N E W   Z E A L A N D

GUIDELINES

FOR UTILISATION OF SEWAGE EFFLUENT ON LAND

PART ONE: THE DESIGN PROCESS

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forest research

2000
New Zealand Land Treatment Collective and *Forest Research*
Rotorua, New Zealand

ISBN 0 478 11005 7

Citation:

1. Part 1

Robb, C. and G. Barkle 2000. *New Zealand Guidelines for Utilisation of Sewage Effluent on Land. Part 1: The Design Process.* (Edited by L.J. Whitehouse, H.Wang and M. Tomer). Joint publication of the New Zealand Land Treatment Collective and Forest Research. Rotorua, New Zealand.

2. Part 2

NZLTC 2000. *New Zealand Guidelines for Utilisation of Sewage Effluent on Land. Part 2: Issues for Design and Management.* (Edited by L.J. Whitehouse, H.Wang and M. Tomer). Joint publication of the New Zealand Land Treatment Collective and Forest Research. Rotorua, New Zealand.

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The preparation and printing of these Guidelines was supported by funding from:

SUSTAINABLE MANAGEMENT FUND, MINISTRY FOR THE ENVIRONMENT

PREFACE

The *Guidelines for Utilisation of Sewage Effluent on Land* comprise a two-part manual prepared to assist persons who design, consent, manage or monitor land treatment systems for municipal or domestic wastewater in New Zealand. Part 1, *The Design Process,* is intended to provide general guidance on methods and concepts involved in the process of designing land treatment systems. Part 2, *Issues for Design and Management*, provides supporting information, serving as a technical reference on key issues related to designing, operating and monitoring land treatment systems. Further detail can be obtained from sources which are referenced in Part 2.

Note that these guidelines are limited in scope to systems where the final treatment of effluent occurs (or will occur) by irrigating it onto a standing crop that is intended for harvest and economic return. Wetland systems and rapid infiltration basins/trenches are not addressed.

Taken as whole, the manual summarises our current technical knowledge of land treatment systems, and suggests a process that, if followed, will help ensure that the chosen system performs successfully – in terms of providing waste treatment, protecting environmental quality and ensuring public health and safety. Figure 1 on page 4 summarises the process involved in designing a land treatment system and indicates which chapters of Part 2 are useful at various stages of the design. The figure shows how the two parts of the manual relate to one another and can be used together to aid planning, implementation and management.

In preparing this manual, we have assumed the reader already has some basic knowledge of land treatment processes and enough experience to exercise professional judgement in applying the information given to a specific situation. The manual should be useful for:

- *System designers.* The documents will be helpful in describing the process of land treatment design, determining what information is needed to evaluate design alternatives, assessing potential environmental effects of those alternatives, and identifying options for monitoring and mitigating any adverse effects.

- *System owners and operators:* The documents provide system owners and operators with guidance on managing application rates, soils, and crops. They describe how to design and implement a monitoring programme, and how to go about evaluating and improving management of the system.

- *Regulatory authorities:* Although these documents are not intended for restrictive or regulatory purposes, they contain information helpful in evaluating the design of a land treatment system, setting appropriate operational conditions, and interpreting data collected from monitoring. They can be used as a reference for developing regional policies for land treatment.

- *Training and education:* Young professionals and students can benefit from the wide range of information on land treatment that is summarised and referenced in this manual.

Note that we have used the words *sewage effluent* in the title and throughout the text of the manual, thereby clearly stating that the guidelines are concerned with managing wastewater from municipal and domestic sources. Any direct application to other sources of wastewater, of which there are many, is outside their intended use.

The manual does not provide exhaustive coverage in all areas, but includes many references to sources of additional information. Periodic update of the manual is recommended as research progresses and improved technical tools become available.

Acknowledgments

The project to develop these documents was undertaken by the New Zealand Land Treatment Collective, with financial assistance provided by the Ministry for the Environment under its Sustainable Management Fund (Contract 9018). Preparation of Part 1 *The Design Process* was partially funded by the Foundation for Research Science and Technology under PGSF Contract LVL805. Thanks to members of the steering committee: Greg Barkle, Andy Bruere, Colin Cranfield, Leo Fietje, Ants Roberts, Nadaraja Selvarajah, Cliff Tipler, Mark Tomer and Hailong Wang. The efforts of these individuals, and of all the contributing authors are gratefully acknowledged. The project was initiated under the guidance of Jean-Michel Carnus, whose energy and vision were instrumental in obtaining the funding. Thanks to numerous LTC members and others who provided feedback on draft versions of these documents. Formal peer review was provided by Dr. Wade Nutter (UGA, retired), Paul Prendergast (Ministry of Health) and by Leroy Leach, Wally Potts, and Raewyn Simpson of the Hamilton City Council.

INTRODUCTION

Part 1 of this manual, *The Design Process,* provides an overview of a process for designing and implementing a land treatment system for municipal or domestic wastewater. At various stages it points the reader to information from Part 2 that can support this process, including issues relating to obtaining of resource consents under the Resource Management Act (1991) (RMA) and ongoing operation and monitoring of the land treatment system. In practice, many of the design and operational parameters will be driven by the need to avoid or minimise adverse environmental effects as required by the RMA. We assume that readers are involved with situations where wastewater irrigation is being considered as a preferred (or the selected) option for final treatment and discharge of a community's waste water.

The design process is illustrated in Figure 1. There are four stages to the process.

i) Feasibility assessment—*waste characterisation and a regional-scale assessment of key constraints and opportunities for a land treatment site*

ii) Site assessment— *identification and screening of suitable sites*

iii) Design of the system and assessment of environmental effects – *based on assessment of environmental effects, determine application system, site monitoring and management for preferred site(s)*

iv) Final design and implementation—*obtain resource consents and finalise design for tendering*

For each step shown in Figure 1, Part 1 provides an overview of what is involved and lists the types of decisions and information required. The reader is pointed to the appropriate sections in Part 2 that provide details of what needs to be considered and relevant information. A glossary of terms is given in Appendix 1 of Part 2 .

Design of land treatment systems is an iterative process involving technical, biological, chemical, physical, economic and social constraints. Only a few decisions within the design process can be made independently from other decisions and so it is necessary to make initial assumptions and continually revisit and refine assumptions until a final design is reached. The process outlined in Figure 1 is not intended to present the only way of designing a land treatment system. The process must be adjusted to cater for the critical constraints and political environments of each land treatment system.

