .... ☐
	Stock records for each paddock .... ☐
	Soil moisture monitoring records .... ☐
3.2	***Climate***
	Rainfall records from abattoir or irrigation area .... ☐
	Long term rainfall records from nearest town (50 years minimum) .... ☐
	Evaporation records (nearest available or a map) .... ☐
3.3	***Environmental Monitoring***
	Laboratory analysis reports for water samples from drains, creeks and dams .... ☐
	Laboratory analysis records for groundwater samples .... ☐
	Laboratory analysis records for soil samples .... ☐
	Water level records for monitoring bores (full historic records) .... ☐

FORM A-3. LICENCES AND RECORDS

ISSUE AND SCORING		WORKING	SCORING METHOD	YOUR SCORE
1.	**Planning Approval**			
1.1	What are the permitted uses of the land?(*Check with local Council if unsure*)	________	If answer to either 1.2 or 1.3 is:	
1.2	Is effluent irrigation specifically allowed without planning consent?	Yes/No/Unknown	Yes = 4 No = 0 Unknown = 0	
1.3	If "no" do you have planning consent?	Yes/No/Unknown		____
2.	**Pollution Permits/Licences**			
2.1	Either: Do you need a pollution control licence for operating an effluent treatment plant? (*Check with EPA or other environmental agency*) Or: Do you need a pollution control licence for discharging effluent to land?(*Check with EPA or other environmental agency*)	Yes - *go to Q 2.2* No - *go to Q 3.1* Unknown - *go to Q 2.2*	Yes = 0 No = 6 Unknown = 0	____
2.2	Are all the required licences/permits current? (*Check the files!*)	Yes/No/Unknown	Yes = 3 No = 0 Unknown = 0	____
2.3	Are you complying with all the conditions of the licence/permit?	Yes/No/Unsure	Yes = 3 No = 0 Unsure = 0	____
3.	**Inspections**			
3.1	How many visits have you had in the last year from inspectors regarding the irrigation system?	____		
3.2	How many of those visits were because of an "incident" or complaint?	____	0 - *go to Q 4.1* 1 or more - *go to Q 3.3*	
3.3	Have all matters noted by the inspectors been fixed?	Yes/No/Unsure	Yes = 3 No = 0 Unsure = 0	____
4.	**Neighbours**			
4.1	How close is the nearest residence to the boundary of the irrigation area?	____	>500 m = 3 300 - 500 m = 2 100- 300 m = 1 <100 m = 0	____
4.2	How many written or telephone complaints have you received in the last year relating to: • odour? • spray drift? • runoff into creeks? **Total complaints**	____ ____ ____ ____	Total complaints: 0 - 5 = 2 6 - 10 = 1 >10 = 0	____
5.	**Records**			
	Do you have a complete set of records of irrigation volume, water quality, soil conditions and cropping?	Yes/No/Unsure	Yes = 2 No = 0 Unsure = 0	____
	TOTAL SCORE FOR THIS TABLE			____

FORM A-4.1 NUTRIENT AND CHEMICAL MANAGEMENT (1) - NITROGEN

No	ISSUE AND SCORING	WORKING	EXAMPLE	YOUR SCORE
1.0	**Nitrogen (N)**			
1.1	What is the average total nitrogen content of the effluent irrigated onto the land expressed in mg/L or ppm? *(Actual measurements preferable. Otherwise use Table A-4.1)*	______	200	
1.2	How many days per year does the abattoir operate?	______	250	
1.3	What is the average daily output of effluent (in kL/day)? *(Use Table A-4.2 to convert imperial units to kL/day)*	______	500	
1.4	Calculate the total yearly output of nitrogen (kg) = (Q 1.1 x Q 1.2 x Q 1.3) / 1,000[1]	(____x____x____)/1000 = ______	(200 x 250 x 500)/1,000 = 25,000	
1.5	What is the total area irrigated in one year (ha)?	______	50	
1.6	Calculate the average nitrogen loading (kg/ha/year) = (Q 1.4 / Q 1.5)	____/____ = ______	25,000 / 50 = 500	
1.7	Calculate your score: 1) Effluent only receives **primary** treatment, irrigation area is **grazed** and: • Q 1.6 is less than 400 Score = 25 • Q 1.6 = 400 to 600 Score = 10 • Q 1.6 is more than 600 Score = 0 2) Effluent only receives **primary** treatment, irrigation area is **cropped** and: • Q 1.6 is less than 700 Score = 25 • Q 1.6 = 700 to 1,000 Score = 10 • Q 1.6 is more than 1,000 Score = 0 3) Effluent receives **secondary** treatment, irrigation area is **grazed** and: • Q 1.6 is less than 200 Score = 25 • Q 1.6 = 200 to 300 Score = 10 • Q 1.6 is more than 300 Score = 0 4) If your effluent receives **secondary** treatment, the irrigation area is **cropped** and: • Q 1.6 is less than 350 Score = 25 • Q 1.6 = 350 to 500 Score = 10 • Q 1.6 is more than 500 Score = 0 **Note: Take land as grazed unless crop is harvested and removed from the land.**		Primary treated effluent on grazed land 500 kg/ha **Score = 10**	____

[1] *"Q" refers to question number in left hand column*

See Section A-4.2 for more details and worked example

FORM A-4.2 NUTRIENT AND CHEMICAL MANAGEMENT (2) - PHOSPHORUS

No	ISSUE AND SCORING	WORKING	EXAMPLE	YOUR SCORE
	Carried forward from Form A-4.1		Score = 10	___
2.0	**Phosphorus (P)**			
2.1	What is the average total phosphorus content of the effluent irrigated onto the land expressed in mg/L or ppm? *(Actual measurements preferable. Otherwise use Table A-4.1)*	______	30	
2.2	How many days per year does the abattoir operate? Same as Q 1.2	______	250	
2.3	What is the average daily output of effluent (in kL/day)? Same as Q 1.3	______	500	
2.4	Calculate the total yearly output of phosphorus (kg) = (Q 2.1 x Q 2.2 x Q 2.3) / 1,000	(___x___x___)/1000 =______	(30 x 250 x 500)/1,000 = 3,750	
2.5	What is the total area irrigated in one year (ha)? - Same as Q 1.5	______	50	
2.6	Calculate the average phosphorus loading (kg/ha/year) = (Q 2.4 / Q 2.5)	____/____ =______	3,750/25 = 75	
2.7	Calculate your score: 1) Irrigation area is **grazed** and: • Q 2.6 is less than 100 Score = 10 • Q 2.6 = 100 to 200 Score = 5 • Q 2.6 is more than 200 Score = 0 2) Irrigation area is **cropped** and: • Q 2.6 is less than 150 Score = 10 • Q 2.6 = 150 to 250 Score = 5 • Q 2.6 is more than 250 Score = 0 **Note: Take land as grazed unless crop is harvested and removed from the land**		Grazed land 75 kg/ha Score = 10	___
	TOTAL FORMS A-4.1 AND A-4.2		10 + 10 = 20	___

[1] *"Q" refers to question number in left hand column*
See Section A-4.2 for more details and worked example.

