On-site Wastewater Management in the Auckland Region

January 2021

Guideline Document 2021/006

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Draft

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Preface

What is the purpose and scope of this guideline?

This document, *On-site Wastewater Management in the Auckland Region* (GD06), provides technical guidance for the design, installation, and management of on-site wastewater systems, in accordance with site and soil conditions encountered in Auckland.

The aim of this guideline is to safeguard against public health risks and minimise adverse environmental effects that have the potential to occur from on-site wastewater treatment systems. The content of this document is applicable for households and institutions (such as schools, commercial and public facilities) in the Auckland region up to the flow limitation of 3,000 L/day (3 m^3/day) and occupancy of 15 or less people.

GD06 applies current good practice to align on-site wastewater system planning and management activities with land use planning and environmental protection. A key feature of this approach is the promotion of a practical risk assessment and remediation framework that is applied throughout the whole lifecycle of on-site wastewater systems. This guideline provides technical design guidance to support Auckland Council's regulatory requirements.

The primary intended audience of this document are professionals, designers, developers and contractors, within the on-site wastewater industry. It also includes useful guidance for council consent processors and compliance officers, as well as developers and householders.

GD06 updates and replaces TP58 - *Auckland Regional Council Technical Publication No.58 On-site Wastewater Systems: Design and Management Manual* (Third Edition, 2004). The regulatory aspects of TP58 are not included in GD06. These will be more appropriately located in the Auckland Unitary Plan following a Plan Change process.

What new inclusions and approaches are in this guideline?

Relevant technical background and design approaches, previously presented in TP58, have been retained in GD06, with further clarification on some essential design aspects, designed to align with current good practice and Auckland's unique needs. Key differences between TP58 and GD06 are set out below.

Significant differences between TP58 and GD06

Item	GD06
Site and soil evaluation	A revised site and soil evaluation chapter has been included to provide users with both theory and technical guidance. More background is provided regarding the importance of functional soils, guidance on sample collection, testing, and analysis.
Soil classification	The seven soil categories presented in TP58 have been adjusted to align with those of AS/NZS 1547:2012 which has six categories.
Slopes and setbacks	Guidance is provided regarding appropriate methods for managing wastewater on slopes and limits for steep slopes. Setback distances have been adjusted for different types of infrastructure and receiving environments based on soil type.
Design loading rates	Guidance is provided on revised design loading rates for different soil categories.

Item	GD06
Construction and operation and maintenance	This expanded chapter provides details of how on-site wastewater systems should be constructed, commissioned and how they should be operated and maintained.
Risk management	This new chapter provides guidance on risk management and design for risk mitigation. Examples are provided to guide the user on risk assessment processes in the context of on-site wastewater systems.

Who was consulted in the preparation of this guideline?

Throughout the document development, drafts were distributed to, and consultations were undertaken with:

- Council/government staff who regularly use the previous TP58, or other on-site wastewater system guidelines
- Focus groups of recognised on-site wastewater system practitioners and contractors
- Mana Whenua representatives.

Future revisions

Auckland Council intends to provide future revisions to this guideline periodically in response to changes in legislation, policies, technologies, national standards and feedback from industry. There is a feedback form available to download at http://www.aucklanddesignmanual.co.nz along with this document, and which can be sent to onsiteww@aucklandcouncil.govt.nz.

Acronyms and Abbreviations

Abbreviation	Definition
AEP	Annual exceedance probability
ARC	Auckland Regional Council
ARPHS	Auckland Regional Public Health Service
AS/NZS	Australia/New Zealand Standards
AS-AWTS	Activated sludge - Aerated wastewater treatment system
ATP	Aerobic treatment plant
AUP	Auckland Unitary Plan
AWTS	Aerated wastewater treatment system
BOD	Biochemical oxygen demand
CFU	Colony forming unit
COD	Chemical oxygen demand
Ct	Concentration x Contact time
DIR	Design irrigation rate
DLR	Design loading rate
DRP	Dissolved reactive phosphorous
ETS	Evapotranspiration seepage
FAC	Free available chlorine
FOG	Fats, oils and grease
FC	Faecal coliform
GIS	Geographic information systems
HRT	Hydraulic residence/Retention time
KISS	"Keep infiltration systems shallow"
K_{sat}	Saturated soil permeability measure (expressed in m/day)
LPED	Low pressure effluent distribution
LPP	Low pressure pipe
MBR	Membrane bioreactor
MLSS	Mixed liquor suspended solids
MPN	Most probable number
N	Nitrogen

Abbreviation	Definition
NH_4	Ammonia
NH_4-N	Ammoniacal nitrogen
NIWA	National Institute of Water and Atmospheric Research Ltd
NTU	Nephelometric turbidity unit
O&M	Operation and maintenance
OSET NTP	On-site effluent treatment national testing programme by the Water New Zealand Small Wastewater and Natural Systems Special Interest Group (SWANS-SIG)
P	Phosphorus
PBR-AWTS	Packed bed reactor aerated wastewater treatment system
PBR	Packed bed reactor, includes sfPBR (sand filter), rtPBR (recirculating textile)
PCDI	Pressure compensating drip irrigation
POMMS	Programmed Operation, maintenance and Management Scheme
PVC	Polyvinyl chloride
RBC	Rotating biological contactor
RMA	Resource Management Act
SWANS-SIG	Water New Zealand Small Wastewater and Natural Systems Special Interest Group
TC	Total coliform
TKN	Total kjeldahl nitrogen
TN	Total nitrogen
TOC	Total organic carbon
TP(#)	Technical publication (number)
TP	Total phosphorus
TSS	Total suspended solids
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
UV	Ultraviolet
WOF	Warrant of Fitness

Definitions

Term	Definition
Activated sludge process	A biological wastewater treatment process by which biologically active sludge (concentrated biomass) is agitated and aerated with incoming wastewater. The activated sludge is subsequently separated from the treated wastewater (mixed liquor) by settlement, and most of it is returned to the process. Treated effluent is then discharged to a land application system.
Advanced secondary treatment	Aerobic biological treatment process, including settling and/or filtering of wastewater. Advanced secondary treated wastewater is expected to be equal to or better than 15 g/m^3 5-day biochemical oxygen demand and 15 g/m^3 suspended solids. Wastewater treatment units that can provide advanced secondary treatment are predominantly sand filters, advanced textile filters and packed bed reactors. Some high performing, stabilised and closely monitored aerobic treatment plants (refer AWTS) can also achieve the same discharge quality.
Advanced tertiary treatment	Further treatment of advanced secondary effluent by nutrient reduction and disinfection.
Aerobic	Having molecular oxygen as part of the environment, or growing/occurring only in the presence of molecular oxygen (as in "aerobic organisms").
Anaerobic	Characterised by the absence of molecular oxygen, or growing in the absence of molecular oxygen (as in "anaerobic bacteria").
Backflow	The undesirable reversal of water flow from private plumbing back into the public water supply system.
Blackwater	Liquid or solid human body waste and the carriage waters generated through toilet usage.
Contaminated land	Land with hazardous substances in or on it that are reasonably likely to have significant adverse effects on the environment and potentially, human health. Hazardous substances can seep through the soil and contaminate the groundwater, which can affect nearby land or waterways.
Decentralised wastewater system	Systems which provide treatment and disposal of wastewater for small communities at, or close to, the point where the wastewater is generated.
Design irrigation rate	The loading rate that applies to the irrigation of a land application area with effluent of a secondary quality. It is expressed in L/m^2/day or mm/day.
Design loading rate	The loading rate that is applied to the distribution of treated effluent to the infiltration surface of a land application system. It is expressed in L/m^2/day or mm/day.
Desludging	Removal of accumulated sludge and scum from the septic tank.
Domestic wastewater	Wastewater originating from households or personal activities including toilets, urinals, kitchens, bathrooms and laundries. Includes wastewater flows from facilities serving staff/employees/residents in institutional, commercial and industrial establishments, but excluding commercial and industrial wastes, large-scale laundry activities and any stormwater flows.
Effluent	Sewage, water, or other liquid, partially or completely treated, flowing out of a wastewater treatment unit, or out of a component of an on-site wastewater treatment system.

Term	Definition
Evapotranspiration	Sum of evaporation and plant transpiration from the land and water surface to the atmosphere. Evaporation accounts for the movement of water to the air from sources such as soil, canopy interception and water bodies. Transpiration accounts for the movement of water within a plant and the subsequent loss of water as vapour through stomata in its leaves.
Filtration	Process of removing particulate matter from water by passing it through a porous medium, such as sand.
Greywater	Domestic wastewater drained from sinks, tubs, showers, baths, dishwashers, clothes washers and other non-toilet sources. (Greywater does not include waste from garbage grinders.)
Groundwater flow	The movement of water through the saturated zone below the water table and is a function of permeability. Includes the flow of water underground and the flow of water from saturated zones into a body of water.
Hydraulic conductivity	Saturated hydraulic conductivity (K_{sat}) in m/day is the measure of soil permeability used in on-site wastewater management.
Infiltration	The process of water or treated effluent (distributed on, or under, the ground surface) entering the soil.
Infiltration rate	Rate at which water (or treated effluent) enters the soil. The infiltration rate depends on soil texture and soil structure. Expressed as mm/day or L/m^2/day
Land application system	The type of land application (dripper irrigation, trench, bed, mound etc.) sized to the daily wastewater flow and wastewater loading rate for discharge/distribution of treated wastewater into the ground for final treatment. Referred to in the Auckland Unitary Plan as “land application disposal system”.
Land application area/field	The area of land used to disperse/dispose of treated wastewater. Provides further treatment within the soils and through plant uptake.
Long term acceptance rate	The steady state rate that a land application system can absorb and treat primary or secondary effluent through the bacterial films which accumulate on the system’s infiltrative surfaces. This steady state condition is established over time (weeks or months) dependent on treated effluent quality and soil characteristics. It allows for loss to the soil by percolation through the base and sidewalls of the land application system and other losses to the atmosphere by evaporation and evapotranspiration.
Non-potable water	Water which is not considered to be safe to drink.
On-site wastewater management	The collection, treatment and dispersal of domestic wastewater effluent within the property boundaries of the dwelling/facility generating the wastewater flow.
On-site wastewater system	The entire on-site management system including treatment and land application of effluent. Also “On-site wastewater management system”.
On-site wastewater treatment unit	The unit that provides treatment of the effluent prior to discharge/distribution to land application area/s.
Orifice	A tank outlet, or pipe orifice, which restricts outflows. This will be of a specific diameter and comprise: • A plate with a machine drilled hole in it or • A short length of pipe discharging to a non-sealed pipe system, if the design outlet diameter coincides with a common pipe size or • A drilled hole in an effluent pipeline distribution lateral.

Term	Definition
Overland flow path	The surface routes taken by stormwater on its way to streams or the sea.
Percolation	The process by which water travels, primarily downwards, through an unsaturated soil matrix.
Permeability	A calculated value derived from the rate at which a head of liquid infiltrates a particular soil, usually measured in m/d and often referred to as K_{sat}.
Potable water	Water which is considered safe for drinking purposes. This is usually provided by a public water supply but can be sourced from rainwater tanks in areas where there is no public water supply available.
Primary treatment	The separation of suspended material from wastewater by settlement and/or flotation in septic tanks, primary settlement chambers etc. prior to effluent discharge to either secondary treatment process or to a land application system.
Public water supply	A reticulated supply of potable water operated by the local authority.
Reserve area	An area set aside for future use as a land application area to replace or extend the original land application area.
Runoff	The movement of water above the ground (overland flow processes) and may include stormwater, but also water from exfiltration (such as seepage or groundwater surfacing).
Secondary treatment	Aerobic biological treatment process, including settlement and/or filtering of wastewater. Secondary treated wastewater is expected to be equal to or better than 20g/m^3 5-day biochemical oxygen demand and 30g/m^3 suspended solids. Wastewater units that can provide secondary treatment include well designed and operated aerated treatment plants (refer to Section D).
Setback	The separation distance that an on-site wastewater system must be situated from any facility boundary, water body or other limiting factor.
Slope	Slope is the rise or fall of the land surface. In this document, slope is expressed in degrees accompanied by the equivalent % grade (see slope conversion table below).
Sewage sludge	The semi-liquid solids settled from wastewater.
Suitably qualified and experienced person	A person who can provide sufficient evidence to demonstrate their suitability and competence.
Tertiary treatment	Further treatment of advanced secondary effluent by disinfection (See also “advanced tertiary treatment”).
Underground services	These are elements of a building service, which may include utilities such as lines for telecommunication, electrical cable or pipes, which are buried in the ground.
Trade waste	Any liquid (excluding domestic wastewater) that is discharged from commercial, industrial, manufacturing or trade premises resulting from any processes or operations.
Water table	The upper surface of groundwater below which the soil is permanently saturated with water.
Wastewater	The contaminated water produced from domestic activities in dwellings, institutions or commercial or public facilities, consisting of all waste, greywater or blackwater. Also defined as “foul water” in the New Zealand Building Code.

Slope conversion table

Slope (degrees)	% Grade	Gradient (Y:X)
1°	1.75%	1 : 57.3
2°	3.49%	1 : 28.6
3°	5.24%	1 : 19.1
4°	6.99%	1 : 14.3
5°	8.75%	1 : 11.4
5.7°	10%	1 : 10.0
6°	10.5%	1 : 9.5
7°	12.3%	1 : 8.1
8°	14.1%	1 : 7.1
9°	15.8%	1 : 6.3
10°	17.6%	1 : 5.7
11°	19.4%	1 : 5.1
12°	21.3%	1 : 4.7
13°	23.1%	1 : 4.3
14°	24.9%	1 : 4.0
15°	26.8%	1 : 3.7
16°	28.7%	1 : 3.5
17°	30.6%	1 : 3.3
18°	32.5%	1 : 3.1
19°	34.4%	1 : 2.9
20°	36.4%	1 : 2.7
21°	38.4%	1 : 2.6
22°	40.4%	1 : 2.5
23°	42.4%	1 : 2.4
24°	44.5%	1 : 2.2
25°	46.6%	1 : 2.1

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A Introduction

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Tables

A1.0 Introduction

A1.1 Aims of the guideline

This guidance document, *'On-site Wastewater Management in the Auckland Region'* (GD06), provides technical guidance for the design, installation, and management of on-site wastewater systems[1]. It provides best practice guidance for effective on-site wastewater management while safeguarding public health and minimising adverse environmental effects.