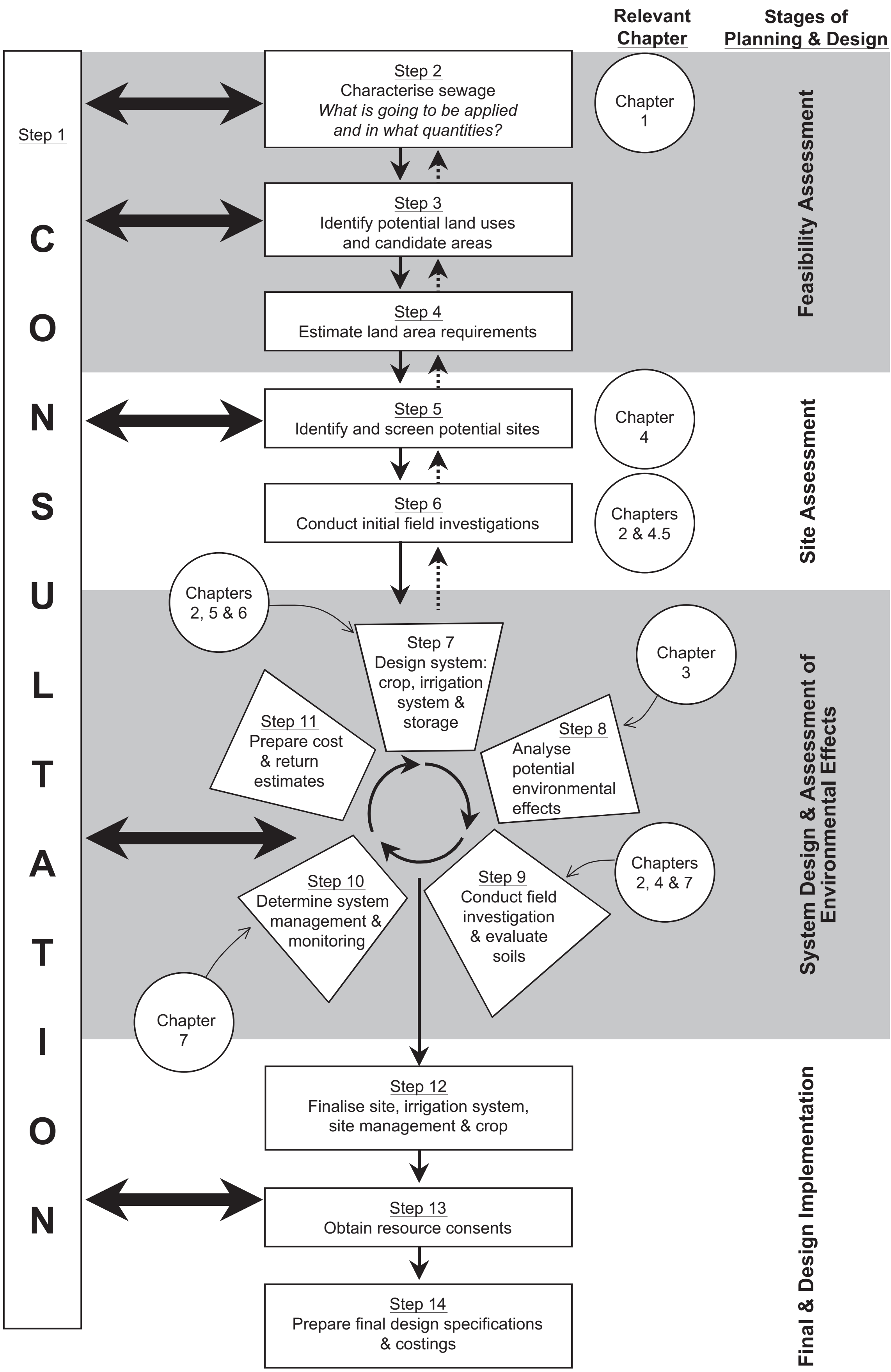


Figure 1: Design process for a land-based effluent treatment system. Chapters refer to Chapters in Part two.

An effects-based approach

The design process presented here is consistent with the consultative and effects-based approach of the RMA. This consistency requires that the guidelines do not adopt a standards-based or prescriptive approach to environmental effects. A standards-based approach would state, for example, that "at all land treatment sites, concentrations of nutrient X in leachate to groundwater must be kept below concentration Y". By contrast, an effects-based approach states that "the concentration of X in groundwater should not be increased to a level that limits the use of groundwater or adversely affects the function of dependent ecosystems".

An effects-based approach assesses the environmental effects of an activity in the context of the receiving environment and the values associated with that environment. Whether an effect is considered significant depends on the uses of and values associated with a site, surrounding land, soil, air and water resources. The acceptability of an environmental effect therefore differs from location to location and it is not appropriate for this manual to give prescriptive values for items such as buffer distances or concentrations of nutrients in leachate. Instead the guidelines provide sufficient information for the environmental effects of a land treatment site to be quantified and informed trade-offs among potential sites and system designs to be made.

Once a land treatment system is designed, prescriptive site-specific standards such as water quality limits can be set and made enforceable through resource consent conditions.

FEASIBILITY ASSESSMENT

Step 1—Establish decision-making and consultative framework

Key questions

- ***What is the purpose of the consultation?***
- ***Who is going to be consulted at each stage in the design process?***
- ***How will the consultation occur?***

Overview

Consultation, both with the owners or users of the effluent treatment scheme and with other stakeholders, will be essential throughout the design process. One of the biggest hurdles in getting a land treatment system established is overcoming negative public perception, and opposition from potential neighbours.

There must be a system for participation of Iwi and other stakeholders representing community groups, local or central government agencies and other interest groups (e.g., environmental, industry or recreational groups). Adequate public consultation can make the consent process simpler by highlighting and addressing as many issues and concerns as possible prior to the formal resource consent process. In addition, these groups can help identify potential sites, possible markets for crops and possible adverse environmental effects.

Method

In many cases the local community is represented by a Territorial Local Authority and close liaison between the system designer and Council staff is essential. Local councils will have experience of consultative processes and can provide advice on appropriate methods, the groups to consult and how to establish initial contact. Councils may choose to run the consultation process themselves using established frameworks and contacts. It is important that a clear framework of responsibilities is agreed and documented by all parties involved in the development of a land treatment system.

Consultation with local Iwi is the appropriate method for determining how a land treatment proposal affects Maori and their cultural and traditional relationships.

Suggested References

Baxter, T. and Fookes, T. 1996: Introduction to public participation and consultation: A reference manual. In: *Public participation and consultation within the RMA*. Local Authorities Upskilling Project Workshop Manual No 2. University of Auckland.

Fitzgerald, G. 1990: Community-based and consultative techniques. In: C.N. Taylor *et al*., *Social Assessment: Theory, Process and Techniques.* Centre for Resource Management, Lincoln University, New Zealand. 202–220.

Whareaitu, T. (Compiler) 1991: *Consultation with Tangata Whenua: A Guide to Local Authorities in Meeting the Consultation Requirements of the Resource Management Act 1991*. Ministry for the Environment. Wellington.

Step 2—Characterise sewage

> ***Key question***
> - ***What is going to be applied and in what quantities?***

Overview

This step characterises the sewage in terms of effluent volumes, nutrients, organic matter, toxic constituents and pathogens.

Method

The list given below indicates information needed to characterise the flow and composition of the effluent ***(Part 2, Chapter 1)***. The data required are for the effluent as it will be applied to the land and so must take into account effects of the sewage treatment system and storage facilities on flow rate and effluent components. Any seasonal fluctuation of sewage volumes and constituents needs to be considered, as does any "special feature" of the effluent such as high concentrations of salts or heavy metals. To adequately characterise flows, both the average flow rate and peak flow rates (daily and instantaneous) are required.

Information requirements

- Design population—current population and growth projections
- Design lifetime of site (anticipated)
- Average dry weather flow rate (m^3/day)
- Peak wet weather flow rate (m^3/day and m^3/s)
- Effect of available storage on peak water flows
- Nutrient loading—concentrations of N, P, K and S in effluent
- Organic loading in effluent
- Dissolved constituents (e.g., sodium, chloride, dissolved solids)
- Amount of suspended material
- Types and concentrations of micro-organisms
- Concentrations of potentially toxic elements (heavy metals, trace organic compounds)
- Oil and grease
- pH

(Note: Any seasonal variations in these factors must be described)

Step 3—Identify potential land uses and candidate land areas

> ***Key questions***
> - ***How could the site be used?***
> - ***What are the markets for potential crops?***
> - ***Where are the suitable areas that might be considered for land treatment?***
> - ***What are the most important environmental concerns in these areas?***

Overview

This step is a critical exercise that sets the context for choosing and assessing potential sites and many subsequent design decisions. It is a broad-scale assessment of land within reasonable distance of the effluent source. It essentially combines design expertise with local knowledge to determine:

- feasible uses of a land treatment site
- the compatibility of local soils, topography, water bodies and climate with a land-treatment system
- the sensitivity of the receiving environment to the potential effects of land-treatment, and possible influences on the human uses and values associated with that environment.

Method

This step is a brain-storming exercise to identify the key issues and options for a potential land treatment system. What are the likely land-uses and crops? Is land purchase a feasible option or can access to a site be guaranteed by an agreement or leasing? Is there ample land available or is land limited? If land area is limited, are options such as improved effluent treatment or storage worth considering? What are likely to be the key environmental issues and public concerns? Many of these questions will be reviewed in detail during system design, but need to be addressed initially in this step so that the feasibility of land treatment can be assessed.

Identification of locally feasible land-uses and potential end-uses of the crop

Potential uses of land treatment sites include: production of agricultural or forest products, development of recreational areas (e.g., golf courses, recreational forests), and buffer areas around public facilities such as airports. The emphasis at this stage is on identifying locally available opportunities and not on an assessment of individual sites.

For example, what crops can be grown successfully in the local climate and soils, if there is irrigation? What local markets exist for various crops or timber? Forestry may be more viable in regions where forestry infrastructure already exists. Direct grazing of the site is an option, but requires larger land areas than other uses and raises significant issues related to nitrogen leaching and pathogens getting into milk or meat. Production of green-feed and pasture silage for off-site use is a better option, providing there are potential buyers within reasonable distance of the site. Alternatives to land purchase, such as leasing land or supplying effluent to existing farmers, can be considered if secure access to a site can be ensured

Public Health Guidelines provide advice on suitable land uses for varying quality of secondary or tertiary treated effluent ***(Part 2, Appendix 4)***.

Potential users should be asked about their requirements for crop quality and palatability. For example, dairy farmers using crops from a land treatment site will be concerned about potential pathogens and associated market risks. Once feasible options have been identified, assumptions can be made about likely crops and the market for harvested material.

Technical and environmental feasibility

The recommended approach is an analysis of broad-scale information on land-use, climate, soils, topography, surface and groundwater bodies, and social, cultural, public health and economic issues. This information is used to eliminate unsuitable land areas and assess on a regional basis which areas are most suited to a land treatment system ***(Part 2, Section 4.2)***. The most suitable areas are flat to gently inclining sites with naturally well-draining soils containing reasonable amounts of organic matter and located away from residential developments, but close to the treatment plant or ponds. The further a land treatment site is located from existing dwellings the less likely that odour and drinking water quality will be a concern. Areas close to surface water bodies, subject to surface flooding, upstream of domestic water supplies or with high water tables should be avoided. The list of possible environmental effects given in Step 8 can be used as a checklist to determine potential environmental and public health issues ***(Part 2, Chapter 3)***. Once suitable areas have been identified, an assessment of the critical or important environmental effects can be made and these effects used in Step 4 to provide an initial estimate of the land area required.