FORM A-4.3 NUTRIENT AND CHEMICAL MANAGEMENT (3) - BOD AND SALT

No	ISSUE AND SCORING	WORKING	EXAMPLE	YOUR SCORE
	Carried forward from Form A-4.2		Score = 20	____
3.0	**BOD**			
3.1	What is the average BOD content of the effluent irrigated onto the land expressed in mg/L? *(Actual measurements preferable. Otherwise use Table A-4.1)*	______	1,000 Units	
3.2	How many days per year does the abattoir operate? - Same as Q 1.2	______	250	
3.3	What is the average daily output of effluent (in kL/day)? - Same as Q 1.3 *(Use Table A-4.2 to convert imperial units to kL/day)*	______	500	
3.4	Calculate the yearly output of BOD (kg) = (Q 3.1 x Q 3.2 x Q 3.3) / 1,000	(___x___x___)/1000 = ______	(1,000 x 250 x 500)/1,000 = 125	
3.5	What is the total area irrigated in one year (ha)? - Same as Q 1.5	______	50	
3.6	Calculate the average BOD loading (kg/ha/year)=(Q 3.4/Q 3.5)	____x____ = ____	125,000/50 = 2,500	
3.7	Calculate your score: • Q 3.6 is less than 10,000 Score = 5 • Q 3.6 = 10,000 to 15,000 Score = 3 • Q 3.6 is more than 15,000 Score = 0		< 10,000 Score = 5	____
4.0	**Salt**			
4.1	Does your plant cure or salt hides, skins or casings? • Yes Score = 0 • No Score = 5		No Score = 5	____
4.2	If answer to Q 4.1 was *"Yes" and* gypsum (or similar) is used to boost calcium concentrations: Score = 2		Score = 0	____
	TOTAL FOR FORM A-4 (A-4.1 + A-4.2 + A-4.3)		20+5+5 = 30	____

[1] *"Q" refers to question number in left hand column*
See Section A-4.2 for more details and worked example.

FORM A-5 IRRIGATION AREA AND WET WEATHER STORAGE

No	ISSUE AND SCORING	WORKING	EXAMPLE	YOUR SCORE
5.1	Where is the abattoir located?	________	Townsville	
5.2	What is the average annual pan evaporation (in mm)? *(from Figure A-5.1 or actual data if you have it)*	____	2,000 mm	
5.3	What is the median annual rainfall (mm)? *(from Figure A-5.2 or actual data if you have it)*	____	1,200 mm	
5.4	Deficit = evaporation - rainfall (mm) = Q 5.2 - Q 5.3 *(Note: if answer is less than 500 adopt 500 mm)*	____ - ____ = ____	2,000 - 1,200 = 800 mm	
5.5	Number of days per year of operation	____	235	
5.6	Average daily flow of effluent (kL)	____	1,250	
5.7	Total effluent flow per year (kL) = Q 5.5 x Q 5.6	____ x ____ = ____	1,250 x 235 = 293,750 kL	
5.8	Determine the "*Basic*"[1] irrigation area (ha) required for effluent disposal[2] = Q 5.7/(Q 5.4 x 10)	____ / (____ x 10) = ____	293,750/ (800 x 10) = 37 ha	
5.9	What area (ha) is used **in one year** for irrigation of effluent?	____	85 ha	
5.10	Ratio of actual area to "Basic" area = Q 5.9 / Q 5.8 Scoring: • Ratio less than 1.5 Score = 0 • Ratio 1.5 - 2.5 Score = 10 • Ratio greater than 2.5 Score = 15	____ / ____ = ____ ____	85 / 37 = 2.3 Score = 10	____
5.11	What is the total volume of wet weather storage[3] available (in kL)?	____	65,000 kL	
5.12	How many days storage of average flow does this represent? = Q 5.11 / Q 5.6	____ / ____ = ____	65,000/1250 = 52 days	
5.13	Look up Figure A-5.3 and find the nearest climate analysis site within the same climatic zone.	________	Townsville	
5.14	In Table A-5.1 read the required days[4] of storage at that location for the nearest multiple of the "basic" irrigation area (from Q 5.10): • Less than quoted range[5] Score = 0 • Within quoted range Score = 10 • Greater than range Score = 15	____ ____	For 2.3 times "basic" area, required days storage: 40 - 110 Score = 10	____
	TOTAL SCORE FOR FORM A-5		10 + 10 = 20	____

N.B. Important notes relating to this table are on the next page *"Q" refers to question no. in left column*

FORM A-6 SOIL MOISTURE MANAGEMENT

	ISSUE AND SCORING		EXAMPLE	YOUR SCORE
6.1	**How far from the irrigation area is the nearest rain gauge?** • less than 500 m • 500 m to 2 km • More than 2 km	 Score = 4 Score = 2 Score = 0	Gauge 1 km from area **Score = 2**	______
6.2	**How often is the rain gauge checked?** • Daily at a regular time • When it has rained	 Score = 3 Score = 1	When it rains **Score = 1**	______
6.3	**How often do you measure soil moisture in the irrigation area?** • Weekly • A few times per year • Never	 Score = 15 Score = 5 Score = 0	Never **Score = 0**	______
6.4	**Do you stop irrigating when it has rained significantly?** • Yes • Sometimes • No	 Score = 5 Score = 3 Score = 0	Sometimes **Score = 3**	______
6.5	**How do you measure/estimate effluent which has been irrigated?** • Measure at least weekly from an in line flow meter • Measure pump running time • Measure water level in the pond • Estimate from abattoir kill • Estimate from abattoir water use	 Score = 5 Score = 4 Score = 1 Score = 1 Score = 3	Estimate from water use **Score = 3**	______
6.6	**Do you keep a daily chart or table of rainfall and irrigation?** • Yes • No	 Score = 4 Score = 0	No **Score = 0**	______
6.7	**Do you check the uniformity of watering by measuring soil moisture at several places in the field or block, checking spray distribution with a row of buckets or checking advance and recession times for surface irrigation?** • Yes • No	 Score = 4 Score = 0	No **Score = 0**	______
	TOTAL SCORE FOR FORM A-6		**2+1+3+3 = 9**	______

FORM A-7.1 GROUNDWATER POLLUTION (1)