GD06 has been prepared for use in the Auckland region. While many of the principles are universal, and can be used elsewhere, these technical specifications have been developed for the geology, topography, receiving environments and context of Auckland. The intended audience of this document is in Table 1.

Table 1: Intended audience

Audience	Intended use
Industry professionals	To provide best practice on-site wastewater system design guidance.
Landowner/developers	To provide guidance on key on-site wastewater system design requirements as well as construction and commissioning, and whole-of-life operation and maintenance.
Regulators	To assist in undertaking on-site wastewater management statutory functions.

A suitably qualified and experienced person is required to design an on-site wastewater systems. Users of GD06 are responsible for working within their capabilities, obtained through training and experience, and for seeking the advice of appropriate specialists who understand the principles and practice guidance outlined in this document.

GD06 establishes the following design criteria and performance requirements:

- The on-site wastewater system provides effective and sustainable amenity service to the user
- Wastewater discharges do not pose a public health threat
- The effects of wastewater discharges on the environment are minimised
- Construction activities and wastewater discharges do not disturb historic heritage sites, or sites of significance to mana whenua
- Land application and reserve areas are retained in a state and condition that does not compromise their use for current and future effluent discharge
- The on-site wastewater system is maintained by a suitably qualified and experienced on-site wastewater service person
- Landowners/users control the use chemicals into the system in order to avoid compromising system performance and effects on the environment.

[1] In this document, the term "on-site wastewater system" means both the treatment and disposal of effluent and is synonymous with on-site wastewater management systems.

GD06 is available on Auckland Council's website at www.aucklanddesignmanual.co.nz.

A1.2 Scope and application of this guideline

The on-site wastewater system (Figure 1) includes those components described in Table 2.

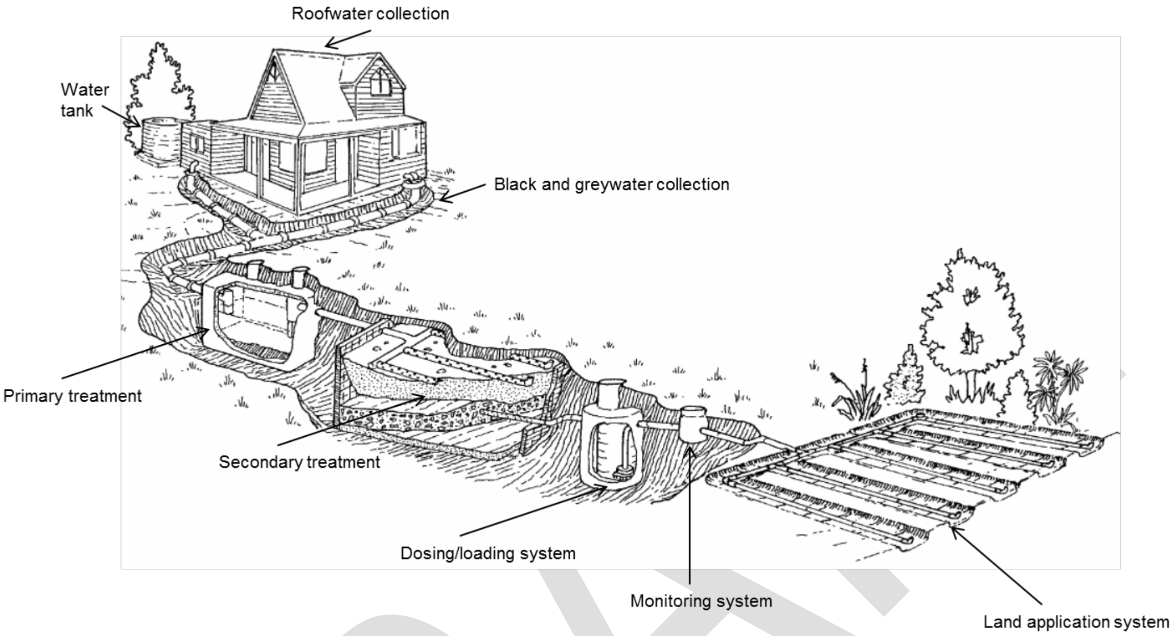

Figure 1: Typical on-site wastewater system components

(Source: Auckland Regional Council TP58 (2004)

Table 2: On-site wastewater system components

Component	
Wastewater treatment unit	This may include either one, or a combination, of primary, secondary and disinfection treatments, designed in units.
Land application system	After passing through the treatment unit system, wastewater is discharged to land. The land application system provides further treatment within the soil followed by assimilation into the receiving environment.
Other operational components	These include dosing or loading controls, emergency storage and monitoring systems.

GD06 addresses design of domestic on-site wastewater systems with flows up to 3,000 L/day (3 m^3/day), from a population equivalent of up to 15 people. However, some sections may still be applicable to the design of larger on-site wastewater systems.

While the content of this design guidance provides for commonly used on-site wastewater systems, this should not be seen as precluding any new, or developing, technologies for on-site wastewater management, provided it can be demonstrated that the device can achieve the on-site wastewater performance (both wastewater treatment unit and land application system) requirements.

A suitably qualified and experienced person who understands the relevant principles and practice guidance outlined in this document should be engaged for the design of on-site wastewater systems.

The scope and application of this document does not include:

- New or existing larger-capacity decentralised systems (those serving more than 15 people or greater than 3 m^3/day)
- Treatment, or disposal, of process wastewater, or trade waste, from commercial or industrial sources, or wastewater contaminated stormwater flows
- Assessment of proprietary devices[2].

GD06 will supersede TP58 *On-site Wastewater Systems: Design and Management Manual* (3rd edition), 2004. It is important to note that GD06 does not include the regulatory scope found in TP58. The Auckland Unitary Plan (AUP) contains provisions relevant to on-site wastewater systems in Auckland. The AUP can be found on the Auckland Council website.

A1.3 How this guideline was developed

GD06 responds to changes in design standards, technological advances, industry practices, and feedback from TP58 users. Key sources of technical information used to develop GD06 include:

- Auckland Regional Council. (2004). '*On-site wastewater systems: Design and management manual*.' Third edition, (TP58)
- The USEPA Onsite Wastewater Treatment Systems Manual (2002)
- The joint Australian and New Zealand Standards (AS/NZS), particularly AS/NZS 1547:2012 *On-site domestic wastewater management"*
- AS/NZS 1546.1:2008 "*On-site domestic wastewater treatment units, Part 1: Septic tanks"*
- AS/NZS 1546.2:2008 "*On-site domestic wastewater treatment units, Part 2: Waterless composting toilets"*
- AS/NZS 1546.3:2008 "*On-site domestic wastewater treatment units, Part 3: Aerated wastewater treatment systems".*

In the preparation of GD06, a comprehensive literature review of national and international research and guidelines was carried out. Consultation was carried out through a series of meetings, correspondence and review opportunities that drew on the technical experience and operational knowledge of industry practitioners, consultants and contractors throughout New Zealand. Workshops with mana whenua were

[2] Where proprietary devices are referred to from time to time within GD06 this does not imply endorsement nor non-acceptance of such devices.

held to ensure Māori knowledge has been integrated throughout the document. All feedback received was carefully considered prior to, and during, document drafting and finalisation.

A1.4 Document structure

The content outline and summary of GD06 is presented in Table 3.

Table 3: Outline and content of document

Section name	Content	
A - Introduction	• Scope, purpose and background, and an introduction to the design process.	
B – Site and Soil Evaluation	• Site and soil evaluation process including assessment of site constraints and soil assessment. • Guidance on how the site constraints such as soils, slopes and setbacks, impact design.	
C – Design Flow Volumes	• Design flow volume considerations including occupancy numbers and flow allowances.	
D – Design of Wastewater Treatment Units	• Overview of wastewater treatment unit design including effluent quality and processes for primary, secondary and disinfection systems.	
E – Design of Land Application Systems	• Overview of the design of land application systems. • Specific design of shallow irrigation and conventional land application systems.	
F – System Construction, Commissioning and Maintenance	• On-site wastewater system installation, commissioning, monitoring and maintenance.	
G – Risk Management	• Hazard identification, risk assessment, management and mitigation.	
Appendices	Appendix A	On-site wastewater consenting process
	Appendix B	Soil description and assessment
	Appendix C	Design report
	Appendix D	Example flow allowance reduction calculations
	Appendix E	Composting toilets
	Appendix F	Post-construction information requirements
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A2.0 Statutory framework

Statutory requirements apply in the form of legislation, National Environmental Policies and Standards under the Resource Management Act 1991 (RMA), plans, and local bylaws.

There is a range of statutes and regulations directly and indirectly relevant to the management of on-site wastewater in Auckland. These are briefly discussed below to provide an overarching context. Statutory and regulatory frameworks change over time, so the reader should seek further advice from their professional advisors and Auckland Council specialists.

A2.1 National statutory requirements

A2.1.1 The Resource Management Act 1991

The RMA is the principal legislation controlling the development of land including the establishment of on-site wastewater systems. The Act identifies matters of national importance (Section 6), which include the protection of historic heritage from inappropriate subdivision, use, and development, and acknowledges the relationship of Māori and their culture and traditions with their ancestral lands, water, sites, wāhi tapu, and other taonga.

The discharge of wastewater into the environment is regulated by Section 15. No person may discharge contaminants, such as wastewater, onto land or into water unless expressly allowed by:

- A national environmental standard or other regulation
- A rule in a regional plan (and any proposed regional plan, if applicable)
- A resource consent[3].

In Auckland, the RMA is implemented through the Auckland Unitary Plan. Auckland Council is a consent authority under Section 104 of the RMA and is responsible for ensuring that all developments comply with the Act. Resource Consent assessment for an on-site wastewater system will be made in accordance with Sections 105 and 107 of the RMA.

A2.1.2 The Building Act 2004, Building Regulations 1992 and Building Code

The Building Act provides a national framework for building control to ensure that buildings and associated infrastructure are safe, sanitary and have suitable means of escape from fire. The Building Regulations (and the Building Code contained in the regulations) set out mandatory requirements and performance criteria that buildings and all relevant infrastructure component, such as an on-site wastewater system, must comply with. Auckland Council is a regulatory authority under the Building Act and is responsible for ensuring that buildings and structures comply with both the Building Act and Building Code.

3 Section 15 of the Resource Management Act, 1991

The installation of an on-site wastewater system requires a Building Consent[4] and must operate in compliance with the Building Code, 1992. The building consent process seeks to ensure that on-site wastewater systems are appropriately installed and will operate without posing a threat to public health or negatively impact buildings. On-site wastewater systems must meet the requirements of the Building Code in respect to:

- Clause B1 Structure
- Clause B2 Durability
- Clause G1 Personal hygiene
- Clause G13 Foul water (sanitary drainage, sanitary plumbing)
- Clause G14 Industrial liquid waste (includes on-site foul water).

It is important to note that while the Building Act regulates the construction and operation of on-site wastewater systems in accordance with the provisions of the Building Code, the wastewater discharges are regulated under Section 15 of the RMA.

A2.1.3 The Health Act 1956

The Health Act (1956) requires Auckland Council to "improve, promote and protect" public health[5], primarily through the detection and abatement of "nuisances" (including conditions likely to be injurious to health or offensive). The Health Act imposes responsibilities on persons by prohibiting any building or part of a building used as a dwelling from being built, sold, let, or occupied unless it has adequate wastewater disposal facilities that comply with the Building Act 2004 and Building Code[6].

With regard to enforcement, the Health Act grants Auckland Council various powers of entry and inspection of buildings, and the ability to issue cleansing orders and closure orders or require repairs if residential facilities (including associated structures such as wastewater treatment units) are unsanitary. Auckland Council Environmental Health Officers can provide further information about duties under the Health Act.

A2.1.4 National Policy Statements

National Policy Statements, issued by Central Government, provide councils with guidance on matters of national significance. The National Policy Statement for Freshwater Management (2014) and the New Zealand Coastal Policy Statement (2010) are particularly relevant to on-site wastewater discharge. In Auckland National Policy Statements are given effect to in the Auckland Unitary Plan.

A2.1.5 National Environmental Standards

National Environmental Standards are RMA regulations that prescribe technical standards, methods or other requirements for environmental matters. Local authorities are required to enforce these standards but may

[4] Refer First Schedule of the Building Regulations, 1992

[5] Section 23 the Health Act, 1956

[6] Sections 128, 41 and 42 of the Health Act, 1956

also impose stricter standards. The National Environmental Standard for Sources of Human Drinking Water (2008) directly impacts the permitted location and required treatment quality of on-site wastewater systems.

A2.1.6 Hauraki Gulf Marine Park Act 2000

The Hauraki Gulf Marine Park Act serves to manage the resources of the Hauraki Gulf and all its contributing catchments. Depending on the location of the on-site wastewater discharge, the quality of the treated wastewater and the on-site wastewater system's discharge of wastewater, it may be subject to the requirements of the Act.

A2.1.7 Heritage New Zealand Pouhere Taonga Act 2014

This Act regulates the modification of archaeological sites on all land and provides for substantial penalties for unauthorised destruction, damage, or modification of these sites. It is advisable to investigate whether an Archaeological Authority from Heritage New Zealand Pouhere Taonga may be required when developing land. The Act's provisions apply regardless of whether:

a) The site is registered or recorded by the Council in planning documents
b) The land on which the site is located is designated
c) The activity is permitted under the district or regional plan
d) A resource or building consent has been granted.

Requirements of this Act directly impact on the permitted location of future land development, including land required as part of the on-site wastewater system.