In considering environmental effects, thought should be given, not just to the treatment site, but also to potential effects from end-use of the crop. The end-use determines the final destination of any effluent constituents taken up by the plants. End-uses which only transfer the potential for adverse effects from the land treatment site to another site should be avoided.

Information requirements

- Location of sewage source (treatment plant)
- Land-use and zoning maps
- Soil maps
- Climate information (including wind data)
- Topographical maps
- Regional groundwater and surface water information
- Locally grown crops and land uses
- Potential markets

Step 4—Estimate land area requirements

> ***Key question***
>
> - ***Based on available information, approximately how much land area will be needed?***

Overview

The aim of this step is to "ball park" the required land area so that potential sites within the candidate areas can be selected for evaluation and screening. The amount of land required is determined by environmental-effect considerations and irrigation-system design. However, environmental effects and design options depend on the specifics of a site. Therefore to start the design process, an estimate of land area is needed so that potential sites can be selected and more detailed assessments can proceed. This initial estimate will be refined during detailed design.

Method

The recommended approach is to carry out preliminary calculations to estimate the effluent loading rate, application depth and rate of application that should keep the important environmental effects within acceptable limits. The land area needed to apply the effluent at the most limiting of these rates or depths can then be calculated. During the broad-scale assessment of Step 3, the designer will have identified the key environmental considerations, some of which will determine the land area needed. In most New Zealand land treatment systems nitrogen loading or hydraulic considerations are the limiting factors. However, neither of these should be assumed to be the limiting factor without looking at other possibilities such as phosphorus, heavy metals or pathogens ***(Part 2, Sections 2.3 and 2.4)***.

At this stage, estimating acceptable effluent application depths and rates requires a number of assumptions, given that potential sites have not yet been selected nor the sensitivity of the receiving environment analysed in detail. However, if reasonable assumptions are made and documented they can be reviewed at any stage in the design process. All assumptions, sources of data, and methods used should be recorded in the design documentation.

Because this step requires initial estimates of several key design parameters it is advisable to involve someone with design experience in similar land treatment systems. Designers have often developed "rules of thumb" or "accepted loading rules" for nutrient or other application rates that can be used to give an initial land area estimate. If these rules are used, care must be taken to check that the rules were developed for similar environmental conditions and are appropriate to use in the current situation.

The practice of using existing fertiliser nitrogen inputs to determine the allowable amount of effluent nitrogen must be used with caution for two reasons. Firstly, the leaching loss under the existing agricultural system may or may not be having an acceptable effect on the environment. Secondly, fertiliser is strategically applied when the crop has the need and ability to respond to additional nitrogen inputs. Under an effluent system the effluent is applied on a much more regular basis and is not matched as closely to the plants' seasonal requirements.

Nitrogen considerations

A preliminary nitrogen budget can be set up to estimate how much nitrogen can be applied each year (kg/ha). A full balance of nitrogen inputs and outputs requires that the nitrogen applied in effluent is matched by crop uptake, denitrification, volatilisation and losses to leaching ***(Part 2, Sections 2.3.1, 3.4.3, 6.1.2 and 6.3.3).*** An example calculation of a preliminary nitrogen budget is given in Box 4.1 on page 12.

Hydraulic loading considerations

There are three factors to consider when setting hydraulic loading for a land treatment site:

i) The ability of the soil to accept the effluent at the design application *rate* without associated surface runoff or waterlogging of soil layers. This rate will be determined by the lowest near-saturated hydraulic conductivity in a soil profile ***(Part 2, Sections 2.2 and 4.6.2)***.

ii) The ability of the soil to accept the design application *depth* without direct flushing of contaminants through the system. The longer effluent is retained in the root zone, the greater the effectiveness of the land treatment system. The residence time of effluent will be maximised if soil moisture contents are kept below field capacity, which implies a deficit irrigation regime. In a deficit irrigation regime, effluent can only be applied when the soil water content is less than field capacity, and, to allow for rainfall, the depth of effluent applied should not bring the soil to field capacity. Deficit irrigation is frequently used in freshwater irrigation where the amount of water irrigated can be matched to crop uptake. In land treatment systems, effluent is delivered to the site throughout the year whether the crops need it or not. For most of New Zealand, deficit irrigation is very unlikely to be an option because it would require sufficient storage capacity to store all effluent over the winter months.

   In most land treatment systems, there will be times when irrigation onto soils that are at or near field capacity will be inevitable. During detailed design, one of the key constraints will be determining a winter irrigation strategy that allows for high winter effluent flows and soil moisture levels yet keeps the effects of leaching loss at acceptable levels (see Step 7). At this stage an initial estimate of land area required can be made based on an assumed irrigation frequency and on a limiting irrigation depth that can be applied during wet periods. A method for calculating this depth is given in Box 4.2 on page 13.

iii) The final consideration is the effect that the increased vertical drainage from the site will have on the local groundwater. It is inevitable under a land treatment system that the vertical drainage from the site will be increased. The impacts that can occur due to this increased drainage include: raised water tables, development of horizontal seepage and springs, as well as changes in groundwater flow direction due to local mounding conditions ***(Part 2, Section 3.4)***. A method for calculating the vertical drainage is given in Box 4.3 on page 13.

The calculations in Boxes 4.1 to 4.3 are intended to provide estimates of required land area, based on readily available information such as published soil and groundwater data. At the more detailed design stages, these data will need to be reviewed because published maps cannot be guaranteed to be sufficiently detailed or up-to-date to show localised variation and changes in land-use.

It is worthwhile considering the role that storage can play in determining land area. The hydraulic loading can be varied by the use of storage, whereas, in a design with no storage, the daily volume of effluent generated by the sewage treatment plant must be applied and may require a substantial land area to cope with peak effluent flow rates. Storage may be required to deal with extreme rainfall events and periods when irrigation cannot happen due to down time for cultivation/harvest, maintenance, frozen ground or snow, and flooding or heavy rain. Storage facilities will also require additional land area. Issues relating to storage are further discussed in Step 7 on detailed design.

Once the land area needed for irrigation has been calculated, the net area must be increased to allow for buffer zones along boundaries ***(Part 2, Section 7.9)***, separation distances to any surface water courses and irregularly shaped areas that cannot be irrigated. As a starting point, it is recommended that the area of land required is assumed to be 25% larger than the net area required for effluent application. Allowance could also be made for future expansion of the land treatment site.

Information requirements

(Assuming hydraulic and nitrogen considerations dominate)

- Effluent characteristics and flow rates (from Step 2)
- Estimates of crop rooting depth and nitrogen uptake
- Monthly rainfall, potential evapotranspiration data and crop factors
- Estimates of "acceptable" hydraulic and nitrogen flows to groundwater
- Indicative soil properties for local soils
  - hydraulic conductivities (minimum value in soil profile)
  - surface infiltration rates,
  - water content at field capacity and field saturation.

<u>*Box 4.1 Calculation of preliminary nitrogen budget*</u>

A preliminary nitrogen budget can be used at this stage based on reasonable assumptions about the various components of the nitrogen balance. As an initial approximation it is reasonable to set denitrification and volatilisation to zero.

The preliminary nitrogen budget then becomes:

Nitrogen applied in effluent (kg/ha) = nitrogen in harvested crop (kg/ha) + leaching loss (kg/ha)

For grazed systems, the "nitrogen in harvested crop" will be replaced with a term to account for nitrogen that is removed through animal production.

An estimate of an acceptable leaching loss will depend on the receiving groundwater and its uses. Nitrogen leaching occurs even in natural undisturbed ecosystems. In most land treatment systems increased leaching loss will be inevitable even if the crop is capable of taking up all the applied nitrogen. This occurs because crop uptake is generally greatest in the spring and summer, whereas effluent volumes are highest during the winter. Later in the design process, a daily simulation of soil water dynamics and crop uptake, based on a more comprehensive nitrogen budget, will be used to determine leachate flows and assess environmental effects.

At this stage, there are two options for determining a leaching loss to enter in the above equation:

- *Information on acceptable nitrogen leaching into similar groundwater systems could be used as the leaching loss.*
- *The leaching loss could be set to zero in the equation, which will give a conservative estimate of land area.*

<u>*Box 4.2 Calculation of effluent application depth to minimise direct flushing of contaminants*</u>

In most land treatment systems, there will be times when irrigation onto soils that are at or near field capacity will be inevitable (NOTE 1). The winter period is likely to be the critical time as crop uptake is at its lowest while effluent flow rates and rainfall are also usually at their highest. However, the potential for freshly applied effluent to be flushed through the root zone can be minimised if the depth of effluent applied at each irrigation is insufficient to saturate the soil. At this stage an initial estimate of land area required can be made based on a limiting irrigation depth that can be applied during wet periods. (Note: *Effluent should not be applied to saturated soils or onto any soils while there is surface ponding).*

The following equation can be used to determine the limiting irrigation depth

Limiting irrigation depth (mm) = (% soil water content at field saturation – % soil water content at field capacity) /100 x rooting depth (mm) x 0.5

Note: If field saturation data are not available, 0.93 x total porosity can be used as an estimate.