No	ISSUE AND SCORING	WORKING	EXAMPLE	YOUR SCORE
7.1	**How important is the aquifer beneath your land disposal area?** (a) No aquifer known, or groundwater in negligible quantities, or aquifer grossly contaminated: Score = 4 (b) A minor aquifer which does not produce large quantities of water, but is important for local supplies and providing base flow to local rivers:Score (c) A major aquifer which is highly productive and used for a public water supply and/or other large users:Score = (d) Don't know: Score = 0		No aquifer **Score = 4**	______
7.2	**What is the geology of the aquifer and its overlying strata?** (a) Fractured rock or low permeability clay/silt: Score = 3 (b) Moderately permeable alluvial material containing some silts and/or clays:Score (c) Highly permeable sand and gravel:Score (d) Don't know: Score = 0		Don't know **Score = 0**	______
7.3	**What is the depth to the water table below your land disposal area?** (a) Greater than 15 metres: Score = 3 (b) 5 to 15 metres: Score = 1 (c) Less than 5 metres : Score = 0 (d) Don't know: Score = 0		Greater than 15 m **Score = 3**	______
7.4	**How well are nutrients and water being managed?** Total scores from: End of Form A-4.3 + Form A-6: • > 60 Score = 4 • 40 - 60 Score = 2 • < 40 Score = 0		30 + 9 = 39 **Score = 0**	______
	TOTAL FOR FORM A-7.1		**Total = 7**	______

FORM A-7.2 GROUNDWATER POLLUTION (2)

No	ISSUE AND SCORING	WORKING	EXAMPLE	YOUR SCORE
	Carried forward from Form A-7.1		Score = 7	____
7.5	**Intensity of groundwater monitoring** (a) Number of groundwater monitoring wells (b) Total irrigation area (ha) (c) Wells per ha = (a)/(b) If wells/ha is: • >0.1 Score = 2 • 0.05 - 0.1 Score = 1 • <0.05 Score = 0	____ ____ ____/____ = ____	4 200 4/200 = 0.02 Score = 0	____
7.6	**How often is water taken from the wells for chemical analysis?** • 12 months or less Score = 2 • 12 to 24 months Score = 1 • more than 24 months Score = 0		12 months Score = 2	____
7.7	**Typical total nitrogen concentration in groundwater:** • < 5 mg/L Score = 2 • 5 - 10 mg/L Score = 1 • >10 mg/L Score = 0		< 10 mg/L Score = 2	____
	TOTAL FOR FORM A-7 (A-7.1 + A-7.2)		Total = 11	____

FORM A-8.1 SURFACE RUNOFF (1)

No	ISSUE AND SCORING	WORKING	EXAMPLE	YOUR SCORE
8.1	How many days per year does irrigation take place?	______	150 days	
8.2	What area is irrigated each day? (ha)	______	5 ha	
8.3	Total effluent flow per year (kL) (from Q 5.7 in Form A-5)	______	293,750 kL	
8.4	Average daily irrigation depth (mm) = Ave daily volume /daily irrigated area = (Q 5.7 / Q 8.1)/(Q 8.2 x 10[1])	(______ / ______)/ (______x10) = ______	(293750/150)/ (5 x 10) = 39	
8.5	Score for average daily irrigation. • If Q 8.4 > 40 Score = 0 • If Q 8.4 = 20 to 40 Score = 4 • If Q 8.4 < 20 Score = 7		Score = 4	
	TOTAL FOR FORM A-8.1		Score = 4	______

Notes: [1] Factor of 10 is necessary to get the units correct.
"Q" refers to question number in left hand column.

FORM A-8.2 SURFACE RUNOFF (2)

No	ISSUE AND SCORING	WORKING	EXAMPLE	YOUR SCORE
	Carried forward from Form A-8.1		Score = 4	____
8.6	**Which of the following best describes the topography of the irrigation area?** • < 1% slope and has been laser graded Score = 3 • Slopes 1% - 2% no depressions Score = 1 • Slopes 2% - 5% undulating Score = 0 • Slopes 5% - 10% rolling Score = 2 • Slopes >10% Score = 3	____	1% -2% Score = 1	____
8.7	**What are the soils in the irrigation area?** • Sands and Sandy loam Score = 0 • Clay loam and Loam Score = 1 • Silty clay and Clay Score = 2	____	Loam Score = 1	____
8.8	**Does the irrigation area have drains to catch runoff?** • Yes Score = 3 • No Score = 0	____	No Score = 0	____
8.9	**Where does water which drains from the irrigation area go to?** • Drain to a separate storage pond Score = 3 • Drain to a natural depression Score = 1 • Drain to a creek or gully Score = 0	____	Natural depression Score = 1	____
8.10	Is collected runoff pumped for irrigation re-use? • Yes Score = 2 • No Score = 0	____	No Score = 0	____
	TOTAL FOR FORM A-8		Score = 7	____

FORM A-9 EMERGENCY PREPAREDNESS

No	QUESTION	EXAMPLE	YOUR SCORE
9.1	**How is the irrigation pump turned off?** • Automatic time clock — Score = 2 • Manually — Score = 1	Manually **Score = 1**	______
9.2	**Can the irrigation area be seen from the irrigation pump site?** • Yes — Score = 2 • Partly — Score = 1 • No — Score = 0	Partly **Score = 1**	______
9.3	**How often does someone check the irrigation area?** • At least 4 times per day — Score = 6 • Daily — Score = 2 • Weekly — Score = 0	Daily **Score = 2**	______
9.4	**If a spillage of effluent occurred, where would the effluent go to?** • Caught in pond within the irrigation area — Score = 5 • Onto neighbours land — Score = 2 • Into creek — Score = 0 • Onto a public road — Score = 0	Neighbours land **Score = 2**	______
9.5	**Does the irrigation system operate at night?** • No — Score = 2 • Yes — Score = 0	No **Score = 2**	______
9.6	**How many people know how to turn off the irrigation system?** • More than 3 — Score = 2 • 2 or 3 — Score = 1 • 1 — Score = 0	2 People **Score = 1**	______
9.7	**Are emergency procedures written down?** • Yes — Score = 2 • No — Score = 0	Yes **Score = 2**	______
9.8	**Do plant security personnel (eg the gate attendant) have a copy of the emergency procedures and have they been instructed what to do?** • Yes — Score = 2 • No — Score = 0	No **Score = 0**	______
9.9	**Is a list of emergency contact names and phone numbers clearly displayed at:** (*Count half a point for each*) • Irrigation pump • Main office • Maintenance shed • Front gate	Main office and front gate **Score = 1**	______
	TOTAL SCORE FOR FORM A-9	Total = 12	____

C-3.2 RECORDS

CONTENTS

IMPORTANT

A good check of whether the records are complete and adequate is to ask yourself:

Could someone else understand what the records mean if I was not around?