A2.1.8 The Health and Safety at Work Act 2015 and its Regulations 2016

The Act seeks to protect workers and other persons from harm to their health, safety and welfare by eliminating or minimising risks arising from work or equipment. It is of particular relevance with respect to the design and construction of on-site wastewater systems. System design significantly influences future requirements for maintenance and operation, and therefore plays a key role in creating a safe workplace. Health and safety in the workplace is therefore not only a matter of safe work practices and procedures but should also be supported by good design decisions.

A2.2 Auckland Unitary Plan

Wastewater discharges must comply with the AUP. The AUP specifies policies, rules, standards and assessment criteria applicable to the discharge of wastewater via an on-site treatment systems and land disposal. On-site wastewater systems must be designed and managed in accordance with the relevant criteria and specifications in the AUP.

GD06 sets out the technical requirements and standards for the applicable activities in the AUP and should be read in that context.

A3.0 Mana whenua values

Te Tiriti o Waitangi (Treaty of Waitangi), RMA and Local Government Act require that mana whenua values are considered in the management of natural resources. Key concepts are:

- The understanding of mauri
- The practical application of mana whenua values in the appropriate context.

A3.1 Mana whenua and mauri

As kaitiaki[7], mana whenua has a responsibility for ensuring that the spiritual and cultural aspects of resources and places are maintained for current and future generations. This involves their on-going protection of mauri from adverse cumulative effects, damage, destruction or modification.

Mauri is a concept recognised by mana whenua as the connection between spiritual, physical and temporal realms. Loosely translated as the life force or life essence which exists within all matter, mauri sits at the very core of sustainable design for mana whenua and Te Ao Māori – the Māori worldview.

A key concern to mana whenua is the effect on mauri of water caused by pollution of a place, stream, river, estuary, catchment or harbour. This can be due to wastewater entering waterways, loss of riparian margins and the loss of native habitat to support native flora and fauna.

Degradation of freshwater quality can also affect the ability for customary harvest and manāki[8] due to depletion in, contamination of, or in some cases the absence of, traditional mahinga kai[9] resources. Contamination, modification, or destruction, of wāhi tapu[10] and wāhi taonga[11] is another potential effect of freshwater degradation.

The restoration, revival and enhancement of mauri should be a focus during the design and construction phases through:

- Prevention of wastewater entering waterways or significant sites as identified by mana whenua
- Protection of habitats of plants and aquatic life which are traditional sources of food for Māori
- Maintaining or restoring a buffer of native vegetation around land application areas
- Water conservation practices in the home
- Avoiding mixing waters from different sources, particularly as it relates to wastewater.

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[7] Kaitiaki is the inherited and integral responsibility for guardianship

[8] The ethic of holistic hospitality whereby mana whenua has inherited obligations to be the best hosts they can be

[9] Traditional food sources

[10] Any place or feature that has special significance to a particular iwi, hapu or whānau including urupā (burial grounds), pā sites (historic settlements) or wāhi pakanga (historic battlefield)

[11] Anything considered to be of value including socially or culturally valuable objects, resources, phenomenon, ideas and techniques

A3.2 The importance of water

The different states and sources of water in the Māori context are provided below. It is also important to consider these as they relate to how the water is changed through urbanisation:

- Wai-ora: (pure water): This is water in its purest form
- Wai-maori: (freshwater): This is referred to as ordinary water which runs free or unrestrained and has no sacred associations
- Wai-kino: (polluted): The mauri of the water has been altered through pollution or corruption and has the potential to do harm to humans
- Wai-mate: (dead water): This class of water has lost its mauri and is dead. It is dangerous to humans because it can cause illness or misfortune
- Wai-tai: (salt or water from the ocean): This term also refers to rough or angry water as in surf, waves or sea tides
- Wai-tapu: (sacred water): This is water that is used for ritual and ceremony.

A3.3 Application of mana whenua values in the context of wastewater

Examples include:

Mana: The status of iwi and hapū as mana whenua is recognised and respected. The principle of mana is that mana whenua are enabled to determine how they are to be involved. For example:

- Cultural monitoring during excavation works
- Increased setback distances where traditional food sources are located directly downstream or downslope to maintain levels of sustainable harvest and supply
- Preparation of cultural impact assessments.

Taiao: The natural environment is protected, restored and /or enhanced. For example:

- Avoiding the mixing of any wastewater into marine and freshwater receiving environments aligns with the principles of Taiao and Mauri Tu
- Natural environments are protected to maintain sustainable harvest of mahinga kai
- Regular monitoring of all high-risk points in the on-site wastewater system needs to be undertaken to ensure any small leaks are identified and groundwater quality is not compromised
- Mitigate the removal of any native trees or shrubs that provide habitat for wildlife, by providing an alternate habitat
- The preference is for tertiary level wastewater treatment.

Mauri Tu: Environmental health is protected, maintained and/or enhanced. For example:

- The use of organic alternatives to households' chemicals and avoiding/limiting their entry into wastewater (refer to Appendix G1.4)
- Native planting around land application areas
- The reuse of greywater for irrigation of edible plants is avoided where possible.

Ahi kā: Iwi/hapū have a living and enduring presence and are secure and valued within their rohe. For example:

- The waterways are an extension of the land and how mana whenua relate to it
- Urupā (traditional burial grounds) are commonly located near watercourses and riparian/coastal margins. In alignment with Ahi kā, extra care should be taken when excavating near these zones
- Recognise mana whenua and ensure their ahi kā is upheld
- Ensure consultation with mana whenua is actioned with the correct iwi and representative.

Tohu: Mana whenua significant sites and cultural landscapes and landmarks are acknowledged

- To align with the principles of Tohu and Mana, accidental discovery protocols should have an updated register of iwi who have mana whenua across the area surrounding a construction site. This will ensure a smooth process in the circumstance of an accidental find
- Use of on-site wastewater systems in proximity to cultural sites must be avoided.

A4.0 Design process

As a first step, the designer should determine whether an on-site wastewater system is the most appropriate wastewater servicing solution for the proposed development. On-site wastewater systems should only be considered where it is not practicable to connect to, or extend, the public wastewater network or establish a decentralised wastewater management system.

The project team is responsible for delivering a functional on-site wastewater system that minimises its public health risks and long-term environmental impacts, as well as the needs of the wider development through:

- Complying with all regulatory requirements
- Identifying critical design assumptions
- Considering cumulative effects and appropriate mitigation measures
- Ensuring a cost-effective, safe design.

A4.1 Roles and responsibilities

On-site wastewater system design, installation and maintenance requires skills and expertise from a range of people. Their roles and responsibilities in the project are shown in Table 4.

Table 4: Potential project team roles and responsibilities

Role	On-site wastewater management responsibilities
Building partners	• System manufacturer, suppliers, installation contractor and maintenance contractor. • Responsible for providing specific guidance around construction elements that impact design, function and cost.
Designers	• Engineers, on-site wastewater specialists, architects and urban designers. • Responsible for developing plans that meet project objectives, from concept to detailed design.
Landowner / developer	• Overall responsibility for ensuring all design regulatory requirements are met in the development. • Ensure all operation and maintenance requirements for the life of the on-site wastewater system are understood and upheld by all occupants of the development.
Project manager	• Responsible for all design elements, ensuring design is fit-for-purpose and meets project objectives and resource consent requirements. • Responsible for facilitating communication with stakeholders. • Responsible for project management and all legal advice.
Specialist advisors	• Site evaluators, soil specialists, engineers, planners, geotechnical specialists, surveyors, ecologists and mana whenua. • Responsible for essential design elements.

Auckland Council planners, development engineers, building inspectors and wastewater specialists should be consulted during the preliminary planning stage of the development.

A4.2 Early design

The on-site wastewater system designer must understand the development proposal to assess design options. Development information for the designer is shown in Table 5.

Table 5: Information required from conceptual design

Key information	Description
Location	• Location (including street address) of the proposed development and any identified cultural heritage sites.
Proposed lots	• Proposed boundary, lot area (total, gross and net).
Proposed infrastructure	• Location and description of any proposed roads, water supply, stormwater drainage, electricity, gas, fibre, greywater supply, etc.
Proposed facilities	• Location and details of the proposed facilities, e.g.: ○ Building footprint location and size ○ Number of bedrooms (and maximum possible occupancy) ○ Proposed land modification ○ Proposed building usage (to be used as a holiday home, home business, etc.).
Proposed impervious area	• Location and size of all proposed impervious areas.
Proposed land modification	• Location and method of proposed earthworks, cut and fill, stock pile location, etc.

A4.3 On-site wastewater system design considerations

The on-site wastewater system's discharge must be of a quality and volume that avoids adverse effects on the environment, public health and amenity. To achieve this the designer should ensure that:

- Site, subsurface and surface investigations have been comprehensively undertaken to identify the optimal location for the on-site wastewater system (Section B)
- The design provides an appropriate level of wastewater treatment (Section D)
- The land application area is selected and sized based on:
  - The development layout including buildings, accessways and drainage
  - The soil properties and typical slope gradient (Section B)
  - The estimated design flow (Section C)
  - Suitable wastewater loading rates (Section E)
  - Consideration of site constraints.
- The land application and reserve areas are outside modified land areas (cut/fill, stockpiles, compaction), geotechnical risks, steep grade etc.

A4.4 Safety in design

Safety in design is a process of managing health and safety risks throughout the lifecycle of structures, plant, substance or other products. It integrates health and safety risk identification and risk assessment early in the design process. Safety must be considered early, to eliminate or minimise the risks of death, injury or illness to those who will construct, operate, maintain, inspect, decommission and demolish an asset. Risks are reduced by involving decision makers, engineers, health and safety professionals, operational and construction staff and the owner from the early design stages.

Safety in design begins in the project's conceptual and planning phases with emphasis on making the right choices about the design, construction methods, ongoing operation and maintenance and materials. It's the design phase that provides the best opportunity to incorporate improvements for safety, time and cost benefits over the life of the asset. Residual risks at the end of any design phase are then identified so that they can be addressed or managed in the next phase.

Examples of safe design considerations include:

- Minimising:
  - Exposure to effluent
  - Impacts to and from neighbouring sites
  - Access to land application areas
- Signage complying with NZS/AS 1319:1994, "Safety signs for the occupational environment"
- Designing around existing services
- Designing for 24/7 all-weather site access
- Avoiding designing below-ground structures, which require confined space entry.

A4.5 Subdivisions

Some design considerations specific to subdivisions are presented in Table 6.

Table 6: Planning considerations specific to subdivisions

Constraint	Description
Scale of proposed development	• Consider the proposed number of lots, their size, proposed dwelling number and size, and the site's design volume and design flow. These will determine the required land application and reserve area. • Cumulative effects must be considered in any subdivision.
Impact of construction on soils	• Construction activities should not impact land application or reserve areas. • Land application or reserve areas should not be placed on soils which have been excavated, stockpiled, compacted or imported to the site. • Pre- and post-construction assessments of soils should be done to assess any impacts.
Land constraints	• Subdivisions should have a full report from a geotechnical engineer or engineering geologist. Templates are available in Appendix B that outline the information requirements for soil characterisation.
Adequate separation distance	• It may be necessary to design for increased setback distances to mitigate potential cumulative effects.
Effluent quality	• The fate of nutrients from the proposed on-site wastewater system must be considered. • Subdivisions should design for a minimum of secondary treatment effluent quality. • Tertiary treatment may be required where there is potential for effluent to enter recreational receiving water.

B Site and soil evaluation

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Tables

B1.0 Introduction

The aim of site and soil evaluation is to identify site and subsurface constraints that should be considered by the designer to determine the most appropriate wastewater treatment unit and land application area, hydraulic loading rates and any additional design considerations to ensure that the proposal minimises the effects of the discharge on the environment.

Land application of treated wastewater provides further wastewater treatment and polishing. Land application effectiveness depends on:

- Site characteristics (e.g. drainage and topography)
- Soil properties that influence its capacity to transmit wastewater, absorb or attenuate residuals, provide biological stabilisation of organic matter and inactivate bacteria and viruses.

The Site and Soil Evaluation Report provides recommendations for the proposed design which accommodates site and soil constraints. It is an essential part of the design proposal for on-site wastewater (or components of wastewater systems). The report must include:

Preliminary site assessment	• Site characteristics and constraints from the desktop study.
Site evaluation	• Comprehensive site evaluation results and descriptions. • Photographs from the site walkover identifying areas of interest should be included. • The landowner's available (and preferred) location/s for the on-site wastewater system should be noted.
Soil evaluation	• Details of all subsurface investigations undertaken and corresponding results including evaluation of the soils underlying the proposed land application area, soil logs and photographs of investigation findings.
Preliminary design	• Assessment of information used to determine the proposed land application and reserve areas and land application methodology.
Conclusion	• Summarising main findings and identifying the location/s of the proposed land application and reserve areas and land application methodology.
Site plan	• The report must be accompanied by a site plan, and include the site layout, including location of proposed land application and reserve areas, soil investigation locations and details.

The report template in Appendix C1.2 provides general guidance on minimum requirements for on-site wastewater system resource consent applications. This may be adjusted, where appropriate, to address site-specific conditions and requirements.

B2.0 Preliminary site assessment

A preliminary site assessment starts with a desktop study to understand site specific information (Table 7). Information can first be obtained from the client and supplemented with data and information including:

- Auckland Council property file records
- Data and information available on the Auckland Council GIS viewer
- NIWA climate data
- Landcare Research maps
- Land Information New Zealand.

A description of the local environment is included in the desktop assessment. The minimum information to assess is presented in Table 7.