This is a preliminary estimate of the limiting irrigation depth (mm) during wet periods when soils are at field capacity. If effluent application depths are kept at or below this depth, and assuming soils have drained to field capacity, the effluent applied will not bring the soil to saturation and some allowance is made for rainfall. The land area required to apply peak effluent flows (taking account of storage) at this depth can be used as an initial estimate of land area required. During more detailed design, irrigation depth and frequency are determined based on keeping hydraulic and contaminant flows to groundwater below acceptable levels.

Irrigation is often applied on a rotational basis and a realistic assumption of a return period must be made in order to estimate land area. The return period influences how long effluent is retained in the root zone and available to the soil/ plant system. It must allow for adequate soil aeration particularly during winter and match as closely as possible the ability of the soil/plant system to assimilate sewage effluent constituents. Return period has a major influence on land area required. If the effluent can be applied at the design depth every five days, then the land area needed will be half that required if the same design depth can only be applied every ten days.

NOTE 1 For soils where preferential flow is a major component of drainage, irrigation is only suitable under deficit irrigation (i.e. for irrigation, soil moisture must be less than field capacity), and large storage capacities will be required. For soils that are prone to cracking and hence preferential flow, soil moisture levels under deficit irrigation must be carefully managed.

<u>*Box 4.3 Calculation of limiting effluent application depth to prevent adverse effects on groundwater*</u>

*The winter period is likely to be the critical time for groundwater hydraulic loading as natural water tables are usually highest at this time, evapotranspiration rates are at their lowest and effluent flow rates and rainfall are also usually at their highest. An estimate is needed of the maximum amount of vertical drainage that can occur over the winter months without causing adverse effects due to groundwater mounding (**Part 2, Sections 3.4.4 and 4.5.2**). This amount of drainage (referred to as "acceptable monthly drainage") will depend on regional groundwater characteristics and depths to groundwater during winter.*

The following equation can be used to determine the monthly depth of hydraulic loading over the winter months that keeps the vertical drainage below the acceptable amount.

Monthly depth of hydraulic loading (mm) = acceptable monthly drainage (mm) – monthly rainfall (mm) (NOTE 1) + monthly evapotranspiration from the crop (mm)

The monthly timestep of this equation is appropriate at this preliminary stage of the design. Later in the design process this hydraulic budget will be re-calculated on a daily basis taking into account soil storage, the crop planted, the irrigation system and the management regime implemented.

NOTE 1 If available, monthly rainfall figures used should relate to a recurrence interval such as the 5-year or 10-year monthly rainfall, rather than average values. Average monthly values can be used for evapotranspiration as winter evapotranspiration rates do not vary to the same extent as rainfall.

SITE SELECTION

Step 5—Identify and screen potential sites

> ***Key question***
>
> - ***Which are the most suitable sites for land treatment?***

Overview

This step involves identifying potential sites from within the candidate land areas and assessing these sites based on readily available information. For example, the assessment may include information on land use, topography, climatic factors, soils, proximity to neighbours, location of groundwater aquifers and distance to surface waters, and knowledge that exists within territorial authorities and local communities.

Method

A list of potential sites can be prepared by examining the candidate land areas (from Step 3) for suitably sized properties based on the required land area (from Step 4) ***(Part 2, Section 4.3)***. The potential sites are then screened to select the most suitable site(s).

Site screening combines all the existing information on the potential sites into an assessment framework to determine a preferred site or sites ***(Part 2, Sections 4.4 and 4.5)***. The recommended approach is to use a matrix to score each site according to key factors. The matrix should concentrate on those factors that differ most between sites and therefore highlight the major tradeoffs to be made among sites. The key factors will differ from situation to situation but must cover the following aspects:

- technical feasibility
- environmental sustainability
- Tangata Whenua acceptability
- social acceptability
- economic viability.

Information requirements

- Regulatory controls—district and regional plans etc.
- Land-use and ownership of site, surrounding properties and potential pipeline routes
- Topography
- Climate information and regional variation, including wind speed and direction
- Soil maps and soils information
- Hydrogeology and surface water hydrology
- Location of neighbouring dwellings, sites significant to Tangata Whenua, wells, recreation areas etc.
- Social, cultural and economic factors

Step 6—Conduct initial field investigations

> ***Key question***
>
> - ***What are the key parameters that require field measurements before design can proceed?***

Overview

This stage involves field investigations at the preferred site(s) to verify existing information, provide local details, and identify site constraints that will need to be considered at the design stage. It overlaps with the more detailed field testing outlined in Step 9.

Method

The type and detail of field data collected in this initial step will vary depending on the level of existing knowledge and dominant environmental considerations. At this stage, field investigations are likely to concentrate on soils. Field testing should enable mapping of important soil physical properties including soil type, texture, depths of each layer in the soil profile, hydraulic conductivities and water holding capacity ***(Part 2, Chapter 2 and Section 4.6)***. Field investigations of groundwater (e.g., installation of piezometers) may be required if the existing information does not provide a clear picture of the aquifer and groundwater movement under a site ***(Part 2, Section 4.7)***. A full list of the type of field data that can be collected is given in Step 9.

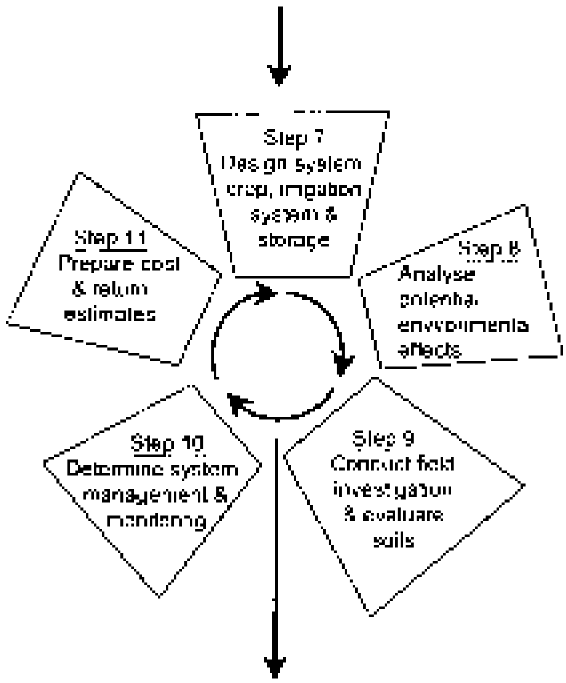
Field testing may be carried out on a prioritised and iterative basis. The level of detail required for field testing increases as the design process moves from confirming a preferred site through to detailed design of the land treatment system. For example, soils could be mapped at a few of the top ranked sites, after which a more detailed physical and chemical analysis is done at the site with the most suitable soils.

Once sufficient soils information has been gathered, a check should be made on the land area requirements. A preliminary nitrogen budget and assessments of hydraulic loading (application rate and depth, winter hydraulic loading to aquifer) were done in Step 4, but these required a number of assumptions because potential sites had not yet been selected. Now that there is more information on the likely soils, the assumptions should be revisited and a check made on the required land area.

Information requirements

- Depth to unconsolidated material, gravels or the water table (high and low levels)
- Soil structure and texture—macropores, low permeability layers
- Soil water holding capacity and water content at field capacity and field saturation
- Surface infiltration rate
- Near-saturated and unsaturated vertical hydraulic conductivity for each soil layer
- Groundwater flow directions and aquifer hydraulic properties
- Nature of any confining layers in the groundwater system

SYSTEM DESIGN AND ASSESSMENT OF ENVIRONMENTAL EFFECTS



Steps 7 to 11 (system design—assessment of environmental effects—field investigations—system management and monitoring—cost estimates) are iterative. For example, the amounts of water and contaminants reaching the groundwater (important information for assessing environmental effects) depend on the crop selected, the application method and daily climate. Adequate assessment of the environmental effects of this leaching may require further investigation of the aquifers under the site. And to avoid or minimise these environmental effects one method may be a feedback system that alters irrigation management in response to soil moisture measurements. Adding this component has implications for monitoring systems, irrigation system design, site operation and costings. Therefore, the design process outlined in these five steps should be considered as a set of interactive parallel processes rather than a series of cut and dried steps.