1. DAILY ACTIVITIES LOG

Date:

Weather:

Rainfall (mm):

Pond Levels:

Pond 1

Pond 2

Pond 3

Field 1

Irrigation time: Start:____________________Finish:____________________

Irrigation: Volume (kL):______________Depth(mm):______________

Location of irrigator: ______________________________

Area irrigated (ha): ______________________________

Water Pressure (kPa): ______________________________

Any signs of ponding or runoff ?: ______________________________

Comments:

Field 2

Irrigation time: Start:____________________Finish:____________________

Irrigation: Volume (kL):______________Depth(mm):______________

Location of irrigator: ______________________________

Area irrigated (ha): ______________________________

Water Pressure (kPa): ______________________________

Any signs of ponding or runoff ?: ______________________________

Comments:

Field 3

Irrigation time: Start:____________________Finish:____________________

Irrigation: Volume (kL):______________Depth(mm):______________

Location of irrigator: ______________________________

Area irrigated (ha): ______________________________

Water Pressure (kPa): ______________________________

Any signs of ponding or runoff ?: ______________________________

Comments:

1. DAILY ACTIVITIES LOG

NOTES: Page 1/1

The Daily Activities Log presents a checklist of items which need to be recorded on a routine daily basis. It includes general information relevant to the operation of the irrigation system. Of particular interest are items such as:

- general climatic data such as weather conditions and rainfall
- water levels in ponds
- total time and volume of irrigation
- where the irrigator is located and the area of the field being irrigated
- the pressure at which the water is being delivered through the irrigation system
- general comments such as whether runoff or ponding is occurring, or any other relevant information.

2a. RAINFALL AND CLIMATE SUMMARY

Location:____________ **Month:** _______ **Year:** ______

Date	Rain (mm)	Wind Run (km)	Max Temp (°C)	Min Temp (°C)	Rel Humid (%)	Cloud Cover (%)	Pan Evap (mm)	Ref Evap (mm)	Comments
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
Total									

2a. RAINFALL AND CLIMATE SUMMARY

NOTES: Page 1/1

Date	Rain (mm) 1	Wind Run (km) 2	Max Temp (°C) 3	Min Temp (°C) 4	Rel Humid (%) 5	Cloud Cover (%) 6	Pan Evap (mm) 7	Ref ETo (mm) 8	Comments 9
1	0	47	27.4	18.3	73	0	5.8	4.1	
2	22.3	142	31.2	22.4	96	75	4.9	3.4	Afternoon rainfall
3	0	97	29.5	21.7	88	55	5.2	3.6	

Notes: 1. **All readings should be made at 9.00 am to allow comparison with official Bureau of Meteorology records.**
2. **Readings should be entered on the day that the reading was made**

Columns:

1 Rainfall
- Rainfall should be measured using a standard 200 mm diameter rain gauge.
- The rain gauge must be located away from any nearby trees or buildings a distance at least equal to the height of the tree or building.

2 Wind Run
- Total wind run as measured with recording anemometer.

3, 4 Temperature
- Maximum and minimum temperature for previous day.

5 Humidity
- Relative humidity is calculated from the difference between wet and dry bulb temperatures (see instructions accompanying wet and dry bulb thermometer). Don't forget to fill the wet bulb water reservoir.

6 Cloud
- Estimated % of sky covered with cloud at time of reading.

7 Pan Evaporation
- Amount of water required to bring evaporation pan up to the reference mark. Scale on the special purpose refill jug is graduated in mm of water from the evaporation pan.

8 Reference ETo
- ETo = Reference crop evapotranspiration = (approx) pan evaporation x 0.7
- Reference crop evapotranspiration is often published daily in areas where irrigation is common.
- May be calculated directly by software in automatic weather station.

9 Comments
- Brief notes should be kept on any particular climatic events (hot dry winds, thunderstorms, etc.)

Relatively inexpensive automatic weather stations are now available for a few thousand dollars and will automatically record for several months. Most of these systems come with the necessary software to download the data to a computer and analyse the data. Some stations can carry out the calculations to estimate reference evapotranspiration based on the data collected.

2b. IRRIGATION AND WATER BALANCE SUMMARY

Field: ________ **Crop:** ________ **Date Planted:** ________ **Month:** ________

Date	Ref ETo (mm)	Days after Start	% Cover	Kc	ETcrop (mm)	Rain (mm)	Irrig Time (h)	Water Pres. (kPa)	Irrig Vol (kL)	Gross Irrig (mm)	Net Irrig (mm)	Balance (mm)	Comments
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													
21													
22													
23													
24													
25													
26													
27													
28													
29													
30													
31													
Total													

2b. IRRIGATION AND WATER BALANCE SUMMARY

NOTES: Page 1/2

Date	Ref ETo (mm) 1	Days after Start 2	% Cover 3	Kc 4	ETcrop (mm) 5	Rain (mm) 6	Irrig Time (h) 7	Water Pres. (kPa) 8	Irrig Vol (kL) 9	Gross Irrig (mm) 10	Net Irrig (mm) 11	Balance (mm) 12	Comments 13
1	6.5	32	85	0.8	5.2	0	-	-	-	-	-	-73.0	
2	6.9	33	85	0.8	5.5	15.2	-	-	-	-	-	-63.7	
3	7.2	34	85	0.8	5.8	0	8		800	40.0	36.0	-29.5	

Note: **One sheet required for each separate area likely to be irrigated in one day - irrigation bay, run of a travelling irrigator or area of centre pivot covered in one day**

Columns:

1 Reference ETo
- Obtained from Column 8 of Rainfall and Climate Summary

2 Days after Start
- If a crop is being grown for harvest, "Start" refers to date of planting.
- If a pasture is being grown for hay, "Start" refers to date of last cut of hay.

3 % Cover
- Estimated % of ground covered by vegetation. (Can help estimate Kc)

4 Kc
- Kc = Crop coefficient is a measure of evaporation of the crop compared to a reference crop (usually short green grass). Kc ranges from 0 (see Section B-2.2.2 of Effluent Irrigation Manual). Kc is dependant on the stage of plant growth (days since planting or hay cutting - column 2) and percent cover (column 3).

5 ETcrop
- ETcrop = Crop evapotranspiration = Reference crop evapotranspiration x Kc = Column 1 x Column 4.

6 Rain
- From Column 1 of Rainfall and Climate Summary

7 Irrigation Time
- Time for which irrigation was applied to the particular field

8 Water Pressure
- For piped irrigation systems it is a good idea to keep a record of the pressure at point near the outlet (eg on the outlet to the travelling irrigator). Changes in pressure over time are a sign that sprinklers are getting worn or pipes are becoming blocked.

2b. IRRIGATION AND WATER BALANCE SUMMARY

NOTES: Page 2/2

9 Irrigation Volume

- Volume of irrigation water applied. (Preferably based on actual flow meter readings at the beginning and end of the day)

10 Gross Irrigation

- Depth of irrigation water applied (mm) = Volume(kL)/(Area (ha) x 10). (Note that area should be the area over which irrigation was applied).

11 Net Irrigation

- Depth of irrigation applied x application efficiency.
(Note that area should be the area over which irrigation was applied).