Table 7: Site and environmental information

Key information	Assessments / actions
Summary of proposed development	
Net lot area	• The area available for primary and reserve land application after excluding: ○ Setback requirements from surface water and areas unsuitable for wastewater discharge (e.g. unstable land, slips, wāhi tapu, etc.) ○ Land areas proposed for other land uses (such as rights-of-way, building footprints, impervious areas).
Existing / proposed lot boundaries	• Establish legal and proposed boundary lines between the lot and neighbouring lot/s.
Existing / proposed building footprint	• Location and extent of existing or proposed building footprints.
Existing / proposed impervious area	• Location and extent of existing or proposed impervious areas, e.g. driveways, concrete paths or parking areas.
Existing / proposed infrastructure	• Location of existing or proposed infrastructure (e.g. stormwater drains, roading, groundwater supply bores, service trenches or other utility services).
Existing / proposed stormwater disposal systems	• Location and method of existing or proposed stormwater drainage and disposal systems such as soakage, disposal trenches/rain gardens or outlets.
Existing embankment and retaining walls	• Assess existing/proposed embankment and retaining walls within or near the proposed development. Identify associated drainage systems. • Sufficient setback distance must be provided to avoid short circuiting of wastewater and safeguard against wastewater ponding. Setbacks provide protection from effluent seepage impacts and structure failure of retaining systems.

Key information	Assessments / actions
Legal user right	• Determine the legal right to proposed wastewater discharge including ownership, easement or existing user-right agreements. • All parts of the proposed on-site wastewater system must be located within the boundary of the legal ownership boundary (unless an alternative easement or user agreement has been reached).
Site limitations	
Cultural heritage	• Location of known cultural heritage sites or features; e.g. Māori Pa or wāhi tapu.
Natural heritage	• Location of known heritage sites or features (e.g. vegetation, volcanic cones, wetlands).
Unitary Plan zoning	• Zoning and precinct area of the proposed development.
Historical activities	• Consider historical land use or events that may have affected the site and influence design. For example, previous horticultural use that may have contaminated soils.
Environmental management areas	• Groundwater, stream, stormwater and water supply.
Protected vegetation	• Assess the location and root extent of any protected vegetation.
Potable water supplies	• Location of potable and animal drinking water supplies (groundwater and surface water sources). • Water bore information (depth of bore, aquifer, bore construction, pumping rates).
Surface water bodies and drainage	• Assess the location of surface water bodies including permanent and ephemeral streams, overland flow paths, lakes, dams, ponds, wetlands, estuaries, coastal marine areas and storm water drains.
Flooding potential	• Assess flood plains, flood-sensitive areas or flood-prone areas to identify flood risk for the 1% (1 in 100-year event) and 5% (1 in 20-year event), Annual Exceedance Probability (AEP) floodplains.
Water supply	• Determine sources of potable water supplies on site and for neighbouring properties. • Identify drainage path from water supply tank overflows.
Geotechnical constraints	• Assess potential geotechnical constraints and/or such as on-site or nearby steep slopes or soil-warnings. • Assess any potential land stability risks.
Site physical features	
Depth to groundwater	• Look for evidence of springs, wet ground, or hydrophilic plants.
Soil / geology	• Review soil and geological maps to understand anticipated site conditions.
Topography	• Review topographic data to assess gradients, aspect, and slope shape.
Existing land cover	• Assess land cover of the potential land application and reserve area, including current vegetation. Understand what vegetation will be retained post-development, particularly in reserve and buffer areas.
Rainfall	• Understand local rainfall data.

Note: The distances from the proposed land application area to each site feature should be recorded in the design proposal.

B3.0 Site evaluation

A comprehensive site evaluation is used to validate the preliminary assessment and is an opportunity to collect further site information and address data gaps. The site evaluation is initiated with a site walkover to confirm information and identify potential constraints. The walkover must be performed by the on-site wastewater designer who has expertise in soil assessment and hydrology.

Site evaluation information is used to define available areas for the land application system and delineate exclusion areas. Optimal locations can then be identified in consultation with the landowner. While on site, a plan for soil assessments in those location should be made (refer to Section B4.1.2).

During the site walkover, key properties of slope (shape and angle), stability and aspect must be assessed and recorded as identified below. Additionally, specific design considerations to be considered during the site evaluation are noted below.

All information collected on site informs the design report and site plans.

B3.1 Topography

B3.1.1 Site slope and stability

Slope is a major design constraint because of the potential for runoff to cause adverse effects beyond the site boundaries. A cross-section survey is recommended for any site with slopes greater than 8.5° (15%).

The survey should:

- Measure the distance and angle down and along the steepest fall line of the slope to principal change points in gradient, measured to 1° accuracy
- Extend a minimum of 20 m beyond the proposed land application area and wastewater treatment unit locations to incorporate any adjacent slopes and features which could affect the site's stability. This includes land outside of the lot boundaries and where access is permitted. Where access is not permitted, an estimate of the slope angle should be made and presented on the section with a note explaining the method of estimation
- Note any features of significance including areas of seepages, hydrophilic vegetation, landslides, terraces or hummocky ground, erosion, watercourses, fences, trees, and adjacent water-shedding slopes
- Present a true scale cross-section, with locations of measured points, and include this with the site evaluation report. The location of the cross-section survey line should be shown on the scale plan for the site
- Identify any slope shapes and locations where depressions/zones with potential for surface water ponding might occur. This information should also be included on the site plan.

The results of the slope investigation will inform the designer of suitable locations for the land application area. To function properly, the land application area must conform to the natural contours of the land while avoiding any depressions where ponding could occur. Section B5.2 details allowable slopes for different on-site wastewater systems.

Where the preliminary site assessment identifies the potential for previous or existing slope instability, or where a geotechnical report has been required for the development, a geotechnical specialist will be needed to assess the impact of the proposed system on the site. These areas will require specific geotechnical measures to address any potential impacts of the land application of wastewater. In some cases, the land may be unsuitable for wastewater irrigation, as frequently wetted areas may exacerbate problems in areas prone to slope failure.

B3.1.2 Site aspects and surroundings

The designer must consider the direction the slope faces and its evapotranspiration potential by positioning the land application area to maximise its exposure to sun and wind (preferably north-facing). Lower points (such as gullies) may limit infiltration and evapotranspiration.

B3.2 Vegetation cover

When evaluating the site, the following should be noted and identified on site plans:

Areas of healthy plant growth	• These may indicate well-drained fertile soils are present.
Types of plants present	• e.g. native bush, exotic landscaping, pasture grasses, water tolerant plants and drought resistant plants.
Areas of plant dieback or lack of vegetation or weeds	• Investigate soils in these areas to understand what the cause may be (such as lack of water, nutrients, saturation, etc.).
Areas with trees	• Trees and their roots may impact infiltration areas. • Roots can significantly impact infiltration areas and large trees reduce the area available for land application (permeable geotextiles may be needed in the design to prevent root intrusion into components of the on-site system, including pipes).
Areas of water-tolerant plants	• The presence of water-tolerant plants may indicate a high water table, frequent wet conditions due to topography or stormwater, locations frequently flooded, springs or other issues.

B3.3 Hydrology

Site hydrology (surface water, groundwater and interflow) can have significant effect on the performance of land application systems and the potential environmental and public health risks. Site conditions need to be understood and documented during both site evaluation and soil assessments, so that hydrological conditions in the land application area can be considered in the system design.

B3.3.1 Surface water

Surface water that enters any component of an on-site wastewater system increases the volume of wastewater and can result in a failing treatment unit or a failing land application area (saturating soils, leading to effluent breakout and discharges to areas outside the property). This can result in environmental and public health risk.

Hydrological features that must be noted include:

- Overland flow paths
- Stormwater drains
- Streams, rivers and wetlands
- Water tank overflows
- Pool backwash filter trenches
- Stormwater discharge infiltration trenches/rain gardens.

Flooding potential must also be assessed. On-site wastewater systems discharging primary treated effluent should not be installed in areas within the 1% AEP (1 in 100-year) floodplain. On-site wastewater systems discharging secondary treated effluent should not be installed in areas within the 5% AEP (1 in 20-year) floodplain.

B4.0 Soil assessment

Soil formation is affected by many factors including climate, parent material, living organisms, time and topography. As a result, soil is very heterogenous and soil types can vary widely over short distances. While high-level soil maps may be available, site investigations are required to determine soil properties in the proposed land application area and as a result, optimise the system design and installation.

Soils are described by assessing horizontal layers, or horizons. Soil properties (colour, texture, structure, consistency, etc.) within a horizon are generally consistent. A consistent change in a soil property marks a different soil horizon. The soil horizons collectively make up the soil profile (see Figure 2).

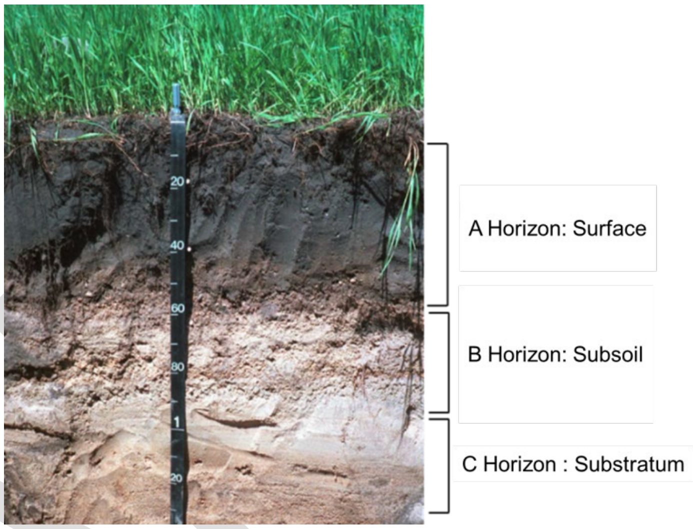

Figure 2: Soil profile example

Most soils have three or four horizons. The topmost A Horizon is generally the most biologically active and therefore provides the greatest opportunity for assimilation of effluent. The B Horizon may also have signs of biological activity, although to a lesser degree than the A Horizon. The C Horizon contains relatively unaltered parent material derived from the underlying rock (R Horizon), and generally occurs quite deep in the soil.

The following sections outline soil assessment requirements for on-site wastewater system design and installation. The information is guidance only and assumes that soil assessments for on-site wastewater design are undertaken by a suitably qualified practitioner. Reference should be made to soil assessment guides including the Soil Description Handbook (Milne et al.) for more specific information.

B4.1 Soil investigation

Soil comprises mineral material, organic material and air voids (pore space). It also contains an abundance of macro-organisms (worms, nematodes, etc.) and micro-organisms (bacteria, protozoa, fungi, etc.). When effluent is applied to land, treatment occurs as it passes through the soil by several processes that include physical filtering, chemical reactions and biological breakdown. When land application areas are designed to distribute effluent within the root zone of plants, they also provide a key role in treatment by taking up water and nutrients.

Land application areas must consist of soils capable of assimilating wastewater for the expected lifetime of the on-site wastewater system. Atypical soils (such as those with very poor drainage characteristics) are outside the scope of this guideline and need special design considerations. In the Auckland region, these include cut-and-fill soils, soils derived from Onerahi Chaos and Mahurangi Limestone and peats.

Soil assessment requires field analysis of soil properties and sampling at specific locations and depths within the site. These soil characteristics provide a soil profile which informs the design of the land application system and design loading or irrigation rates. The land application area must be sited and designed to ensure that soils are sufficiently deep so that, under the peak hydraulic loading rates, adequately treated effluent is able to enter the soil without ponding or creating runoff.

Laboratory analysis of soils or groundwater may be necessary, particularly where contamination or fill soils are suspected or where the impact of wastewater discharges needs to be better understood. Section B4.3 provides more information on laboratory analysis of soils.

B4.1.1 Investigation techniques and methods

Four main methods (in order of preference) are used to expose the soil profile:

Test pit	• Excavation of a pit, by hand or machine, large enough to allow detailed visual inspection of the soil profile. • A test pit provides for assessment of soil structure and texture down the soil profile.
Hand auger	• A hand-operated steel auger is used to remove a core of the soil profile. • The diameter of the soil core should allow for adequate soil characterisation and care should be taken to keep the soil core intact for correct characterisation. This technique is good for small sites where the soils are loose, shallow and easily sampled by hand. • On completion of augering and sampling, all material should be replaced in the hole.
Machine boreholes	• This technique requires specialist hydraulic drilling equipment where a bore hole is sunk into the site. • It is rarely used but could be of benefit in larger developments where multiple bore holes are required during construction.
Hand sampling	• Soils may also be sampled by hand with a shovel. • The technique is only useful in very shallow soils.

After representative soil samples have been collected from the soil profile, any field observations should be recorded on a bore log/test pit log (a template is provided in Appendix B1.9 noting the depths where soil characteristics change within the soil profile.

B4.1.2 Soil assessment locations

Multiple soil assessment locations should be investigated to provide a representative assessment; further characterisation of discrete areas of interest may also be needed.

The number of soil cores or soil test pits required to characterise the soil will vary. As soil characteristics change with topography and soil disturbance is common, the boreholes/test pits should be spread across the area proposed for land application. At least three locations within the land application area and one in the reserve area should be assessed. The locations should include as a minimum:

- A soil core near the location where treated wastewater effluent will enter the land application area
- A soil core at the far end of the land application area
- A test pit in the centre of the land application area.

Hand augering over a wider area is useful to confirm observations made in the test pit.

B4.1.3 Investigation depths

Site assessments should include various depths within the soil profile to characterise specific soil horizons. The assessment should access all soil horizons and be:

- To a minimum depth of 1 m below the base of the proposed land application system, or
- To the depth of the limiting horizon (hardpan, bedrock, seasonal water table), or
- Until adequate setback distance is confirmed from the base of the land application area and the groundwater table.

After representative soils have been collected, field observations should be recorded on the borelog/test pit log noting the depths where soil characteristics change within the soil profile.

B4.2 Assessment of soil properties

Soil samples (representing each soil horizon) can be assessed for texture, structure, colour, plasticity and relative density.

B4.2.1 Soil texture

Soil texture is determined using the “Feel” method (Appendix B1.2).

B4.2.2 Soil structure

Soil structure is the aggregation of individual soil particles into larger units called “peds”. Soil structure influences soil permeability and the potential loading rates through the degree, size, shape, and orientation of peds (Appendix B1.3).

B4.2.3 Soil colour

Soil colour provides valuable information about the nature and conditions of the soil. Correct colour identification and description are critical because many other landscape, soil and hydrologic factors are interpreted based on the soil colour.