Step 7—Design the land treatment system

> ***Key questions***
>
> - ***What type of irrigation system(s) will be used and how?***
> - ***What crop(s) will be grown, and how will they be managed and harvested?***
> - ***How much storage is required?***

Overview

This step is the design of the land treatment system and its method of operation. Requirements for ongoing management and maintenance of the site are covered later in Step 10, but are closely linked to design decisions made at this stage. Potential end-uses and markets for the crop must now be confirmed. Values used in the characterisation of the waste carried out in Step 2 may need to be reviewed and any additional effects of pipe transportation and storage on effluent quality or flow rates to the site taken into account.

The methods and design criteria applying to each of the three key aspects—irrigation system, crop, and storage—are outlined separately below.

Method—Design of irrigation system

Design of the irrigation system essentially involves determining how to apply the annual effluent load in a way that avoids surface runoff, maximises soil and plant renovation of effluent constituents and minimises leaching to groundwater. Detailed engineering design of pipes and application systems is included in Step 14. The irrigation parameters which are important for determining effluent renovation and environmental effects are:

- effluent application rates (mm/hr)
- the depths of effluent (mm) applied at each irrigation
- the return period (days).

Other considerations include potential for creation of spray drift and aerosols and filtration requirements. An irrigation application method can be selected once the necessary design characteristics have been determined ***(Part 2, Section 5)***.

Significant variation in soil properties or topography will need to be taken into account in the design. It may be appropriate to vary irrigation management and systems across a site.

Effluent application rate

The application rate must be matched to the capacity of the soil to absorb and transmit water. The limiting value is the smaller of the surface infiltration rate and the near-saturated vertical hydraulic conductivity of the least permeable soil layer ***(Part 2, Sections 2.2 and 4.6)***. The influence of rainfall also needs to be taken into account by selecting a design rainfall intensity (mm/hr). In choosing a design rainfall intensity, the designer must consider what will happen in rainfall events of greater than this intensity. Can irrigation be deferred? If not what are the implications of surface re-distribution and ponding during very heavy rain events? Application rates for various irrigation systems are given in **Section 5.4** of **Part 2**.

Irrigation depth and frequency

The irrigation depth and return period can vary throughout the year and will be set by an irrigation strategy. The strategy sets the criteria that are used to determine where and at what depth effluent will be applied on a given day. Estimates of limiting application depths and return periods (as calculated in Boxes 4.2 and 4.3) can be used to guide initial selection of an irrigation strategy. The final strategy will be designed to avoid or minimise any adverse environmental effects associated with drainage and leaching to groundwater and also maintain soil moisture conditions suitable for the crop ***(Part 2, Sections 2.2, 3.3.6, 3.4.4, 4.6 and 4.7)***.

A simple soil water balance, as used in the design of freshwater irrigation systems, is the best method for assessing alternative irrigation strategies. Daily simulations of evapotranspiration, rainfall and irrigation, combined with the water-holding capacity of the soil, are used to predict daily drainage flows. Calculations are on a daily basis because soil moisture dynamics are driven by the daily variations in climate, crop uptake and effluent application. Climatic data collected over several years are used to assess the range of variation in climatic conditions. The same soil moisture balance model can also be used in ongoing monitoring of a land-treatment site ***(Part 2, Section 7.8.1)***.

Irrigation strategies which match effluent application as closely as possible to crop requirements will produce less drainage and hence increase the time effluent is held in the root zone. Except in the summer months, the volume of effluent will exceed crop requirements and one of the key design constraints will be determining an irrigation strategy for winter periods that keeps both hydraulic and nutrient flows to groundwater below acceptable levels.

One option for an irrigation strategy is to use a fixed depth and return period throughout the year, another is to use an indicator, such as soil moisture levels, to determine effluent application. A deficit irrigation strategy based on daily soil moisture measurements (see Hydraulic Loading Considerations in Step 4) is considered “good management practice” for freshwater irrigation, and adopting such practices can minimise leaching losses and thus maximise soil renovation of effluent constituents and crop uptake of nutrients. However, unlike freshwater, effluent is delivered to the site throughout the entire year whether the crops need it or not. During winter, using soil moisture conditions to initiate irrigation is likely to result in a number of days when there is no or insufficient land area that meets the criteria for irrigation. An irrigation strategy may need to differentiate between summer and winter conditions.

The results will help identify an irrigation strategy that best suits the climate, crops and soils at a land treatment site and minimises the potential for adverse effects on groundwater.

Design criteria

- *Check effluent application rate against soil surface infiltration rate.* If the irrigation rate plus design rainfall intensity (mm/hr) is less than the surface infiltration rate all water will generally be absorbed and large-scale surface ponding and runoff is unlikely to occur during irrigation.
- *Check effluent application rate against limiting hydraulic conductivity.* If the irrigation rate plus design rainfall intensity (mm/hr) is less than the lowest near-saturated hydraulic

conductivity of the soil profile, water will not accumulate at low-permeability layers and significant water logging of surface or subsoils is unlikely to occur.

- *Check that minimum return period allows for adequate residence time and soil aeration.* The longer effluent is retained in the root zone, the greater the opportunity for the soil/plant system to assimilate or treat the effluent constituents. When there is drainage, the length of time that the drainage water has been held in the root zone will be influenced by the irrigation return period. Return periods must also be long enough to allow the soil to aerate. On free-draining soils, provided applications are low enough to prevent saturation, the soil can be irrigated every day and remain aerated. On other soils, there must be a suitable time between irrigations to allow soils saturated by irrigation and/or rainfall to drain and aerate.
- *Check that soil moisture conditions throughout the year are suitable for the proposed crop.* Soil moisture levels can be checked to ensure they provide enough, but not too much, water to the crop. If necessary, supplementary freshwater irrigation can be used over the summer to maintain soil moisture and avoid putting the crops under moisture stress and hence reducing nitrogen uptake. For land treatment systems the aim is to maximise nutrient renovation, and not necessarily to make the most efficient use of water.
- *Check depths of water draining to groundwater for "acceptable" hydraulic and contaminant loads to aquifers.* The daily drainage depths can be summed to weekly, monthly or annual totals and used to calculate nutrient, contaminant or hydraulic flows to groundwater. These are essential inputs to the groundwater component of the environmental effects assessment (see Step 8) and depending on the destination of the groundwater, can also influence other environmental aspects such as surface water quality. A method for calculating the nitrogen load to groundwater, given the results of the soil moisture balance, is shown in Box 7.1 on page 22. Similar procedures should be followed for all effluent components that have potential to cause adverse environmental effects.

The time scale over which the loadings are considered will depend on how the loadings and the receiving environment vary over the year. For example, winter is likely to be the critical time for hydraulic loading as natural water tables are usually highest at this time, evapotranspiration rates are at their lowest and effluent flow rates are at their highest.

Method—Crop selection

Plants play an important role in land treatment systems, by taking up water and nutrients in the waste, providing cover and preventing erosion, and by maintaining the soil physical properties and biological activities through rooting. Ensuring good health and growth of the crop is vital to maximise nutrient removal and maintain site productivity. Waste application can, however, be detrimental to plants and it is important to recognise this in crop selection. Long-term considerations include the sustainability of the crop, build up of toxins or other contaminants in the soil and the security of the proposed market. In some situations, the best option may be a combination of crops ***(Part 2, Section 6)***.

Design criteria

- *Check crop uptake of effluent constituents.* Crops have different nutrient uptake rates and the rates can vary significantly throughout the year. Calculations of nutrient removal must only consider the crop biomass to be removed from the site. Estimates of yields and nitrogen uptake for the most commonly used crops have been published ***(Part 2, Sections 6.2.4 and***

6.2.5). However, it is preferable to use local data on growth and uptake if such data are available. Seasonal variations in production and nutrient uptake are important. A crop that grows throughout most or all of the year will allow better utilisation of effluent than one that can only take up nutrients for a short period.

- *Check nutrient availability, given effluent irrigation, with crop requirements.* Probable crop fertility problems can be predicted based on the effluent constituents, soil properties and crop fertility requirements. The tolerance of a crop to potential salt or sodicity problems should be assessed. Some crops may require the addition of fertiliser to obtain sufficient nutrients (e.g., P, Ca, Mg, K) ***(Part 2, Section 7.7.2)***.
- *Check suitability of soil moisture for crop requirements.* Plants may be at increased risk of developing problems with disease and rooting if soils become too wet. Outbreaks can be difficult to predict and are best addressed by a monitoring system that detects problems early, in combination with a flexible irrigation regime that allows operators to reduce or defer irrigation ***(Part 2, Section 7.7)***. Low soil moisture conditions during the summer can be remedied by freshwater irrigation.
- *Check suitability of soil quality for crop.* Adverse chemical conditions in the soil, such as high heavy metal concentrations or high or low pH, can affect crop growth and health.
- *Check establishment, cultivation and harvest requirements of the crop*. Cultivation and harvesting equipment may cause compaction if the soil is too wet. A crop that requires less frequent cultivation for renewal is preferable because cultivation increases the risk of nitrate leaching especially during fallow periods. Tree removal or cultivation increase the rate of nitrogen mineralisation, and are followed by a period of low growth and nitrogen uptake as the crop is re-established. The compatibility of the crop with the proposed irrigation system also needs checking. Crops that need to be harvested at a set time of year do not provide as much flexibility as ones that can be harvested on a rotational basis throughout the year ***(Part 2, Section 6.2.3)***.
- *Check suitability of irrigated crop for proposed end-use.* A land treatment system involving cropping relies on there being an end-use for the crop. Some of the sewage constituents, particularly heavy metals and pathogens, have the potential to render a crop unsuitable for particular end-uses.