12 Balance

- Balance = Balance from previous day - ETcrop + Rain + Net Irrigation
= Balance from previous day - Column 5 + Column 6 + Column 11
- Balance is the amount by which the soil moisture store is depleted and is always a negative number. When the soil moisture store is full the balance is zero.
- Balance should be periodically checked against field observations such as soil moisture readings or observations of the soil being saturated. When a reading is made the balance should be reset to the observed moisture in the soil store. (e.g. The record sheet indicates that the soil should have a balance of -73 mm but soil moisture measurements show that the actual storage in the root zone is -50. The balance calculations should re-start using -50 mm)
- (Note that rainfall or irrigation running off the land does not necessarily mean that the soil is saturated. It might be that rainfall or irrigation rate exceeded irrigation capacity).

13 Comments

- Record any observations about the state of the soil (e.g. runoff after irrigation or rainfall).

2c. EFFLUENT QUALITY SUMMARY

Month: ____________

Date	Time	Sample No	Location	TKN (mg/L)	Ammonia (mg/L)	Nitrate (mg/L)	Ortho-phosphorus (mg/L)	Total Phosphorus (mg/L)	BOD (mg/L)	Oil & Grease (mg/L)	Salinity (EC or µS/cm)[1]	Comments

Notes: [1] Units must be shown

Attachments:
1. Laboratory report(s)
2. Plan showing location of sampling points

2c. EFFLUENT QUALITY SUMMARY

NOTES: Page 1/1

Date	Time	Sample No 1	Location 2	TKN (mg/L) 3	Ammonia (mg/L) 4	Nitrate (mg/L) 5	Ortho-phosphorus (mg/L) 5	Total Phosphorus (mg/L) 6	BOD (mg/L) 7	Oil & Grease (mg/L) 8	Salinity (EC or µS/cm)[1] 9	Comments 10
17	9.45	1013	Final pond outlet	180	150	5	4.2	22.5	800	<10	2310	
24	11.05	1014	Final pond outlet	170	145	5	3.8	23.2	870	<10	2410	
31	8.30	1015	Final pond outlet	169	147	8.3	4.7	26.5	915	<10	2280	

Columns:

1 Sample No • Every sample should be given a unique reference number so that it does not get confused with other samples.

2 Location • Location where sample was taken should be clear and unambiguous. Particularly for ponds, it should be clear whether the sample was taken at the inlet or outlet. Attach a plan showing exactly where each sampling point is.

3 TKN • TKN stands for "Total Kjeldhal Nitrogen" and refers to a digestion process used to determine the total nitrogen in a sample.

4 Ammonia • Refer to laboratory results.

5 Nitrate • Refer to laboratory results.

6 Ortho-Phosphate • Refer to laboratory results.

7 Total Phosphorus • Refer to laboratory results.

8 Oil & Grease • Refer to laboratory results.

9 Salinity • Refer to laboratory results.

10 Comments • Record any relevant comments.

3a. GROUNDWATER - QUARTERLY SUMMARY

Month:____________**to Month:**____________

Date	Time	Sample No	Location/ Bore No.	Depth to Watertable (m)	pH	Salinity (EC or µS/cm)[1]	Total Nitrogen (mg/L)	Comments

Notes: [1] Units must be shown

Attachments:
1. Laboratory report(s)
2. Plan showing location of sampling points/boreholes

3a. GROUNDWATER - QUARTERLY SUMMARY

NOTES: **Page 1/2**

Date	Time	Sample No 1	Location Bore No. 2	Depth to Waterhole (m). 3	pH 4	Salinity (Ec or µS/cm).[1] 5	Total Nitrogen (mg/L). 6	Comments 7
16/11/95	12:15	A3	2	4.5	7.2	435	0.4	
16/11/95	12:20	47	6	7.2	6.7	520	0.3	

Columns:

1. **Sample No.**
   - Every sample should be given a unique reference number so that it does not get confused with other samples. When sampling groundwater it is important to get a sample which is representative of the surrounding groundwater. The water standing in the test well may well be unrepresentative because it has been standing for several months. If possible, the well should first be emptied using the sampling bailer. Then allow the well to fill again before taking a sample for analysis.

2. **Location/Bore No.**
   - Location where sample was taken should be clear and unambiguous. A plan showing the location and the bore no. should be attached.

3. **Depth to Watertable**
   - This is measured from the ground level to the watertable. It can be expected that the shallower the depth to the watertable, the more monitoring bores around the perimeter and within the irrigation area will be required to be installed. The table below gives an indication of the number of bores which might be required.

4. **pH**
   - Refer to laboratory results.

5. **Salinity**
   - Refer to laboratory results.

6. **Total Nitrogen**
   - Refer to laboratory results.

7 **Comments**
   - Record any relevant comments.

There are a variety of test kits on the market which allow you to do your own testing at a much cheaper price than sending samples to a commercial laboratory. Whilst these kits are relatively cheap and quick to use, the results obtained are only likely to be useful for your own monitoring purposes. For regulatory purposes, most State Environmental Agencies insist on samples being tested by a NATA registered laboratory.

NOTES: Page 2/2

Number of Test Bores Required per 100 ha

Depth to Watertable (m)	Salinity of Groundwater (μS/cm)		
	0-2,000	2,000-5,000	>5,000
0-5	5	3	1
5-15	3	2	1
>15	2	1	1

3b. SURFACE WATER QUALITY - QUARTERLY SUMMARY

Month: ____________ **to Month:** ____________

Date	Time	Sample No.	Location	Temperature (^{0}C)	Turbidity (NTU)	TKN (mg/L)	Total Phosphorus (mg/L)	Salinity (EC or µS/cm)[1]	Comments

Notes: 1 Units must be shown

Attachments:

1. Laboratory report(s)
2. Plan showing location of sampling points

3b. SURFACE WATER QUALITY - QUARTERLY SUMMARY

NOTES: Page 1/1

Date	Time	Sample No. 1	Location 2	Temperature (^{0}C) 3	Turbidity (NTU) 4	TKN (mg/L) 5	Total Phosphorus (mg/L) 6	Salinity (EC or µS/cm)[1] 7	Comments 8
14/2/91	9:20	42	Bridge	20	43	1.1	0.1	165	
15/2/91	9:35	43	Pump	22	47	1.1	0.1	175	

Columns:

1. **Sample No.** • Every sample should be given a unique reference number so that it does not get confused with other samples. Where there is a defined creek or river running adjacent to the effluent area, surface water should be collected one site upstream and one site downstream of the effluent irrigation area. The most sensitive time for sampling would be when the flow is low. It is important to keep the sampling technique consistent for all samples.
2. **Location** • Location where sample was taken should be clear and unambiguous. It is recommended that the locations where samples are taken from remain the same for each subsequent test.
3. **Temperature** • Refer to laboratory results.
4. **Turbidity** • Refer to laboratory results.
5. **TKN** • Refer to laboratory results.
6. **Total Phosphorus** • Refer to laboratory results.
7. **Salinity** • Refer to laboratory results.
8. **Comments** • Record any relevant comments.