Soil colour is affected by the soil’s organic matter and mineral content, with iron minerals providing the greatest variety of colour. Iron is mostly from the soil parent material but can also accumulate from the movement of water. Where soils colours are bright this may indicate aeration or presence of oxygen present most of the time.

Soil horizons may contain different colours, which are derived from either the parent material or the soil-forming process. These processes may result in the formation of layers, banding, clay accumulations, coatings, organic stains, and nodules, of different colours.

Interpretation of soil colour can indicate where water movement slows with short periods of saturation (indicated by mottling) and longer periods of saturation (indicated by grey colours). Soil colour is an important indicator of drainage properties and can be used to identify the depth to the seasonally high water table and/or perched water table conditions (Table 8). Soils subjected to seasonal saturation can be speckled with different colours, known as mottles.

Table 8: Indicative interpretation of drainage based on soil colour

Colour	Description	Indicative drainage
Red, yellow, or brown and mainly free from mottling.	• Soils are typically bright (high chroma and value) in the upper soil generally fading with depth. • Uniformly red, yellow, or brown in colour.	Well drained
Red, yellow, or brown with prominent mottles at depths >40 cm	• Soils have bright matrix colours (high chroma and value) in the upper subsoil. Prominent mottles at depths >40cm.	Moderately well drained
Mottled (speckled) [Note 1]	• Soils are mottled (speckled) directly below the A horizon. • Matrix colours may vary. Soil chroma is low (<3).	Poorly drained
Pale, grey or blue	• Soils permanently or mostly saturated.	Very poorly drained

Note: Not all soils show mottles when exposed to variably saturated conditions. Assessment of the landscape and other soil characteristics may be needed to allow a more accurate interpretation of groundwater conditions in the local situation.

B4.2.4 Groundwater

Soil treatment of wastewater requires adequate soil depth and aerobic soil conditions. The depth to groundwater is crucial to understanding the available soil depth on-site wastewater system's performance. A high water table will lead to anaerobic soil conditions allowing partially treated wastewater to enter the groundwater. This increases the likelihood of effluent breakout and surface discharges occurring. Land application of wastewater can also cause localised mounding of groundwater (a rise in the groundwater level around the land application area) which can impact the treatment function of the soils (Figure 3).

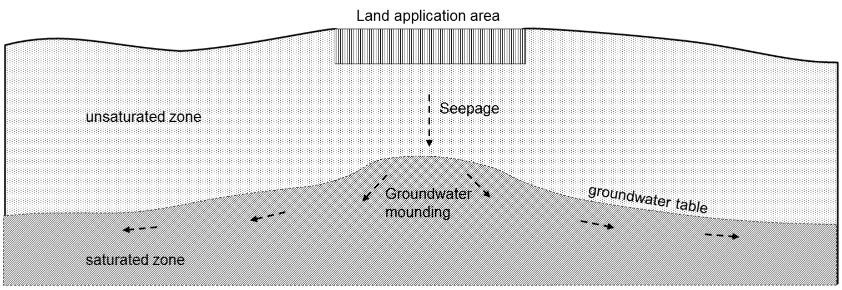

Figure 3: Illustration of groundwater and mounding

Any on-site wastewater system design must take into consideration the depth and potential use of the groundwater and likely environmental fate of any contaminants in the effluent. An on-site wastewater system within a sensitive aquifer management area may require more advanced treatment prior to discharge to land (e.g. UV disinfection and/or nitrogen reduction). A minimum vertical setback distance is required between the base of the land application area and the groundwater level to satisfy one of two situations (also refer to setback distances provided in Section B5.4):

- Where no public health or environmental constraints exist then the clearance must be adequate to ensure that hydraulic conductivity requirements are met (and no adverse groundwater mounding occurs)
- Where such constraints are present (e.g. due to the use of groundwater for individual or community water supply) then the setback distance should be increased to ensure the wastewater discharged can be adequately assimilated into the soil without breakout, down-slope seepage or runoff.

B4.2.5 Interflow

Interflow is the lateral movement of water through the upper layers of soil, above the water table. This may occur if the top soil layer has high permeability, and it is underlain by an impermeable, or a very low permeability soil layer. It also occurs as down-slope seepage on a sloping terrain with lower permeability subsoils.

Interflow potential is a function of subsoil permeability, subsoil depth, and ratios of slope length to soil layer depth. Land application area design must be based on the limiting soil layer and ensure that the irrigation (loading) rate is adjusted on a sloping site.

B4.2.6 Ecosystem features

The presence, or absence, of plant roots and worms, can indicate the soil's health. Soils with good drainage and an active ecosystem will have a high presence of roots, worms, worm casts and burrowing insects. Roots are indicators of soil structure condition, saturation and aeration.

Soils should be examined (Appendix B1.8) for root depth, abundance, direction of growth and whether they have penetrated soils uniformly (or are restricted to cracks in the soils). Indicators of poor soil health include:

- Roots growing horizontally may indicate a compacted soil pan or clay soil where roots cannot travel vertically into the soil
- Roots following cracks or fissures in the soils
- Low root growth may indicate poor growth conditions and limited soil ecosystem health.

The presence of water-tolerant vegetation may also indicate high groundwater levels.

B4.3 Additional testing

Additional testing may be required as described below.

B4.3.1 Laboratory testing of soils

Soils may be sent to a laboratory for geochemical testing or physical property testing (e.g. where contamination or fill soils are suspected). Soil samples should be labelled with:

- Collection date and time
- Sample identifier: Unique identifying number or code which can be tracked back to the specific sample records
- Testing method to be performed
- Name of person/s who collected the sample.

Handling, preservation and transport of soils need to be considered prior to collection. The consultant laboratory can advise the preservation requirements and timeframes for submitting soil samples.

B4.3.2 Groundwater testing

Water testing may provide baseline information to understand the ongoing impact of the wastewater discharge on public health and the receiving environment. Where water testing is required, sampling must commence before the on-site wastewater system is commissioned. Alternatively, an upslope control bore or piezometer can be installed and monitored. Water sampling protocols must be followed to ensure samples are representative and not inadvertently contaminated. Groundwater and surface water sampling methods and analyses are presented in Table 9.

Table 9: Groundwater sample collection and analytical methods

Sample type	Collection methods	Laboratory analysis
Surface water quality	Grab sampling	Geochemical and microbial testing (e.g. general water chemistry parameters, nutrients, indicator bacteria)
Groundwater quality	The following methods require an installed groundwater bore or piezometer: • Installed pump • Dedicated bailer • Waterra inertial pump • Low-flow purging methods.	Geochemical and microbial testing (e.g. general water chemistry parameters, nutrients, indicator bacteria)

B4.3.3 *In situ* soil permeability testing

Extensive soil investigations are required for any development where the design loading rate exceeds those recommended in this document. Permeability testing, to determine the soil's saturated and unsaturated hydraulic conductivity (the rate at which water is able to disperse into the soils), is required in this instance. Permeability testing can assist the identification of any risk of bypass of wastewater flows through the soil, ponding and runoff.

Soil permeability testing should not be used as the criterion for determining design hydraulic loading rates. However, it may be a useful tool in providing supporting information for soil category selection. Soil permeability testing is particularly important in assessing areas where land has been cut and filled and/or the soils have been compacted through earthworks. Testing is recommended where:

- Pans are present within 1 m of the land application system installation depth
- There is evidence that soils have been compacted (soil pugging, repeated traffic, etc.)
- Fill materials are present (design for these soils is not included in GD06).

AS/NZS 1547:2012 Appendix G provides a method for constant head testing. In this test, water that seeps out of an unlined test hole in the ground is replenished at the same rate from a reservoir, so that the head of water in the hole remains constant. The loss of water from the reservoir is measured over time and a mathematical model is used to calculate the saturated soil permeability (hydraulic conductivity, K_{sat}) from the measurement. This method is suitable for a soil permeability range of 0.009 to 2.9 m/day (8.6 to 2900 mm/d) or 1×10^{-7} to 3×10^{-4} m/s. Soil permeability measurement should only be carried out when the water table is at least 0.5 m below the test hole.

Some practitioners use other methods of determining Ksat test results such as:

- Double ring infiltrometer
- Amoozemeter
- Disc permeameter.

B4.4 Soil category selection for design

Soil category (1 through 6 in Table 10) is used in the selection of a suitable land application system and in determining an applicable design loading or design irrigation rate.

The soil category should:

- Be recorded in the soil log (together with photos) for each soil horizon (i.e. each soil horizon will have an assigned soil category)
- Use the most limiting soil type within the soil profile to assign the soil category for the design
- Assimilate the actual information collected for soil colour, texture and structure
- Assimilate the actual topsoil depth and underlying limited soil type
- Represent the most conservative assumptions

- Provide guidance for slopes (Section B5.2), conservative setback distances (Section B5.4) and reserve areas (Section B5.5)
- Make allowance for soil structural influence on soil infiltration capacity by adjusting the hydraulic loading rate to suit the limiting soil properties.

The designer should use their best professional judgement in assessing soil properties, assigning soil category and relating that information to design loading. The person undertaking this assessment must be suitably qualified and experienced.

Table 10: GD06 soil category description

Soil category	Soil texture	Soil Subcategory	Soil structure	Typical clay content	Indicative permeability (K_{sat}) (m/d) [Note 1]
1	Gravels and sands	1a	Structureless	<5%	>3.0
		1b	Weakly structured	<5%	>3.0
2	Sandy loams	2a	Weakly structured	5 – 10%	>3.0
		2b	Massive	10 – 20%	1.4 – 3.0
3	Loams	3a	High/moderate structured	10 – 20%	1.5 – 3.0
		3b	Weakly structured or massive	10 – 25%	0.5 – 1.5
4	Clay loams	4a	High/moderate structure	20 – 30%	0.5 – 1.5
		4b	Weakly structured	20 – 30%	0.12 – 0.5
		4c	Massive	25 – 35%	0.06 – 0.12
5	Light clays	5a	Strongly structured	35 – 45%	0.12 – 0.5
		5b	Moderately structured	35 – 40%	0.06 – 0.12
		5c	Weakly structured or massive	40 – 50%	<0.06
6	Medium to heavy clays	6a	Strongly structured	40 – 55%	0.06 – 0.5
		6b	Moderately structured	>50%	<0.06
		6c	Weakly structured or massive	>50%	<0.06

Notes:

1) Indicative permeability K_{sat} values are based on the movement of water, not effluent, through the soil. They are estimates only and should be used with caution in assisting the determination of the soil category.
2) Soil category descriptions align with AS/NZS 1547:2012 and supersede those in TP58.
3) No correlation is implied between factors in this table. Individual testing/assessment is required for site specific soil categorisation.

B5.0 Applying the evaluation to design

The aim of undertaking a site and soil evaluation for an on-site wastewater system is to identify site and subsurface constraints. These constraints are used to determine the:

- Most appropriate on-site wastewater system design
- Most appropriate land application area (including location, size, and reserve area)
- Land application methodology
- Level of wastewater treatment required (and type of wastewater treatment unit required).

This section will help determine the most appropriate on-site wastewater system for the site. Guidance for specific design of the on-site wastewater system components are covered in Section D (wastewater treatment units) and Section E (land application systems).

B5.1 Constraints of subsoil types

The wastewater treatment function of natural soils should be protected and enhanced at the design, construction and operational stages. Methods to retain and enhance soil properties for on-site wastewater treatment are listed below.

Design	• Designing for a higher quality effluent (secondary treatment quality or better) • Using conservative loading rates • Avoiding discharge into, or onto, cut or fill soils • Avoiding stormwater discharge onto the land application area or drains excavated through the land application area.
Construction	• Excluding land application areas from construction machinery • Provision of good topsoil depths • Protecting from overland flow across the area by installation of: ○ Up-slope surface cut-off drains where a surface/shallow wastewater land application system is proposed ○ Up-slope swale diversion drains • Planting of the land application area with high evapotranspiration plant species.
Operation	• Excluding or limiting, certain contaminants from entering the wastewater (e.g. sodium-, potassium- or phosphorus-based cleaning chemicals, antimicrobial agents, etc.) • Avoiding shocking or overloading the on-site wastewater system • Resting the land application area (e.g. through rotation of trenches) • Controlling peak flows • Regular flushing of the irrigation lines • Regular on-site wastewater system maintenance inspection.

Designers must consider and evaluate the site and soil conditions carefully before selecting a land application system. Table 11 specifies the suitability of various land application systems for different soil categories (Section B4.4).

The designer must determine which of the soil categories of Table 11 is the most limiting at the site when deciding on the type of land application system that might be used.

Consideration should be given to the following:

- Discharge of primary treated wastewater into Category 6 soils is not appropriate. Special design techniques will be required for Category 6 land application areas
- Some soils are outside the scope of this design guideline; e.g. cut and fill soils, and some soils specific to Auckland (e.g. Onerahi Chaos, Mahurangi Limestone and peats)
- Downgradient water takes which may be impacted by effluent discharge or accidental spills
- Subsurface or surface irrigation systems, particularly pressure compensating drip irrigation systems, can be used in Category 1 through Category 5 soils. However, nutrient leaching may occur with Category 1-3 soils. Additional treatment or special design of the land application system is required where groundwater protection is needed
- Conventional trenches may be used in well-drained areas with low groundwater tables and where upper soils have adequate percolation. For Category 1 soils, groundwater contamination is more likely (due to fast drainage characteristics of these soils) and special design (i.e. discharge control trenches) is required
- Evapotranspiration seepage beds are suitable only for Category 3 to 5 soils
- Wisconsin mound systems are designed for Category 1 to 3 soils.