Method—Storage

Adequate storage must be provided for times when climatic conditions or other factors halt or reduce effluent irrigation (***Part 2, Section 7.6.1***). Storage plays a key role in determining how well a land treatment system will cope with winter loading rates. In addition, storage can be used to attenuate peaks in effluent flows. A land treatment system that always applies the daily volume of effluent generated by the sewage treatment plant may require a substantial land area to cope with peak effluent flow rates.

Design criteria

- *Consider how the system will cater for the peak daily and instantaneous peak loads*. Is there sufficient storage to absorb excess flows when effluent flow rates exceed the capacity of the land treatment systems? If not, where will the excess water go and is that acceptable in terms of the environmental effects?

- *Consider what will happen to the effluent if irrigation is suspended.* Storage may be required to retain effluent at times when irrigation must be suspended due to surface ponding, repair or maintenance of irrigation equipment, down time for planting, cultivation, fallow periods or harvest, or during unsuitable climatic conditions such as frozen ground, snow, flooding or heavy rain.

- *Does the irrigation strategy incorporate using stored effluent?* If storage is used, allowance must be made in the system design, land area requirements and/or irrigation strategy for reduction of storage volume. There will be times when both flows from the storage reservoir and incoming flows need to be applied to the land.

Information requirements

- Soil physical and chemical properties
- Effluent characteristics and loading
- Daily climate information—rainfall and potential evapotranspiration
- Crop rooting depth, evapotranspiration factors
- Crop yield and nutrient uptake
- Crop establishment, cultivation and harvest requirements
- Tolerance of crop to various soil conditions
- Markets for harvested crop and transportation options
- Length of growing season
- Effects of effluent quality on crop
- Public health requirements for public access, stock access and consumption of crops

<u>Box 7.1 Calculation of nitrogen loads to groundwater.</u> The amount of nitrogen available to be leached (N_{excess}) can be estimated from the monthly nitrogen budget ***(Part 2, Sections 2.3.1, 3.4.3 and 6.1.2)****, and the following rules of thumb.*

N_{excess}(kg/ha) = Nitrogen applied in effluent (kg/ha) – denitrification – volatilisation – crop uptake of nitrogen – nitrogen in animal product *(all units are kg/ha)*

Nitrogen uptake by crop or animal is relevant only for that proportion of the crop or animal product that will be removed from the site. Crop uptake varies depending on the time of year and the age of crop. For forestry systems, crop uptake varies over the life of the trees. For grazed systems, crop uptake will be zero but volatilisation and denitrification losses apply to both the effluent and the animal faeces and urine.

The above equation determines the amount of nitrogen available to be leached but not necessarily the amount that will leach. If there is little or no drainage in a given month not all of the available nitrogen will leach and some will be stored in the soil. In the following month there will be more nitrogen available than the above monthly budget will calculate. Nitrate peaks have been detected in early autumn due to lower crop uptake and no leaching over summer. To provide for this effect, a storage term can be added to the above equation and an estimate of the amount of nitrogen leached made on the basis of the amount of drainage occurring in the month. The amount of excess nitrogen which is unable to be leached because of insufficient drainage is considered to be stored in the soil and calculated from:

$$N_{stored} = N_{excess} - N_{leached} \qquad \text{(all in kg/ha)}$$

Incorporating these terms into the monthly nitrogen budget gives:

$$N_{excess} = N_{applied\ in\ effluent} + N_{stored\ \ in\ previous\ month} - \text{denitrification} - \text{volatilisation} - \text{crop uptake of N} - N_{in\ animal\ product} \qquad \textit{(all units are kg/ha)}$$

The amount of nitrogen leached is a function of N_{excess} **and** the amount of drainage.

$$N_{leached} = \beta \times N_{excess}$$

where

$\beta = 1$ if the monthly drainage depth exceeds the water holding capacity of the soil; or

β = (Drainage depth/Water holding capacity of the soil) if the monthly drainage depth is less than the water holding capacity of the soil

Notes:

- *This approach does not recognise distribution of drainage flows over a month. In situations where the day-to-day distribution of nitrate flows is an environmental concern, then calculations should be carried out on a daily basis.*

- *The above equation does not take into account the increased mineralisation of organic N that can occur during cultivation and harvest. Such disturbances will result in an increase in nitrogen excess. In addition, fallow periods or lower crop uptake as the crop re-establishes following harvest/cultivation will increase the amount of nitrogen available for leaching. In situations where a significant disturbance is anticipated the effects on nitrogen leaching should be examined in more detail.*

Step 8—Analyse potential environmental effects

> ***Key question***
>
> - ***What are the potential environmental effects and how significant are they?***

Overview

Many of the design and operational parameters will be driven by the need to avoid or minimise adverse environmental effects as required by the RMA. This step verifies the existing information on environmental, social, economic and cultural issues, provides further detail and analysis, and identifies environmental constraints that will need to be taken into account in the system design, operation and monitoring. The results can be used to prepare the Assessment of Environmental Effects that must accompany the resource consent application (Step 13).

Method

Chapter 3 of Part 2 details the possible environmental effects associated with a land treatment site and provides methods for quantifying those effects. The following list summarises potential effects that should be considered. Because the RMA is concerned with effects on the environment, the list relates to receiving environments (e.g., air, land and water) rather than particular contaminants.

Effects on air (Part 2, Section 3.2)

- Spray drift, aerosols, odour, pathogens

Effects on land (Part 2, Chapter 2 and Section 3.3)

- Soil contamination—pathogens, heavy metals and other toxic constituents, salt toxicity
- Soil structure—sodicity, organic matter, mechanical effects of cultivation and harvest
- Effects on neighbouring land from spray drift, runoff and wind erosion

Effects on groundwater (Part 2, Sections 3.4, 4.5.2 and 4.7)

- Pathogens, nitrate-nitrogen
- Mounding, groundwater flows

Effects on surface water (Part 2, Sections 3.5 and 4.5.3)

- Water quality changes—through runoff, spraydrift or groundwater contamination
- Flow quantity changes due to increased inflows or the effect of groundwater level changes on stream-aquifer interactions
- Effects of flood events

Human health and ecosystem effects (Part 2, Sections 3.2, 3.3, 3.4 and 3.5)

- Aerosols, spray drift, odour
- Groundwater quality and flow, position and depth of wells, and locations of springs and zones of surface water recharge.
- Use and values of surface water
- Direct contact with pathogens in soil, crop or effluent—staff and visitors to site
- Palatability and quality of crop, particularly pathogens and heavy metals

Economic, social and cultural effects (Part 2, Section 3.6)

- Property values and land treatment costs
- Amenity values**,** visual and aesthetic effects
- Effects on Tangata Whenua values

Information requirements

- Cropping and application system design (Step 7)
- System management, monitoring and feedback requirements (Step 10)
- Effluent characteristics (Step 2)
- Soil characteristics and ability to renovate effluent constituents (Step 6)
- Microbial survival rates ***(Part 2, Section 2.4 and Appendix 4)***
- Climatic data
- Atmospheric dispersion modelling
- Surrounding land use and location of residences, water supplies, recreation areas, ecologically and culturally significant sites
- Hydrogeology and aquifer hydraulic properties
- Groundwater modelling
- Surface water hydrology
- Topography
- Property value information
- Capital, operational and maintenance costs of land treatment
- Revenue from crop and potential market risks
- Public and interest group definition of social and cultural effects

Step 9—Conduct field investigations and evaluate soils

> ***Key questions***
>
> - ***Which parameters require further field investigations in order to accurately describe system performance and environmental effects?***
> - ***How will the soils and plants perform as an effluent treatment medium?***

Overview

This step allows for further field investigation to help clarify environmental effects, provide final design parameters and assess monitoring options. The information will allow a detailed assessment of the soils' ability to renovate effluent constituents. These field investigations and methods can be used to provide baseline information and then later will be expanded into an ongoing monitoring and management system ***(Part 2, Chapter 2 and Sections 4.6, 4.7 and 7.8)***.

Method

The list of information requirements given below indicates the type of field data that can be collected from a land treatment site. The level of detail required will depend on the accuracy of existing information, the specific nature of the system design and monitoring programme and the significance of various environmental effects.

A detailed description of field investigation of soils is given in Balks, 1995 ***(reprinted in Part 2, Appendix 2)***.