3c SOIL CHEMISTRY AND STRUCTURE - QUARTERLY SUMMARY

(i) Chemical Properties

Month:__________ to Month:__________

Date	Time	Sample No.	Location	pH	Salinity[1] (EC or µS/cm)	Total N (mg/L)	Nitrate (mg/L)	Avail P (mg/L)	P Sorption (ppm)	Total K (mg/L)	Organic Carbon (mg/L)	SAR	Na (mg/L)	Ca (mg/L)	Mg (mg/L)	Chloride (mg/L)	Exchang Cations (meq/100g)	ESP (%)	Comments

Notes: [1] Units must be shown

Attachments:
1. Laboratory report(s)
2. Plan showing location of sampling points

3c SOIL CHEMISTRY AND STRUCTURE - QUARTERLY SUMMARY

(i) Chemical Properties

NOTES: Page 1/2

Date	Time	Sample No. 1	Location 2	pH 3	Salinity (EC or µs/cm) 4	Total N (mg/L) 5	Nitrate (mg/L) 6	Avail P (mg/L) 7	P Sorption (ppm) 8	Total K (mg/L) 9	Organic Carbon (mg/L) 10	SAR 11	Na (mg/L) 12	Ca (mg/L) 13	Mg (mg/L) 14	Chloride (mg/L) 15	Exchang Cations meq/100g) 16	ESP (%) 17	Comments 18

Columns:

1. **Sample No.** • Every sample should be given a unique reference number so that it does not get confused with other samples. Three samples (50 cm core) should be taken per 100 ha or within each paddock or separate soil type.

2 **Location** • Location where sample was taken should be clear and unambiguous. Attach a plan showing exactly where each sampling point is .

3. **pH** • Refer to laboratory results.

4. **Salinity** • Refer to laboratory results.

5. **Total Nitrogen** • Refer to laboratory results.

6. **Nitrate** • Refer to laboratory results.

7. **Available Phosphorus** • Refer to laboratory results.

8. **Phosphorus Sorption** • Refer to laboratory results.

9. **Total Potassium** • Refer to laboratory results.

10. **Organic Carbon** • Refer to laboratory results.

11. **SAR** • Refer to laboratory results.

3c SOIL CHEMISTRY AND STRUCTURE - QUARTERLY SUMMARY

NOTES: Page 2/2

12	**Na (Sodium)**	• Refer to laboratory results.
13	**Ca (Calcium)**	• Refer to laboratory results.
14	**Mg (Magnesium)**	• Refer to laboratory results.
15	**Chloride**	• Refer to laboratory results.
16	**Exchangeable Cations**	• Refer to laboratory results.
17	**ESP**	• Refer to laboratory results.
18	**Comments**	• Record any relevant comments.

3c. SOIL CHEMISTRY AND STRUCTURE - QUARTERLY SUMMARY

Month:__________to Month: ____________

(ii) Physical Properties

Date	Time	Sample No.	Location	Soil Classification	Colour	Texture	Surface Characteristics	Bulk Density (kg/m^3)	Comments

Attachments:
1. Laboratory report(s)
2. Plan showing location of sampling points.

3c. SOIL CHEMISTRY AND STRUCTURE - QUARTERLY SUMMARY

(ii) Physical Properties

NOTES: Page 1/1

Date	Time	Sample No 1	Location 2	Soil Classification 3	Colour 4	Texture 5	Surface Characteristics 6	Bulk Density (kg/m^3) 7	Comments 8

Columns:

1	**Sample No.**	• Every sample should be given a unique reference number so that it does not get confused with other samples. Three samples (50 cm core) should be taken per 100 ha or within each paddock or separate soil type.
2	**Location**	• Location where sample was taken should be clear and unambiguous. Attach a plan showing exactly where each sampling point is .
3	**Soil Classification**	• Refer to laboratory results.
4	**Colour**	• Refer to laboratory results.
5	**Texture**	• Refer to laboratory results.
6	**Surface Characteristics**	• Refer to laboratory results.
7	**Bulk Density**	• Refer to laboratory results.
8	**Comments**	• Record any relevant comments.

4a. ANNUAL NITROGEN BALANCE

Field: ____________

YEAR	FROM LAST YEAR		FERTILISER	EFFLUENT			CROP			GRAZING				RESIDUAL
	Est. (kg/ha)	Tested (kg/ha)	Amount Added (kg/ha)	Volume (kL/ha)	Conc. (mg/L)	Total Added (kg/ha)	Type	Yield (t/ha)	N Removed (kg/ha)	Animal Type	Ave Stocking (no./ha)	N Removed (kg/ha)	N Returned (kg/ha)	(kg/ha)

4a. ANNUAL NITROGEN BALANCE

NOTES: Page 1/2

YEAR	FROM LAST YEAR		FERTILISER	EFFLUENT			CROP			GRAZING				RESIDUAL
	Est. (kg/ha) 1	Tested (kg/ha) 2	Amount Added (kg/ha) 3	Volume (kL/ha) 4	Conc. (mg/L) 5	Total Added (kg/ha) 6	Type 7	Yield (t/ha) 8	N Removed (kg/ha) 9	Animal Type 10	Ave Stocking (no/ha) 11	N Removed (kg/ha) 12	N Returned (kg/ha) 13	(kg/ha) 14

Note: **For this table, "year" refers to a cropping year. This should be taken as either the beginning or end of the main growing season. The most important thing is to start at the same time each year.**

Columns:

1 **Estimated from last year:** • Estimated nitrogen from the end of last year = Column 14 from previous line. Provides a starting point for assessment of nitrogen balance over this year.

2 **Measured from last year** • Measured nitrogen from the end of last year. If soil tests have been done, the actual test result should be used as the starting point for calculating the overall balance for the year.

3 **Fertiliser added** • Amount of nitrogen fertiliser added during the year (if any)

4 **Effluent volume added** • Total volume of effluent used to irrigate the particular area (field or bay) during the year.

5 **Concentration of nitrogen** • Average concentration of total nitrogen in the effluent (from Record Form 2c).

6 **Total nitrogen added** • Volume of effluent (Column 4) x Average concentration (Column 5) x 0.7 / 1000.
(The factor 0.7 allows for the remaining nitrogen available in the soil after allowing for volatilisation and denitrification See Effluent Irrigation Manual - Section B-2.3. Factor of 1000 converts units to kg/ha).

7 **Crop type** • Type of crop or pasture grown - used to estimate the nitrogen removed in the crop.

8 **Yield** • Yield of the crop or pasture harvested.