Table 11: Suitability of land application systems in soil categories

Land application method		Soil category					
Type	Method	1 Gravel, coarse /medium sand	2 Loamy sand and sandy loam [Note 1]	3 Fine sandy loam, loam, silt loam	4 Sandy clay loam, fine sandy clay, clay loam, silty clay loam	5 Sandy clay, light clay, silty clay	6 Clays and hardpan
Shallow irrigation systems	Pressure compensating drip irrigation (surface and subsurface) (PCDI)	[Note 2] [Note 4]				[Note 3]	[Note 3]
	Low pressure pipe subsurface irrigation (LPP)		[Note 5]	[Note 5]	[Note 5]	[Note 3]	
	Low pressure effluent distribution (LPED) subsurface irrigation		[Note 4]	[Note 4]	[Note 5]	[Note 3]	
	Low pressure effluent distribution (LPED) surface trickle irrigation		[Note 5]	[Note 5]	[Note 5]	[Note 3]	
Conventional land application systems	Conventional trenches						
	Shallow trenches						
	Discharge control trenches	[Note 6]					
	Discharge control beds	[Note 6]					
	Deep trenches		[Note 7]				
	Conventional beds						
	Evapotranspiration seepage beds (ETS)						
	Wisconsin mounds						
	At-grade fill mounds						
	Bottomless sand filters						

Notes:

Shading denotes applicable use in this soil type with additional information provided in the number notes.

1) Fine wind-blown sands can exhibit characteristics similar to Category 4 and 5 soils and require careful design.
2) Emitter and drip line spacing to be reduced to 300 mm by 300 mm.
3) Special design precautions are required in these soil conditions and good topsoil depth is essential
4) Minimum topsoil depth 150 mm.
5) Minimum topsoil depth 250 mm.
6) For use in gravels and coarse sand.
7) Only for use where no public health, environmental or site constraints are present.

B5.2 Slope constraints

Slope constraints on the selection of land application systems are generally difficult to quantify but can be managed by a thorough site and soil evaluation and corresponding land application system design precautions, e.g. setbacks and reduction in loading rates. Table 12 provides slope gradient limitations for common land application methods.

In some instances, site-specific constraints (such as slope instability or mass movement) will require geotechnical assessment of the suitability of a proposed land application area.

In steeper site situations, outside the limitations set out in Table 12, special design precautions will be required. Their application must be justified in the design report.

Table 12: Slope gradient limitations for various land application systems[1]

(adapted from AS/NZS 1547:2012).

Land application system	Slope gradient limitations [Note 1]	Notes
Surface irrigation (spray, drip and low-pressure effluent distribution irrigation)	<5.7° (10%)	• Due to low risk of effluent run-off during wet weather. • Assumes little disturbance occurs during construction. • This is limited by natural infiltration rate and even distribution.
Subsurface drip irrigation (i.e. pressure compensating drip irrigation)	<16.7° (30%)	• All irrigation lines should be installed along the land contours. • If this is not possible, and if the lines have non-leak emitters, then lines may run through contour lines in accordance with the manufacturer's specifications. • A copy of the specifications should be included with the system design for approval.
Subsurface low-pressure effluent distribution or low-pressure pipe	<8.5° (15%)	• Shallow and narrow trenches for low pressure effluent distribution or low-pressure pipe systems must be constructed along the contour.
Evapotranspiration beds	<5.7° (10%)	• High soil disturbance and erosion issues may arise during construction on steeper slopes.
Trenches and beds, including discharge control trenches and beds	<8.5° (15%)	• Construction becomes difficult and costly when slopes are high. • High soil disturbance and erosion issues may arise during construction on steeper slopes.
Mounds	<8.5° (15%)	• High soil disturbance and erosion issues may arise during construction on steeper slopes.

Note 1: Slope angles provided for stable land only. If a geotechnical report has been produced for the site, geotechnical assessments will be required to confirm the stability of the land, taking into account the additional infiltration.

[1] Adapted from Table K1 and K2 of AS/NZS 1547:2012

B5.3 Other considerations for selection of land application systems

Table 13 provides other factors that may affect the selection of land application systems including surface water drainage, soil depth, groundwater depth, wastewater quality, lot size, climatic factors, etc. are included in Table 13.

More than one land application area may be used to achieve acceptable performance. Development options will be significantly constrained where land application systems are unable to provide satisfactory performance.

The selection of a land application system is an important component of overall risk management and should be managed within the risk management framework, which will consider a combination of factors such as treatment unit selection, setback distance selection, reserve area allocation, and operation/monitoring measures. Further discussion on the risk management framework is provided in Section G.

Table 13: Other considerations for land application system selection

Land application system	Soil depth	Depth to highest seasonal groundwater table [Note 8]	Dispersive (sodic) soil	High content of stones, cobbles, or boulders	Land availability	Climatic influence	Other comments
Conventional trenches and beds	>0.6 m beneath bottom of trench/bed. [Note 1]	>1.0 m [Note 4]	Larger trench may be required, due to risk of permeability loss.	Larger area may be required due to lack of water storage capacity.	Large area may be required, depending on the soil category. [Note 6]	Not heavily influenced by heavy rainfall.	Suitable for various circumstances, subject to soil and site constraints.
Evapotranspiration beds	>0.6 m beneath bottom of bed. [Note 2]	>1.0 m [Note 4]		Larger area may be required due to lack of water storage capacity.	Large area may be required, depending on the soil category. [Note 7]	It's important to ensure that evapotranspiration exceeds precipitation [Note 6]	Suitable for various circumstances, subject to soil and site constraints.
Mounds	N/A [Note 3]	>0.6 m [Note 5]	Offers more advantages compared to trenches and beds. Design should consider limiting the infiltration rate in the underlying natural soil. Seepage may occur along mound toe.	Not relevant.	Space may be limiting on steep land.	Not heavily influenced by heavy rainfall.	Suitable for shallow soil. May be suitable for shallow water table.
Subsurface irrigation	>0.6 m beneath bottom of drip lines.	>1.0 m [Note 4]	Offers more advantages compared to trenches and beds. Larger area or lower DIR may be required, due to risk of permeability loss.	Larger area may be required due to lack of water storage capacity.	Large area may be required, depending on the soil category.	Not subject to rainfall influence.	Suitable for various circumstances, subject to soil and site constraints. Recommended for higher slope site (refer Table 11). May be suitable for higher water table (Section B5.4).

Land application system	Soil depth	Depth to highest seasonal groundwater table [Note 8]	Dispersive (sodic) soil	High content of stones, cobbles, or boulders	Land availability	Climatic influence	Other comments
Surface irrigation	>0.6 m beneath bottom of drip lines.	>1.0 m [Note 4]	Offers more advantages compared to trenches and beds. Larger area or lower DIR may be required, due to risk of permeability loss.	Less relevant.	Space may be limited due to wider buffer zone requirements.	Can be heavily influenced by intense rainfall.	Suitable for various circumstances, subject to soil and site constraints. Design should consider that no human traffic is allowed except for maintenance purposes. Not suitable if system is periodically inundated. Not suitable if there are sensitive ecological area or water bodies downstream.

Source: AS/NZS 1547:2012 Notes:

1) Further setback distance may be required for more permeable soils (Section B5.4).
2) Not advisable for highly permeable soils such as Category 1 – 2 soils. Further setback distance may be required for more permeable soils (Section B5.4).
3) Not a constraint: mounds are designed to overcome shallow soil limitations.
4) Setback distances may be adjusted based on slopes and treated wastewater quality and soil category (Section B5.4).
5) Mounds are specifically designed to overcome high water table levels. Further setback distance may be required (Section B5.4).
6) A water balance can be done to assess the excess precipitation over evapotranspiration during winter wet periods, and design allowance made for sideways seepage into the topsoil between adjacent beds. Bed spacing should be increased as required to accommodate this seepage.
7) Trenches and beds are relatively inefficient in effluent distribution and require a larger area. Dose loading (rather than gravity loading) of treated effluent will improve distribution effectiveness.
8) A smaller area may be possible if evapotranspiration is expected to be higher than precipitation.
9) Groundwater depth is defined as the vertical distance from the base of the land application system to the highest seasonal water table level prior to the installation of the system.

B5.4 Setback distances

Setback distances between land application system components and site features (such as property boundaries, existing or planned structures, waterways, etc.) are required to maintain performance and allow for repairs/maintenance. The site features that need to be considered include boundary lines, water supplies, wetlands, watercourses, buildings and utilities, etc. (Table 14).

Effluent contains potentially pathogenic micro-organisms, dissolved nutrients and chemicals capable of traveling long distances, more so once in the saturated zone. Land application areas should be located well above the seasonal high groundwater level and as far as possible from drinking water supplies and surface waters to minimise the possible health hazard and pollution potential of treated effluent, Proximity to any ecologically sensitive or high amenity value receiving environment should be carefully evaluated.

It should be noted that:

- The wastewater treatment unit must comply with the Building Code
- If an on-site wastewater system has not been assessed through OSET NTP, or international equivalent, the design should provide greater setbacks (such as those for primary effluent)
- Design loading and irrigation rates should comply with those recommended in Section E1.2. Lower loading rates should be adopted if minimum setback distances cannot be achieved
- On-site wastewater systems should not be located in municipal water supply catchments
- Small lots system design should provide a consistently high level of treatment
- Greater setback distances are required to mitigate the potential for cumulative effects.

When designing a land application system, consideration should also be given to:

- Potential future on site changes or improvements that may impact on the land application area
- Maintaining the reserve land application area in a condition that does not impede its use for wastewater discharge if required in the future (i.e. the area shall not be sealed or used for vehicle parking, buildings, driveways or any other form of development)
- Designing for any future public sewer line connection. If the on-site wastewater system cannot be constructed in front of a home, then a dry (not connected) sewer line can be installed to accommodate any future public sewerage connection
- The potential impacts of climate change on groundwater and soils.

Table 14: Minimum setback distance from edge of land application area to edge of site feature for different effluent treatment levels

Site feature	Soil category	Primary treated (septic tank + effluent filter)	Secondary treated (e.g. AWTS)	Advanced secondary (e.g. Packed bed reactor)	Tertiary (disinfection) [Note 1]	Advanced tertiary (nutrient reduction and disinfection) [Note 2]	Notes
1: Buildings or houses [Note 3]	N/A	3 m	1.5-3 m	1.5-3 m	1.5-3 m	1.5-3 m	Minimum setback is 5 m if downslope boundary includes stormwater disposal trench. For sloping land, additional minimum setbacks apply: ○ Add 2 m from downslope building/boundary for 10˚ (17.6%) to ≤15˚ (26.8%) ○ Add 2 m if adjoining boundary side contains a field tile drain. ○ Add 3 m from downslope building/boundary for >15˚ (26.9%) to 18˚ (32%) ○ Add up to 10 m for steeper slopes.
2: Property boundaries (and sealed main access paths and driveways) [Note 4]	N/A	1.5 m	1.5 m	1.5 m	1.5 m	1.5 m	
3: Surface waters [Note 5] including streams (to top of streambank), downslope stormwater drains or downslope drainage channels, wetlands, estuaries, coastal marine area at high tide mark, dams or lakes and overland flow paths	Soil category 1 Soil category 2 Soil category 3-5 Soil category 6	[Note 6] 20 m 20 m [Note 6]	15 m 15 m 15 m 20 m	12.5 m 12.5 m 15 m 15 m	10-12.5 m 10-12.5 m 10-15 m 10-15 m	10 m 10 m 10 m 10 m [Note 7]	Setbacks should be measured from the top edge of surface water. For steep sloping land (where only pressure compensating drip irrigation can be used), additional minimum setbacks for surface waters may be needed: ○ Add 1 m for every degree over 10° (17.6%) with no land steeper than 18° (33%) New subdivisions should have minimum setbacks of 15 m (with additional setback based on gradient) [Note 8]. For coastal marine areas setback distances should be a minimum of 15 m above mean high water spring.

Site feature	Soil category	Primary treated (septic tank + effluent filter)	Secondary treated (e.g. AWTS)	Advanced secondary (e.g. Packed bed reactor)	Tertiary (disinfection) [Note 1]	Advanced tertiary (nutrient reduction and disinfection) [Note 2]	Notes
4: Services							
4a: High risk underground pipework (trenched, downslope of land application area, etc.)		10 m	5 m	3 m	2 m	1.5 m	Pipes in trenches in gravel, sand or scoria can act as a conduit for wastewater and may require additional setback distances as applicable for surface water above.
4b: Low risk underground pipework (trenchless, upslope of land application area, etc.)		0.5 m	0.5 m	0.5 m	0.5 m	0.5 m	Setbacks are generally not required for trenchless installation when the pipe is more than 1.5 m below the base of the discharge system.
5: Water supply bore (cased)	Soil category 1 Soil category 2 Soil category 3-5 Soil category 6	[Note 6] 20 m 20 m [Note 6]	20 m	20 m	10 m	10 m	Setback distances from water supply bores should be assessed based on site-specific constraints including soil type, bore depth, casing depth and quality, water usage, groundwater flow, presence of downstream users and wastewater quantity and quality.
6: Groundwater (winter high)	Soil category 1 Soil category 2 Soil category 3-5 Soil category 6	[Note 6] 1.5 m 1.2 m [Note 6]	1.5 m 1.2 m 0.9 m 0.6 m	1.2 m 0.9 m 0.6 m 0.6 m	1.0 m 0.6 m 0.6 m 0.6 m	0.9 m 0.6 m 0.6 m 0.6 m	Measured vertical distance from base of land application system or point of discharge (e.g. pipes or trench) to seasonal high water table. Groundwater setbacks for subdivisions should be greater than 1 m.
7: Floodplain (located outside of % AEP floodplain) [Note 9]		1%	5%	5%	5%	5%	AEP is Annual Exceedance Probability and is equivalent to: 1% AEP (one in 100 year), 5% (1 in 20 year).
8: Embankments/retaining walls		3.0 m or 45° angle from toe of wall (whichever is greatest)					Applies to land application systems upslope of retaining walls and embankments. Stormwater setbacks should be applied to all downslope walls where behind-wall drainage is in place. Wall stability must be assessed where over 5 m high, or in locations where a failure could cause direct damage.