Properties which need to be assessed are:

- ability to receive hydraulic loading
- ability to retain effluent in the rooting zone and minimise potential for leaching
- ability to renovate or absorb nutrients, dissolved constituents and micro-organisms
- suitability for growing proposed crop(s)
- ability to receive effluent loading without creating conditions unsuitable for the crop(s)
- ability to withstand mechanical pressure from cultivation and harvest equipment.

Information requirements

Field data for evaluating effluent application rate. Key measurements are:

- surface infiltration rate
- near-saturated and unsaturated vertical hydraulic conductivity for each soil layer.

Soil field data for evaluating irrigation depth and frequency, and determining drainage depths. Key factors are:

- depth to unconsolidated material, gravels or the water table (high and low levels)
- depth of each layer in the soil profile and boundary transitions
- soil colour, structure and texture—macropores
- soil physical properties—bulk density, field capacity, porosity
- available water content (plant available) water for each layer.

Soil field data for evaluating suitability for crop growth, cultivation and harvest, and for determining crop uptake and leaching of effluent constituents. These should include:

- phosphorus retention, pH, organic matter, cation exchange capacity, total carbon
- soil nutrient levels—N, P, K Mg, Ca and Na
- other soil quality indicators including biological properties ***(Part 2, Section 7.8.1)***
- soil physical properties—bulk density, field capacity, porosity.

Collection of archive soil samples.

Surface water and hydrogeological field data required to assess environmental effects (***Part 2, Sections 4.7 and 7.8.3***). These should include:

- groundwater level variation (throughout the year and from year to year)
- groundwater flow directions and hydraulic properties
- nature of any confining layers in the groundwater system
- existing groundwater and surface water quality (including variation).

Reference

Balks, M.R. 1995: Field Investigations of Soil Properties. *In* New Zealand Land Treatment Collective Technical Review No. 13. "*Land Treatment Systems: Design and Monitoring*".

Step 10—Determine system management and monitoring

Key question

- ***How will the land treatment system be monitored and managed on an ongoing basis?***
- ***What are likely risks and contingency plans?***

Overview

Land-based treatment systems operate within a dynamic natural system in which crops, soils and climate interact. Even a very detailed design process, based on extensive field trials, will not be able to precisely predict the performance or environmental effects of a land treatment system. Many of the assumptions used in design may need to be refined during actual operation. With careful management, particularly early in the operation of the system, these refinements can be made with minimal adverse effects on the system performance or the environment. To achieve this, ongoing monitoring is required and results must be reviewed regularly to determine if the system is functioning properly and if its management and operation can be improved ***(Part 2, Chapter 7)***.

Method

Effective site management and monitoring procedures are the key to a successful land treatment system. Requirements and responsibilities for day-to-day operation, environmental monitoring, public health protection, reporting etc. need to be detailed in written plans that are accessible and understood by anyone who carries out activities described in them ***(Part 2, Section 7.4)***. Management plans must set guidelines for site security, public access, visitor safety and staff health and safety. Adequate staff training and close communication between the designer and operators are also essential. Box 10.1 on page 28 contains a suggested outline of a site management and monitoring plan.

The monitoring system should be designed and organised to:

- track effluent and nutrient loadings
- assess the condition of crops or stock on the site
- record operational and environmental performance
- clearly specify how the monitoring results are to be used to adjust operation of the site
- ensure consent conditions are met, including any external review or auditing of site management
- provide a comprehensive, but efficient, database that helps the manager keep abreast of operational and environmental data on a timely and systematic basis
- identify events and conditions that signal if a review of the management or monitoring system is needed.

Monitoring design must detail the parameters to be monitored, the frequency and methods of sampling and analysis, and information feedback ***(Part 2, Section 7.3.2)***. The monitoring required to manage the system will be considerably more than is specified within the resource consent conditions. A recommended suite of monitoring activities is provided in **Table 7.2 of Part 2**. The frequency of monitoring and the time lag between causing an effect and identifying it are important considerations. For example, a contaminant may take years to reach a monitoring well once it leaches below the root zone of the soil. Management of that contaminant should therefore include conservative management of effluent loading rates, and monitoring of shorter term indicators such as the amount of the contaminant in soil or crops.

Planning for construction and commissioning phases

Adequate planning of the construction and commissioning phases is very important to the success of a land treatment site. What takes place between final approval of a system design and it becoming fully operational will largely determine whether operation goes as anticipated. Problems resulting from construction can be minimised by making specifications flexible and tailored to account for specific attributes of a site. A phased start-up of the new system should be planned to allow standing crops and soil biota to adjust, and address any unforeseen problems with the system. Other considerations include baseline monitoring, staff training, and public communications ***(Part 2, Section 7.2)***.

Information Requirements

The information requirements of a site management and monitoring plan are detailed below.

Box 10.1 Suggested outline of site management and monitoring plan

- *Introduction and system objectives*—design approach, key environmental constraints, purpose of monitoring
- *Land treatment system description*—covers site and layout, topography, soils, water resources.
- *Process operation*—covers infrastructure, operational procedures, responses to monitoring data, equipment specification and manuals
- *Maintenance procedures*—routine or automated ***(Part 2, Section 7.5)***
- *Site Administration*—record keeping system, staff responsibilities, staff training
- *Effluent Management and Monitoring*—covers irrigation schedule and variation. Monitoring quality and quantity of effluent, and application depths ***(Part 2, Section 7.6)***.
- *Vegetation (or Stock) Management and Monitoring*—covers crop requirements, harvesting, market requirements, probable pest, disease and fertility problems. Responses to monitoring results ***(Part 2, Section 7.7)***.
- *Environmental Monitoring*—covers monitoring programmes for soil, climate, air, surface and groundwater, and performance levels, warning flags and subsequent actions ***(Part 2, Section 7.8)***
- *Buffer zones*—layout and logic ***(Part 2, Section 7.9)***
- *Consent and Compliance Monitoring*—covers consent conditions and monitoring requirements, external review or auditing, liaison contacts for consent authorities
- *Public use and liaison*—covers control of access, site security, public information and education, complaints recording and response, role of community advisory groups in ongoing site operation, liaison with neighbours, community groups or representatives
- *Health and safety procedures*
- *Contingency*—procedures in the event of a spill, accident or equipment failure

Step 11—Prepare cost and return estimates

> ***Key questions***
>
> - ***How much will the land treatment system cost to install and operate?***
> - ***What is the anticipated revenue from the site?***

Overview

This step estimates the capital and operational cost of land-treatment. It is important to assess the cost of options as early as possible to ensure all the proposed options are affordable. Cost and return estimates can be prepared for a few potential options to allow cost-benefit comparison by local community and stakeholders.

Method

The following references provide indicative costs for irrigation hardware, crop revenues, construction materials and installation.

Financial Budget Manual. Updated annually. Lincoln University, Department of Farm and Horticultural Management.

Rawlinson's New Zealand Construction Handbook. Updated quarterly. Rawlinson and Co Ltd, Wellington.

Information requirements

- Land cost or cost of ensuring access to site if not purchased (e.g., if leasing)
- Crop establishment costs, input and harvesting costs, and anticipated crop revenue
- Indicated capital cost of transfer, pipeline, power supply, pumping and application systems
- Estimated operating and maintenance costs
- Monitoring costs
- Development costs for roading, storage areas, and site preparation.
- Cost of existing effluent treatment

FINAL DESIGN AND IMPLEMENTATION

Step 12—Finalise site, irrigation system, site management and crop

> ***Key question***
>
> - ***Which combination of crop, irrigation system, site(s) and site management/ monitoring provides the best balance between achieving acceptable environmental effects and minimising cost?***

Overview

Steps 7 to 11 will evaluate a number of alternative designs and culminate in the recommendation of a preferred option that meets environmental standards and offers the best balance between minimising adverse environmental effects and minimising cost.

Method

- Discuss and confirm all design decisions with stakeholders
- Finalise design application rates and irrigation strategy, and select appropriate irrigation system.
- Finalise crop selection and management
- Prepare site management plan
- Prepare draft monitoring plan
- Document cost and return estimates
- Document design decisions and rationale

Some detailed engineering design, such as pipe sizes or location of storage reservoir, may be required at this stage, depending on the level of detail required for resource consent applications under the RMA. Case law states that the proposed activities must be described in sufficient detail to “enable those who might wish to make submissions on it to be able to assess the effects on the environment, and on their own interests”

Step 13—Obtain resource consents

Key questions

- ***What resource consents are required?***
- ***What are the requirements for resource consent application(s)?***

Overview

The proposed land treatment activities must comply with provisions of the RMA. The number and type of resource consents required will depend on rules in district, city and regional plans for land-use and discharge of contaminants to air, water and possibly land.

In order to provide sufficient information in the resource consent applications design decisions will need to have been made on the irrigation system, crop and site management and monitoring. Although the formal consent process is not initiated until this final stage, consultation with owners, council consent staff and potentially affected parties should be ongoing throughout the design process. The level of information required in a resource consent application must be sufficient to enable those affected by the proposal to assess its effects on the environment and on their own interests. Consultation will help identify issues of concern and allow them to be addressed as early as possible in the design process.