4a. ANNUAL NITROGEN BALANCE

NOTES: Page 2/2

9	**Nitrogen removed**	• Crop yield (Column 8) x % nitrogen in the crop (from Table B-2.3 in Effluent Irrigation Manual) x 10 (Factor of 10 converts units to kg/ha).
10	**Animal Type**	• Type of animals grazed.
11	**Number**	• Average number grazed over the whole year. If area has only been grazed for "n" months then multiply the number of animals for those months by n/12 to get an average for the whole year.
12	**Nitrogen Removed**	• Estimated nitrogen removed by stock over the year (estimated from Table B-2.6 of Effluent Irrigation Manual).
13	**Nitrogen Returned**	• Estimated nitrogen returned in stock wastes over the year.
14	**Residual**	• Net balance of all gains and losses over the year = + Column 2 (if available) otherwise use Column 1 + Column 3 + Column 6 + Column 13 - Column 9 - Column 12

4b. ANNUAL PHOSPHORUS BALANCE

Field: ____________

YEAR	FROM LAST YEAR		FERTILISER	EFFLUENT			CROP			GRAZING				RESIDUAL
	Est. (kg/ha)	Tested (kg/ha)	Amount Added (kg/ha)	Volume (kL/ha)	Conc. (mg/L)	Total Added (kg/ha)	Type	Yield (t/ha)	P Removed (kg/ha)	Animal Type	Ave Stocking (no./ha)	P Removed (kg/ha)	P Returned (kg/ha)	(kg/ha)

4b. ANNUAL PHOSPHORUS BALANCE

NOTES: Page 1/2

YEAR	FROM LAST YEAR		FERTILISER	EFFLUENT			CROP			GRAZING				RESIDUAL
	Est. (kg/ha) 1	Tested (kg/ha) 2	Amount Added (kg/ha) 3	Volume (kL/ha) 4	Conc. (mg/L) 5	Total Added (kg/ha) 6	Type 7	Yield (t/ha) 8	P Removed (kg/ha) 9	Animal Type 10	Ave Stocking (no/ha) 11	P Removed (kg/ha) 12	P Returned (kg/ha) 13	(kg/ha) 14

Note: **For this table, "year" refers to a cropping year. This should be taken as either the beginning or end of the main growing season. The most important thing is to start at the same time each year.**

Columns:

1 **Estimated from last year:** • Estimated phosphorus from the end of last year = Column 14 from previous line. Provides a starting point for assessment of nitrogen balance over this year.

2 **Measured from last year** • Measured nitrogen from the end of last year. If soil tests have been done, the actual test result should be used as the starting point for calculating the overall balance for the year.

3 **Fertiliser added** • Amount of phosphorus fertiliser added during the year (if any)

4 **Effluent volume added** • Total volume of effluent used to irrigate the particular area (field or bay) during the year.

5 **Concentration of phosphorus** • Average concentration of total phosphorus in the effluent (from Record Form 2c).

6 **Total phosphorus added** • Volume of effluent (Column 4) x Average concentration (Column 5) / 1000. (Factor of 1000 converts units to kg/ha).

7 **Crop type** • Type of crop or pasture grown - used to estimate the phosphorus removed in the crop.

8 **Yield** • Yield of the crop or pasture harvested.

4b. ANNUAL PHOSPHORUS BALANCE

NOTES: Page 2/2

9	**Phosphorus removed**	• Crop yield (Column 8) x % phosphorus in the crop (from Table B-2.3 in Effluent Irrigation Manual) x 10 (Factor of 10 converts units to kg/ha)
10	**Animal Type**	• Type of animals grazed
11	**Number**	• Average number grazed over the whole year. If area has only been grazed for "n" months then multiply the number of animals for those months by n/12 to get an average for the whole year.
12	**Phosphorus Removed**	• Estimated phosphorus removed by stock over the year (estimated from Table B-2.6 of Effluent Irrigation Manual)
13	**Phosphorus Returned**	• Estimated phosphorus returned in stock wastes over the year.
14	**Residual**	• Net balance of all gains and losses over the year = + Column 2 (if available) otherwise use Column 1 + Column 3 + Column 6 + Column 13 - Column 9 - Column 12

4c. ANNUAL SALT BALANCE

Field: ____________

YEAR	FROM LAST YEAR		EFFLUENT			LEACHING		SALT BALANCE		
	Est. (kg/ha)	Tested (kg/ha)	Volume (kL/ha)	Conc. (mg/L)	Total Added (kg/ha)	Est. depth (mm)	Salt removed (kg/ha)	Total gains (kg./ha)	Total losses (kg/ha)	Net (kg/ha)

4c. ANNUAL SALT BALANCE

NOTES: Page 1/1

YEAR	FROM LAST YEAR		EFFLUENT			LEACHING		SALT BALANCE		
	Est. (kg/ha) 1	Tested (kg/ha) 2	Volume (kL/ha) 3	Conc. (mg/L) 4	Total Added (kg/ha) 5	Est. depth (mm) 6	Salt removed (kg/ha) 7	Total gains (kg/ha) 8	Total losses (kg/ha) 9	Net (kg/ha) 10

Note: **For this table, "year" refers to a cropping year. This should be taken as either the beginning or end of the main growing season. The most important thing is to start at the same time each year.**

Columns:

1 **Estimated from last year**
- Estimated salt from the end of last year = Column 10 from previous line. Provides a starting point for assessment of salt balance over this year.

2 **Measured from last year**
- Measured salt from the end of last year. If soil tests have been done, the actual test result should be used as the starting point for calculating the overall balance for the year.

3 **Effluent volume added**
- Total volume of effluent used to irrigate the particular area (field or bay) during the year.

4 **Concentration of salt**
- Average concentration of total salt in the effluent.

5 **Total salt added**
- Volume of effluent (Column 3) x Average Concentration (Column 4)/1000 (factor of 1000 converts units to kg/ha).

6 **Estimated depth**
- Estimate of depth to which leaching was carried out.

7 **Salt removed**
- The total amount of salt removed as a result of leaching.

8 **Total gains**
- Total gains = Total added (Column 5)

9 **Total losses**
- Total losses = Salt removed (Column 7)

10 **Net balance**
- Net balance of all gains and losses over the year =
  \+ Column 2 (if available) otherwise use Column 1
  \+ Column 8
  \- Column 9

5a INCIDENT REPORT

Date:

Description of the incident and steps taken to rectify the incident:

Time incident occurred:

Time incident rectified:

Did incident halt operations:

If so, time operations resumed:

Other comments:

Attachments:
1. Photographs
2. Report by tradesperson(s)

5a INCIDENT REPORT **NOTES: Page 1/1**

In any operation, no matter how well designed and operated, there will be occasions when something goes wrong. Irrigation systems are no exception. It is therefore important that some thought is given to what steps can be taken to ensure that when something does go wrong, you are prepared for it.

Three examples of these types of incidents are:

- a travelling irrigator becomes stuck, a pipe breaks or some other system failure occurs, resulting in excess runoff;
- a pump breakdown, pipe failure or excess spray drift and odour are experienced;
- the groundwater is being polluted.

In order to deal with these incidents, it is a good idea to maintain a schedule of:

- where assistance can be obtained, eg tradespeople, regulatory personnel;
- the various regulatory agencies which need to be informed.