Notes:

1) Disinfection refers to the reduction in number of faecal coliforms per 100 ml of wastewater and the level of reduction is likely to vary depending on site constraints. A maximum number of 200 CFU/100 ml is accepted here as the minimum level of reduction.
2) Nutrient reduction is necessary where a discharge may adversely impact surface and/or groundwater water quality and requires ongoing monitoring and reporting of system performance. For example, the recommended maximum nitrate nitrogen level is 10 g/m^3.
3) Setback distances from houses of less than 3 m are only appropriate where drip irrigation (covered or subsurface lines) land application areas are being used with low design irrigation rates, or where shallow subsurface systems (low pressure effluent distribution) are being used with equivalent low areal loading rates. The reduced setback distances may be applied where the land application area is downslope from a dwelling.
4) Setback distances from upslope boundaries as low as 0.5 m may be possible where drip irrigation land application is used with low design irrigation rates (e.g. 2.5 mm/day), or where shallow subsurface systems are being used with equivalent low areal loading rates and slopes down to, and not away from, the land application area.
5) Setback distance from surface water area is defined as the areal edge of the land application area (design area plus surrounding absorption buffer) to the edge of the waterway (e.g. the bank of a pond, stream, river, stormwater channel).
6) Specific design considerations are required for discharge of effluent into Category 1 & 6 soils. Where groundwater quality protection is required in Category 1 soils (gravels) the level of in-ground treatment will be limited unless measures are taken to slow the soakage rate.
7) Nutrient reduction is necessary where a discharge may adversely impact surface water quality and requires ongoing monitoring and reporting of system performance.
8) Specific setbacks may be required for areas of new subdivisions to mitigate cumulative adverse effects.
9) Land application areas must be outside the 1 in 20-year coastal inundation areas (or equivalent). Refer to Section B3.3.1.

B5.5 Reserve area requirements

A reserve area is an area set aside for future use as a land application area to replace or extend the original land application system. Guidelines for reserve area are provided in Table 15. It should be noted that:

- The smaller reserve areas can be applied where:
  - Conservative wastewater production rates have been used in the design flow assessment, and
  - Lower irrigation rates have been used for determining the land application area requirements
- The reserve area may be reduced where secondary effluent is discharged in on-site wastewater systems normally designed for primary effluent
- In all cases, 100% reserve area is required with primary effluent
- The design must consider factors such as density of development, slope of land application area, potential for further site development, exposure to wind and sun and risk of adverse effects
- More than 50% reserve area should be provided where designs assume water reduction fixtures are installed to mitigate future removal of those devices
- An additional reserve area must be allocated where there is doubt concerning the actual water usage and/or there is a possible lack of conservatism in the establishment of the design flow volume
- Additional design requirements, such as additional planting, cut-off drains and fencing to restrict access, may be required to ensure the integrity of the reserve area
- The reserve area is a design contingency that should be proportional to the degree of risk. As the scale of the on-site wastewater system increases beyond that of a typical house, (i.e. any on-site wastewater system with a flow greater than 3 m^3/day), then greater reserve areas should be provided to mitigate any design, and/or ongoing maintenance uncertainties, or uncertainties in the owner meeting their long-term responsibilities. An additional reserve allocation is important to provide an additional factor of safety in proportion to the greater scale of potential effects in the event of a significant failure.

Table 15: Guidelines for reserve application areas

Land application method	Reserve area allocation
Subsurface drip irrigation (pressure compensating) (Where non-conservative design flow based on less than 145 L/p/d)	33% - 100% (67% - 100%)
Surface drip irrigation (pressure compensating) (Where non-conservative design flow based on less than 145 L/p/d)	50% - 100% (80% - 100%)
Shallow trenches (with primary treated effluent)	100%
Standard/deep trenches (with primary treated effluent)	100%
Evapotranspiration seepage beds	100%
Shallow trenches (with secondary treated effluent)	50% - 100%
Mound systems	100%

In cases where the design flow is based on greywater only with all toilet wastewater discharged to a compost toilet, the reserve allocation should be 140% to 150% (Appendix E).

B5.6 Site modification

Land application areas should not be located where earthworks have occurred unless subject to special design. Specific points to note regarding soil modification:

- Protect soils in the land application area from compaction before, during and after construction
- Land application systems should not be built on unstabilised fill material or disturbed soil
- Filled or disturbed areas should be allowed to stabilise by natural settlement for a period of at least six months before soil characterisation (Section B4.0) is performed
- Mechanical compaction with shallow lifts (15 cm) may be appropriate if the fill material contains only granular sand or sandy loam
- Fill material used for a raised land application system, such as mounds, should have a permeability test undertaken at an undisturbed location at the borrow pit and this should be repeated after the stabilisation period to confirm the percolation/infiltration rate.

All the proposed site modification work should be undertaken under the supervision of a suitably qualified and experienced person. The potential site modification measures may include those listed in Table 16.

Table 16: Site modification to accommodate specific site constraints

Constraints	Measures	Comments
Shallow depth to bedrock, cracks, crevices, depressions, sinkholes or other susceptible geologic formations	• Installation of a 150 mm clay barrier in the proposed land application area. • At least 1200 mm usable soil or usable topsoil should be placed above the clay layer, in the proposed land application area, including the proposed reserve area.	• Careful design required on steep slopes. • A suitably qualified and experienced person should supervise the construction and certify the as-built plan.
Limited useable soils	• Top-up of usable soil with imported media. • The depth of usable soil (native soil and/or imported media) should be at least 1200 mm for the proposed land application area and the reserve area.	• Permeability tests must be conducted in the stabilised fill material during the normal high groundwater period. [Note 1] • A conventional trench system may be designed based on the tested permeability rate. [Note 2] [Note 3] • Where drip irrigation is proposed the recommended 1200 mm useable soil depth may be reduced.

Constraints	Measures	Comments
Free draining soils	• If a conventional trench is proposed, a discharge control trench or an elevated mound system may be applicable. • The site may be modified using a cut and fill system, so that the proposed trenches are bounded (both horizontally and vertically) by at least 600 mm of a known soil type with lower permeability.	• Conventional land application methods are not advisable. Shallow irrigation methods are recommended. • Refer to Section D for design details of discharge control trenches and mound systems.
Sloped sites	• Sites with at least 300 mm of permeable soil and slope not higher than 11.5° (20%) may be modified by grading (e.g. cut and fill) to meet the 8.5° (15%) maximum slope.	• Slope constraints for various land application systems are presented in Table 12. • For conventional trenches, the maximum site slope is 8.5° (15%). • Conventional trench slope constraints are mostly related to construction risks. • All filled area should be allowed to stabilise before testing to confirm permeability. • Appropriate ditches, berms, and drains should be installed to control surface drainage and groundwater.

Notes:

1) Permeability testing is required on any fill or compacted soils since soil texture will not be an accurate indicator of soil permeability.
2) A land application system should not be constructed with less than 150 mm of naturally occurring soil from original ground level to bedrock.
3) No land application system should be constructed if there is fractured bedrock at grade, or within 600 mm of original grade.

C Design flow volumes

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Tables

C1.0 Design considerations

This section provides guidance for determining design flow volume: the peak occupancy or usage numbers of a household or facility multiplied by the design flow allowance per person.

Wastewater design flow volume depends on each of the following:

- Type of facility (Table 17)
- Per capita water consumption rates (Table 18)
- Installed water-use reduction fixtures.

Underestimation of design flow rate can result in overloading and system failure. Consequently, designers should use peak daily flow allowances (i.e. peak occupancy) and not average flow rates.

Other design considerations include:

Conservative design	• Design flows should be based on the maximum number of people occupying the premises, and a per capita wastewater flow allowance (e.g. peak daily flow).
Water source	• A slightly reduced per capita water usage is allowed where water supply is via roof water. If water use cannot be measured, then the larger allowances should be used.
Use of water reducing fixtures	• Design flows can include water-reducing fixtures where those fixtures are installed and operated at the estimated flow rate. • Design flows should assume standard fixtures where there is uncertainty that water reducing fixtures will be installed/retained. Water reduction fixture allowances are provided in Appendix D.
Greywater reuse	• Greywater reuse to reduce wastewater flow volumes can be considered. • Further information on reuse of treated wastewater is provided in Section D1.8.

Design flow rates may be adjusted if there are reliable long-term water meter readings, in conjunction with long-term occupancy data. In some cases, data from comparable facilities may provide reliable design flows.

C1.1 Calculating the total design flow volume

The total design flow volume of an on-site wastewater system is determined via the following equation:

$$Total\ design\ flow\ volume = maximum\ design\ occupancy\ number\ \times design\ flow\ allowance\ per\ person$$

- The maximum occupancy number is dependent upon factors such as the intended use, size and internal floor plan of the facility or dwelling
- The design flow allowance per person is dependent on factors such as the installed water fixture facilities, user's water-use pattern and source of water supply.

On-site wastewater system designers need to make a reasonable professional judgment to determine both the maximum occupancy number (Section C2.0) and design flow allowance per person (Section C3.0) based on the proposed development and professional experience.

C1.2 Alternative data

Water allowances for various facilities are provided in Table 18. This is not an exhaustive list.

The design report should provide justification of any alternative data used. Measured flow data can provide more certainty of site-specific water usage and is a good means of verifying the proposed design flow volume. For this, daily flow meter readings and occupancy numbers need to be recorded at the same time each day for at least 6 - 8 weeks for the existing activity and then extrapolated to represent predicted peak flows under the future maximum occupancy/usage. Conservative values should always be applied.

C1.3 Intermittent flow scenario

Sometimes, wastewater flow into the on-site wastewater system occurs intermittently, e.g. community halls, marae, clubrooms, where daily and/or overnight occupancy varies.

In these cases, the design report should include:

- A day-by-day (and/or night-by-night) maximum occupancy
- The per-person flow allowance for individual user groups, from Table 18
- A weekly or monthly total flow
- Water storage capacity of the on-site wastewater system to verify sufficient wastewater storage volume between peak usage events
- Average daily flow volume for the weekly or monthly period
- Land application area, sized on daily average flow
- Maximum daily flow discharge volume. Sufficient storage capacity for that flow is should be available within the land application system and a water balance completed to ensure adequate system disposal capacity
- Capacity of a separate or supplementary storage system, if required.

C2.0 Design occupancy numbers

Recommended design occupancy allowances for various types of facilities are provided in Table 17. The design for intermittently loaded on-site wastewater systems (such as holiday dwellings subject to occasional or regular weekend use and fulltime use during summer vacation periods) should provide an on-site wastewater system sized for permanent use.

Table 17: Occupancy allowances

Facility	Occupancy for design purposes
Homes	
Number of bedrooms	
1	2
2	4
3	5
4	6
5	8
6	9
Holiday accommodation	
Guests	Maximum occupancy
Staff	Maximum number of staff
Hospitals [Note 1]	
Patients	1 person per bed
Staff	Maximum number of staff
Retirement villages [Note 1]	
1 bedroom	1.3 persons per unit
2 bedrooms	1.3 – 2.0 persons per unit
3 bedrooms	2 – 4 persons per unit
Staff	Maximum number

Note 1: Occupancy data are derived from literature and observed levels. Average NZ retirement village average occupancy is 1.3 people per unit with occasional overnight guests. Retirement home occupancy should be based on the number of beds per bedroom. A higher water use per person should be allowed in facilities providing community care (unless site-specific data are available).

An additional occupancy allowance should be made in situations where large, modern dwellings are proposed which have additional rooms that could be used as bedrooms (e.g. office, media rooms, games room or study). Rooms with an ensuite are considered to provide capacity for 2 people (unless capacity for additional guest beds is evident).

Design occupancy should allow for a seasonal peak, not just the average daily flow. Holiday homes tend to have intermittent occupancy but when occupied are likely to have a higher occupancy than a continuously occupied dwelling. Peak flow storage within the treatment and/or land application system should be provided, and/or the use of a conservative design loading rate in sizing the land application system.

Designers should provide a water balance showing the time period for the stored effluent to fully discharge via the land application area before the storage volume refills.

C3.0 Design flow allowance per person

Table 18 provides recommended design wastewater per capita flow allowances for standard dwellings, as well as a range of other domestic-type facilities. Where there is any uncertainty, the higher, more conservative, flow allowance figures should be applied in the design.

These flows are recommended minimums for design purposes. Ranges of design flow rates reflect the inherent uncertainty associated with actual per-capita wastewater production.