Method

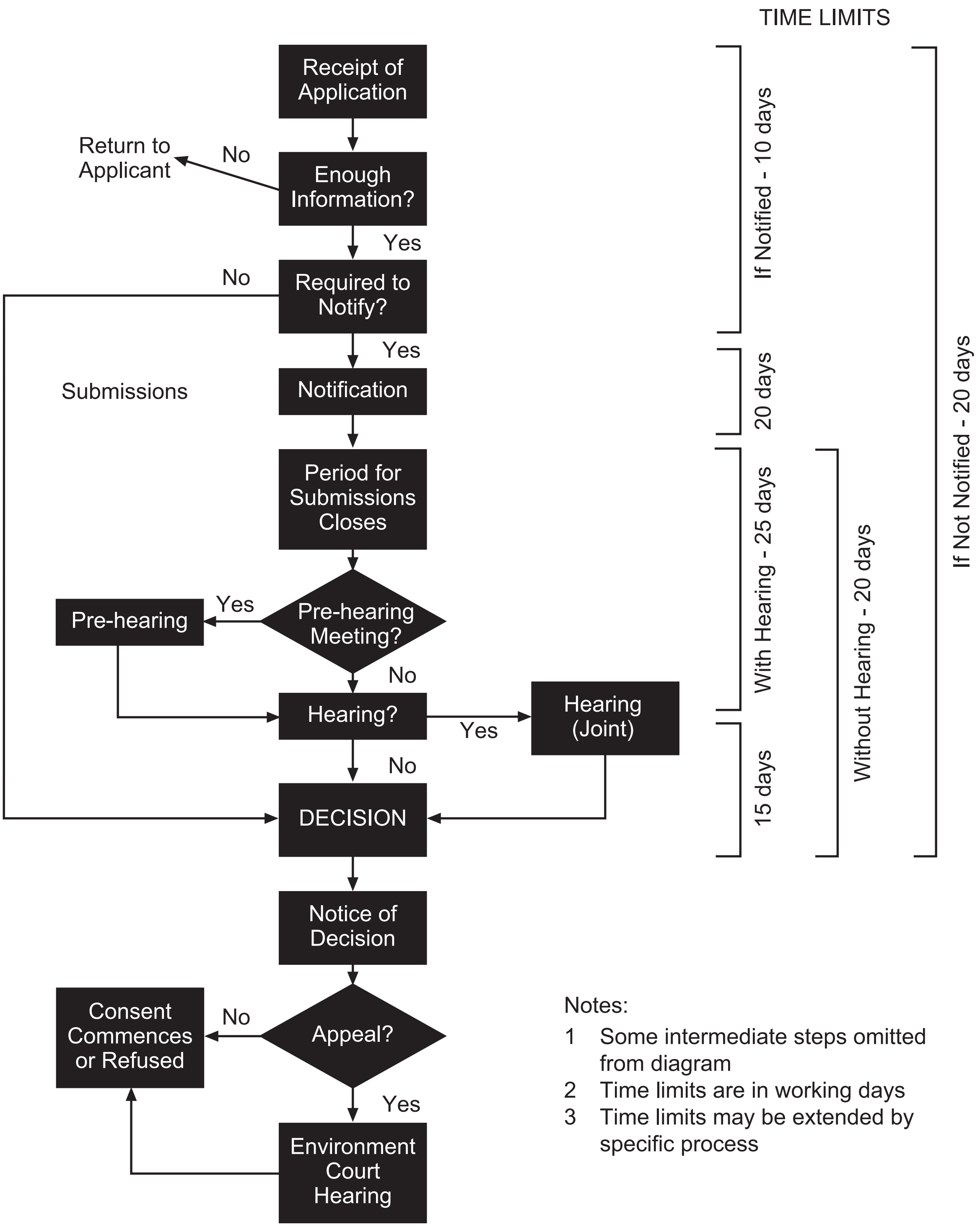
The following resource consents will usually be required:

- a land–use consent from the district/city council for the operation of a land treatment site
- a discharge permit from the regional council to discharge contaminants onto or into land in circumstances that may result in contaminants entering water
- a discharge permit from the regional council to discharge contaminants to air.

Consents to take water may also be required if there is any freshwater irrigation or other water use on site. A further discharge permit may be required to allow for any seepage or leakage from storage ponds. If site works involve any disturbance to the bed of a surface water course, a consent will be required from the regional council. Field testing, for example the installation of groundwater testing bores, may require consent or compliance certificates from regional or district councils.

The procedure for processing resource consents is shown in Box 13.1 on page 32.

Box 13.1 Resource consent processing pathways (source: Environment Waikato)



Notes:

1 Some intermediate steps omitted from diagram
2 Time limits are in working days
3 Time limits may be extended by specific process

The requirements for a resource consent application are set out in S.88 of the RMA. Documents supplied must provide a description of the proposed activity and its location, plus an assessment of the environmental effects. The application must also cover any information requirements specified in plans or regulations and list all other necessary consents.

Requirements for the "assessment of environmental effects" in the application are: (1) that the level of detail corresponds to the scale and significance of the actual or potential effects and (2) it is prepared in accordance with the Fourth Schedule of the RMA. Fourth schedule requirements include:

- a description of possible alternative locations and methods
- details of the nature of any discharges to the environment and the sensitivity of the receiving environment to adverse effects, including any alternative methods or receiving environments for disposal
- description of mitigation methods to help prevent or reduce environmental effects
- identification of persons interested in or affected by the proposal, the consultation undertaken with them and any response to their views
- description of how the effects will be monitored, and by whom
- effects on neighbourhood and local community, landscape, ecosystems and habitats, natural and physical resources, and natural hazard risk.

In making its decision, under S.104 of the RMA, the consent authority is required to "have regard to":

- actual and potential effects on the environment
- any relevant national, regional or district policy statement or plans, and other regulations
- nature of the discharge and the sensitivity of the proposed receiving environment to adverse effects, and the applicant's reasons for making the proposed choice
- any possible alternative methods of discharge, including discharge into any other receiving environment
- significant adverse effect on aquatic life.

In addition, under s.107 which relates to the discharge of contaminants in circumstances which may result in a contaminant entering water, consent authorities cannot grant consent if, after reasonable mixing, the contaminants or water discharge is likely to give rise to the following:

- the production of any oil or grease films, scums or foams, or floatable or suspended materials
- any conspicuous change in colour or visual clarity
- any emission of objectionable odour
- the rendering of freshwater unsuitable for consumption by farm animals.

A consent can be granted if these effects are present, but only if the discharge is temporary, or associated with necessary maintenance work, or if there are other exceptional circumstances.

Information requirements

Most of the information can be taken directly from Step 8 (Analyse Potential Environmental Effects) in which relevant information on system design, management and monitoring (Steps 7 and 10), and the consultation process was previously compiled. Information on the environmental effects of the existing or alternative disposal systems will be required and can help put the environmental effects into context.

Step 14—Prepare final design specifications and costings

Key questions

- ***How will the effluent be reticulated to and around the site?***
- ***What size and materials are the pumps, pipes, etc.?***
- ***How and where will storage be provided?***
- ***What are the capital, installation and running costs?***
- ***What are the details of the site management and monitoring system?***

Overview

This step covers the detailed engineering design of the irrigation, distribution and storage hardware. The site management and monitoring plans will be confirmed at this stage, and include resource consent conditions. Details of site construction and commissioning will be confirmed.

Much of this stage involves standard engineering design procedures for pipe design and irrigation systems adapted to the specific characteristics of the effluent. These procedures are not covered in these guidelines; readers are referred to the texts below and to manufacturers of effluent irrigation systems.

Jensen, M.E. (Ed). 1983: *Design and Operation of Farm Irrigation Systems*. American Society of Agricultural Engineers. Michigan.

NZS 5103. 1973:. *The design, installation and operation of sprinkler systems*. SANZ Wellington.

Water Pollution Control Federation 1981: *Design of Wastewater and Stormwater Pumping Stations. Manual of Practice No FD-4 Facilities Development*. WPCF Washington DC.

SUMMARY

Steps 1 to 14 guide those charged with making decisions on treatment of municipal or community wastewater, in a logical progression, through the issues and decisions involved in designing a land treatment system.

The outcome of this process will be:

- a land treatment system that will perform successfully in terms of providing waste treatment, protecting environmental quality, and ensuring public health and safety
- an informed community and informed stakeholder groups
- appropriate resource consents
- documentation of the design process, rationale, key parameters and assumptions
- documentation and drawings of the system design appropriate for use in the tendering process
- a site management and monitoring plan.

These guidelines are intended to provide an understanding of a complex design process. Correct implementation will generally require the input of local knowledge as well as assistance and advice from those with experience in land-based waste treatment.