The incident report should detail a description of the incident, time of occurrence, whether operations were halted and if so the time they re-commenced, rectification measures taken and any other relevant information such as persons involved and injuries reported etc.

5a INCIDENT REPORT - SUMMARY

Date	Description of Incident

5b COMPLAINT REPORT

Date:

Details of the complainant:

- Name:
- Address:
- Telephone No:

Description of the complaint:

Action taken (if any) to resolve the complaint:

Other comments:

5b COMPLAINT REPORT **NOTES: Page 1/1**

The purpose of this report is to register any operational problems the irrigation system is experiencing. It should include details such as:

- Date of the complaint;
- Name, address and telephone number of the complainant;
- Description of the complaint;
- Action taken (if any) to resolve the complaint.

Complaints from neighbours are likely to arise from one of the following situations:

- runoff of effluent from your property onto a neighbouring property;
- spray from irrigators drifting onto a neighbouring property;
- odours emanating from the effluent being smelt on a neighbouring property;
- noise, from the operation of the irrigation system, being heard on a neighbouring property.

5b COMPLAINT REPORT - SUMMARY

Date	Description of complaint

APPENDIX C-4

FORMULAE AND CONVERSIONS

CONTENTS

C-4.1 Units and Conversions

Volume

mL	-	millilitre
L	-	litre (1 L = 1000 mL)
kL	-	kilolitre (1 kL = 1000 L)
ML	-	megalitre (1 ML = 1000 kL)
m^3	-	cubic metre (1 m^3 = 1 kL)

Area

m^2	-	square metres
ha	-	hectare (1ha = 10,000 m^2)

Mass

mg	-	milligram
g	-	gram (1 g = 1000 mg)
kg	-	kilogram (1 kg = 1000 g)
t	-	tonne (1 t = 1000 kg)

Length

μm	-	micrometre
mm	-	millimetre (1 mm = 1000 μm)
cm	-	centimetre (1 cm = 10 mm)
m	-	metre (1 m = 1000 mm)
km	-	kilometre (1 km = 1000 m)

Time

s	-	second
min	-	minute (1 min = 60 s)
hr	-	hour (1 hr = 60 min)

Electrical

μs	-	microsiemens (1 μS = 1 EC unit)
dS	-	decisiemens (1 dS = 10^5 μS)

Other

Bq	-	becquerel
meq	-	millequivalent
Hz	-	hertz
MHz	-	megahertz (1 MHz = 10^6 Hz)
kPa	-	kilopascal
bar	-	(1 bar = 100 kPa)
ppm	-	parts per million (1 ppm = 1 mg/L = 1 g/m^3)
NTU	-	nephelometric turbidity unit

C-4.2 Formulae and symbols

- **FC = PWP + AWC**

  where

  FC(mm/m) - field capacity
  PWP(mm/m) - permanent wilting point
  AWC(mm/m) - available water capacity

- **W = AWC x d**

  where

  W(mm) = total water available
  AWC(mm/m) = available water capacity
  d(m) = rooting depth

  Assuming that the 'refill' point represents 50% of the total available water within the root zone,

  $$W_p = \frac{W}{2}$$

  where

  W_p(mm) = plant available water

- **TDS ≅ 0.64 x EC** or
  EC ≅ TDS x 1.56

  where

  TDS(mg/L) - total dissolved salts
  EC(μS/cm) - electrical conductivity

- $$W_g = \left[\frac{W_w - W_d}{W_d}\right] \times 100$$

  where

  W_g(%) = gravimetric moisture content
  W_w(g) = weight of wet soil
  W_d = weight of dry soil

  $$W_v = W_g \times \rho$$

  where

  W_V(%) = volumetric moisture content
  ρ(t/m^3) = bulk density of the soil.

- $$\text{ESP} = \frac{\text{ESC}}{\text{CEC}} \times 100$$

  where

  ESP(%) - exchangeable sodium percentage
  ESC(mg/L) - exchangeable sodium concentration
  CEC - cation exchange capacity, expressed in centimoles of positive charge per kg of soil.

- $ET_c = ET_o \times K_c$ and

  $ET_o = E_{pan} \times K_{pan}$

  $\therefore ET_c = E_{pan} \times K_{pan} \times K_c$

  where

  ETc(mm/day) - potential crop evapotranspiration rate
  ET_o(mm/day) - reference crop evapotranspiration rate
  E_{pan}(mm/day) - pan evaporation rate
  K_c - crop co-efficient (or crop factor)
  K_{pan} - pan co-efficient (or pan factor)

- $$\text{SAR} = \frac{Na^+}{\frac{(Ca^{++} + Mg^{++})^{1/2}}{(2)^{1/2}}}$$

  where

  SAR - sodium adsorption ratio
  Na^+(meq/L) - sodium ion concentration
  Ca^{++}(meq/L) - calcium ion concentration
  Mg^{++}(meq/L) - magnesium ion concentration

- $$P = \frac{R}{(N+1)} \times 100$$

  where

  P(%) - probability of a rainfall being exceeded
  R - ranking of yearly rainfall (1 = lowest, 2, 3 etc.)
  N - number of years of record

- $$\mathbf{D = \frac{SM-RM}{ET_p}}$$

  where

  D(days) - irrigation interval
  SM(mm) - full soil moisture capacity
  RM(mm) - refill soil moisture
  ET_p(mm/day) - peak evapotranspiration rate

- $$\mathbf{C_i \times V_i = C_d \times V_d}$$

  where

  C_i(mg/L) - salt concentration of the irrigation water
  C_d(mg/L) - salt concentration of the drainage water
  V_i(mm or L) - volume of irrigation water
  V_d(mm or L) - volume of drainage water

Expressing the salinity in the irrigation and drainage water in terms of electrical conductivity (EC);

$$\mathbf{EC_i \times V_i = EC_d \times V_d}$$

where

EC_i(μS/cm) - electrical conductivity of the irrigation water
EC_d(μS/cm) - electrical conductivity of the irrigation drainage water

Expressing the electrical conductivity of the drainage water in terms of the electrical conductivity of the saturated soil extract:

$$\mathbf{EC_d = 2 \times EC_e \times 1000 = 2000\ EC_e}$$

where

EC_e(dS/m) = electrical conductivity of saturated soil extract

since, in practice, the soil water salinity at field capacity is about twice that for the saturated extract. The '1000' converts dS/m to μS/cm.

$\therefore EC_i \times V_i = 2000\ EC_e \times V_d$

$$V_d = \frac{EC_i\ V_i}{2000EC_e}$$

- $EC_e \cong EC_{1:5}$ **x multiplier factor**

where

$EC_{1:5}$(dS/m) - electrical conductivity as measured in a 1:5 soil solution.

- $$LF = \frac{V_d}{V_i} \times 100$$

$$= \frac{EC_i}{2000EC_e} \times 100$$

$$= \frac{EC_i}{20EC_e}$$

where

LF(%) - leaching fraction