Table 18: Minimum domestic wastewater flow allowances

Category	Source	Typical wastewater flow allowance	
		L/person/day	
		On-site roof water tank supply [Note 1]	Reticulated community or bore water supply
Domestic flow allowances			
A	Up-market/luxury or large rural lifestyle households with extra wastewater producing fixtures, such as in-sink grinders, dishwashers, modern shower or bath facilities or other comparable fixtures	220	220
B	Households with standard fixtures including 6/3 or 11 L flush water cisterns; automatic washing machine and dishwasher. These flow allowances should also be used for all rental properties regardless of fixtures	180 – 200	200
C	Households with dual flush toilet/s and standard fixtures, low water use dishwasher and no in-sink grinder	160	180
D	Households with 6/3 L flush toilet/s and standard water reduction fixtures and no in-sink disposal grinder [Note 2]	145	165
E	Households with full water reduction fixtures on all water outlets and no garbage grinder [Note 3]	120	145
F	Households with full water reduction fixtures without permanent electricity supply (fixtures as per Note 2 and Note 4 also apply)	100 – 120	120
G	Decreased flow allowances for households with full water reduction facilities as in Category E (including dual flush 6/3 L toilet systems, standard water reduction fixtures and no bath) where subject to a discharge consent	100 – 115	135
H	Households with full water reduction facilities plus reclaimed water recycle for toilet cistern flushing [Note 5]	95 – 100	100 – 115
I	Households – blackwater only (based on an 11 L flush toilet discharging to land application area)	66	

Table 18 continues on following pages

Category	Source	Typical wastewater flow allowance	
		L/person/day	
		On-site roof water tank supply [Note 1]	Reticulated community or bore water supply
J	Households – blackwater only (based on an 11/5.5 L flush toilet)	45	
K	Households – blackwater only (based on a 6/3 L flush toilet)	25	
L	Households – greywater only	130	140
M	Households – greywater only (with extra water reduction fixtures)	95 – 100	100 – 115
Commercial flow allowances for standard fixtures [Note 6]			
Holiday accommodation [Note 7]	• Guests, residential staff	220	
	• Reception rooms	30	
	• Non-resident staff	40	
	• Bar trade (per customer)	20	
	• Restaurants (per diner)	30	
Restaurant/bar/cafe [Note 8]	• Per dinner patron	30	
	• Per lunch patron	25	
	• Per bar patron	20	
Lunch bar (per customer)	• Without restroom facilities	10	15
	• With restroom facilities	15	25
Function centres and Community halls	• Catering	20	30
	• Meetings	10	15
Marae [Note 9]	• Day only manuwhiri/manuhiri[1]	15 – 40	
	• Day and overnight manuwhiri/manuhiri	65 – 80	
Schools (pupils plus staff) [Note 10]		15 – 30	15 – 30
Child care facilities	• There is insufficient data available to assess flows from childcare facilities. Estimated flows should be assessed on a case-by-case and would require validation monitoring.		
Public toilets (including hand wash) [Note 11]		10 – 20	10 – 20
Camping grounds [Note 12]	• Fully serviced	100	130
	• Day only visitors	50	65
Rest homes/hospital/care facilities [Note 13]		220	250
Retirement home	• Per resident [Note 13]	200	220
	• Per day staff	40	50

[1] Manuwhiri/manuhiri is guest or visitor

Category	Source	Typical wastewater flow allowance	
		L/person/day	
		On-site roof water tank supply [Note 1]	Reticulated community or bore water supply
Day staff	• High water usage e.g. some factories and/or shower facilities [Note 14] • For all standard facilities • Facilities with full water reduction fixtures [Note 15]	60 40 20 – 50	

Notes:

1) Where a site is reliant on water supply being supplemented by a water tanker, the design flow allowances should be based on those for reticulated water supply.

2) Standard water-reduction fixtures include dual flush 6/3 L toilet cisterns, aerator faucets, shower flow restrictors, water conserving automatic washing machines and restricted, standard automatic washing machine and dishwasher, but no in-sink grinder.

3) Full water reduction fixtures include the combined use of the dual flush 6/3 L toilet cisterns, shower flow restrictors, low pressure aerator faucets (taps), front load/low water consumption water conserving automatic washing machines and low-water use dishwasher, no in-sink grinder, and fixed orifice flow control devices in all water use outlets or flow restriction valves to achieve the following flow rates:

   - Laundry faucets: 10 L/min
   - Kitchen faucets: 9 L/min
   - Bathroom faucets: 6 L/min
   - Shower head: 9 L/min
   - Washing machine: 11 L/min.

   The basis for the recommended flow allowance reductions for households is provided in Table 73 in Appendix D1

4) A reduced allowance is assumed for sites not connected to a continuous electricity supply. Water usage on sites with poor electricity supply and with low water pressure supply may be considered equivalent to that of houses with full water reduction fixtures (Category F) unless they have high water consumption appliances installed. A higher flow allowance of 135 L/person/day should be applied where gas califonts are installed.

5) Design flow allowances as for Note 3 plus on-site recycle to toilet cisterns for flushing. The flow allowance reflects the removal of toilet flush water from the land application system. The designer should be aware that the wastewater treatment unit is to be sized to treat the pre-water conservation flow volume (to account for the same or higher BOD_5 load).

6) Commercial waste should be assessed in terms of specific effluent load, not only volume since concentrations will vary depending on site-specific practices. The designer should be aware that water conservation measures installed in commercial premises, e.g. bars and restaurants, may not provide the same level of savings as achieved by domestic uses. Conservative flow allowances should be applied unless specific metered consumption information is available.

7) Evidence does not support lower water usage by staff or guests of commercial premises, so no differentiation is made to the flow allowances according to the water supply source. Some reduction (up to 25%) may apply to the per guest water usage allowance if laundry is done off site.

8) Evidence does not support lower water usage by staff or guests of commercial premises, so no differentiation is made to the flow allowances according to the water supply source. For bar patrons, it is assumed that there is minimal food served. Where meals are served, meal water usage allocations per patron, apply. In bar facilities, where full water-reduction fixtures are installed on all water usage outlets and patrons are only present for short periods (and no food is provided), a water usage allowance of 10 L/person/day may be appropriate.

9) Additional allowances should be made where there are other wastewater generating facilities e.g. laundries, butcheries, private dwellings or papakainga. Marae wastewater design information has been supplied by NIWA through the MBIE Contract C01X1237 – *Resilient Marae and Community Water and Wastewater Infrastructure Programme*. Programme details and marae partners can be found in Colliar *et al.* 2015.

10) Figures from the lower end of the range should be supported by actual water usage records. Additional allowances also need to be made in the design flows for schools that also have cafeterias (with on-site catering) and/or gyms with shower facilities.

11) For low water use toilets with 6/3 L flush cisterns and standard public facilities, the lower end of the range applies; for modern upmarket toilet facilities, the higher range applies.

12) Fully serviced includes for overnight campers using showers and communal cooking facilities.

13) Flow allowances for individual dwellings within a retirement village may be based on the recommended flow allowances for households or alternatively, on flow meter rates where these are available. Where extra-care facilities are provided, the actual per capita rates will be higher than standard rates provided, and a conservative design allowance should be used.

14) Increased water usage allowances are appropriate where staff activities are likely to involve regular cleaning of themselves and/or the facilities, e.g. rural food preparation factory. Where staff are likely to use showers, the designer should consider all the activities being undertaken by staff and rates higher than 60 L/person/day may apply.

15) Lower water usage allocations apply where staff water usage is likely to be minimal due to short hours and full water reduction fixtures (equivalent to the allocation for a café customer). The provision of flow reduction fixtures may not result in significant water usage reduction for staff due to equivalent cleaning needs, irrespective of the water fixture devices.

D Design of wastewater treatment units

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D1.0 Design of wastewater treatment units

D1.1 Introduction

Design considerations for on-site wastewater treatment units include:

- Provision for an adequate level of treatment while allowing for high fluctuations of flow rate and wastewater concentrations
- Site-specific constraints
- Safe design
- Operation and maintenance needs, including access.

Treatment units must comply with Building Code requirements (Clauses G13 and G14) as set out in the First Schedule to the Building Regulations 1992 and allow ready access for maintenance, including desludging.

New subdivisions require higher effluent quality (minimum secondary), as well as allowing for disposal of nutrients. Disinfection may also be needed. Parameters that may be considered during the early design of on-site wastewater systems are provided in Table 19.

Table 19: Parameters to be considered during design and selection of on-site wastewater treatment units[1]

Parameters	Considerations
Aesthetics concern	• Odour control (e.g. gas tight lids, carbon filters, vents) • Visual aesthetics including above-ground components (e.g. tank cover, air pump, control panels) • Noise (e.g. pumps, aerators)
Flow rate variability	• Acceptable variability in flow and constituent loading
Maintenance needs	• Access for maintenance • Frequency (e.g. solid removal frequency, outlet filter cleaning, media replacement, cleaning emitters and spray nozzles) • Responsible party (e.g. manufacturer, third party, ownership changes) • Maintenance costs and fees • Time and skill required for maintenance
Monitoring	• Capacity for remote monitoring (e.g. pump on/off cycles, pump run-time, tank liquid levels, alarm conditions, constituent concentrations, UV lamp status) • Capacity for remote control (e.g. pump setting, alarm reset)

1 Adapted from Metcalf & Eddy 2006

Parameters	Considerations
Performance and reliability	• Performance and reliability (e.g. pathogens, nutrient reduction) in relation to the sensitivity of the receiving environment • Power outages (e.g. a short period, one longer than 24 hours or an extended period) • After extended periods of no flow (e.g. family vacation) • Effect of slug dosing of toxic chemicals (e.g. chlorine bleach) • Start-up time required (e.g. hours, days, weeks) • Whether the secondary treatment unit has gone through the On-site Effluent Treatment National Testing Programme by the Water New Zealand Small Wastewater and Natural Systems Special Interest Group (SWANS-SIG)
Power usage	• For pumping, disinfection, control systems, monitoring and telemetry equipment
Scalability and retrofitting	• Ability to expand or upgrade the process to accommodate higher hydraulic and mass loading
Service life	• Warranties for process components • Life-span for pumps, electrical components, tankage, media, etc.
Ownership	• Where the treatment unit is leased to building owner • Where the treatment unit is owned by building owner
Tank construction requirements and risks	• Non-corrosive, lids watertight, lids lockable, above-ground UV resistant material
Volume	• Hydraulic retention time • Emergency storage in case of power failure or clogging

D1.2 Wastewater quality

D1.2.1 Wastewater constituents

Characteristics of wastewater generated by various establishments (e.g. residential dwellings or non-residential institutions, etc.) can be distinguished by their physical, chemical and biological composition.

There is currently few data on non-residential wastewater composition, which creates uncertainty when determining organic loading rates for treatment units. It is therefore essential for designers to use site-specific (monitored) data or allow for adequate safety factors to accommodate potential variations of wastewater mass loading.

Constituent mass loading figures are important for the operation and design of treatment processes. Typical parameters are presented in Table 20.

Table 20: Wastewater constituents and analytes

Wastewater constituents	Analyte
Particulate matter	• Total suspended solids (TSS) [Note 1] • Turbidity (NTU) [Note 2]
Organic matter	• Biochemical oxygen demand (BOD_5) [Note 1] • Chemical oxygen demand (COD) • Total organic carbon (TOC)
Nutrients	• Total nitrogen (TN) • Ammoniacal nitrogen (NH_4-N) • Total Kjeldahl nitrogen (TKN) • Nitrate (NO_3) • Dissolved reactive phosphorus (DRP) • Total phosphorus (TP)
Faecal indicator micro-organisms [Note 3]	• Enterococci spp. • Faecal coliforms • Total coliforms • Escherichia coli

Notes:

1) Although waste disposal units (garbage grinders) are not recommended for use in residential properties serviced by on-site wastewater systems, in some situations owners will, against advice, insist on their installation. In these instances, higher loadings of TSS, BOD_5 and flow need to be allowed for in design loading rates for both the wastewater treatment unit and land application system.
2) Turbidity assessment is important for secondary treated effluent, if followed by a UV disinfection process.
3) Faecal indicator organisms are an important indicator of disinfection system efficacy for tertiary treated effluent.

D1.2.2 Composition of untreated wastewater from residential sources

Table 21 provides typical wastewater concentrations and mass loads. These are based on USEPA data for residential properties with concentrations based on a per-capita flow allowance of 225 L/person/day. The data should not be used for design and is provided for information only. The concentration and loading of various pollutants in wastewater must also be considered:

- Domestic wastewater has a significantly lower organic content than restaurant-derived wastewater, which requires careful design consideration to avoid organic overloading and failure of the wastewater treatment units and land application systems
- Using water-conservation fixtures does not reduce the organic loading in the wastewater stream. On-site wastewater systems should be sized for the full organic loading
- Hydraulic and organic loading rates can be reduced by eliminating appliances such as in-sink grinders.

Table 21: Typical concentrations and mass loads of untreated wastewater constituents from residential sources

Constituent			Concentration	Mass loading (grams/person/day)
Total suspended solids	(TSS)	(g/m³)	155 - 330	35 - 75
Biochemical oxygen demand	(BOD_5)	(g/m³)	155 - 286	35 - 65
Chemical oxygen demand	(COD)	(g/m³)	500 - 660	115 - 150
Total nitrogen	(TN)	(g/m³)	26 - 75	6 - 17
Ammoniacal nitrogen	(NH_4-N)	(g/m³)	4 - 13	1 - 3
Total phosphorus	(TP)	(g/m³)	6 - 12	1 - 2
Fats, oils, and grease	(FOG)	(g/m³)	70 - 105	12 - 18
Surfactants		(g/m³)	9 - 18	2 - 4
Total coliform	(TC)	(MPN/100 mL)	10^8 - 10^{10}	-
Faecal coliform	(FC)	(MPN/100 mL)	10^6 - 10^8	-

Source: USEPA 2002

D1.2.3 Effluent quality for different treatment systems

Effluent quality data for a variety of treatment units, based on monitoring results from recorded systems that have been correctly operated and maintained, are presented in Table 22. These data are provided for information only and may not be reflective of values found in New Zealand. Individual systems will perform differently depending on design, influent and operation.

Table 22: Typical domestic treated effluent quality

Treatment system	Typical concentration (g/m³)						
	TSS	BOD_5	COD	TN	NH_4-N	PO_4-P	Turbidity (NTU)
Primary treatment without effluent filter	40-140	150-250	250-500	50-90	30-50	8-12	15-30
Primary treatment with effluent filter [Note 1]	20-50	100-140	160-300	50-90	30-50	8-12	10-20
Intermittent single-pass sand filter [Note 2]	0-5	0-5	10-40	<30	1-5	6-10	0.01-2
Recirculating (or multi-pass) sand filter	0.5-15	5-10	20-40	7-20	1-3	6-10	0.1-2
Compact activated sludge process	10-30	20-60	40-120	20-40	1-5	6-10	
Hybrid activated sludge with fixed or suspended media	5-30	10-40	20-80	20-40	1-5	6-10	
Rotating biological contactor	1-15	2-20	10-50	5-30	1-5	6-10	
Constructed wetland	10-20	10-20	25-50	5-20	1-10	4-8	

Treatment system	Typical concentration (g/m^3)						
	TSS	BOD_5	COD	TN	NH_4-N	PO_4-P	Turbidity (NTU)
Intermittent sand filter + phosphorus reduction	0-5	0-5	10-40	<30	0-5	<0.5	0.01-2
Intermittent sand filter + nitrogen reduction	0.5-15	10-30	20-60	0.5-5	1-4	6-10	
Intermittent sand filter + nitrogen reduction + phosphorus reduction	0.5-15	10-30	20-60	0.5-5	1-4	<0.5	
Membrane bioreactor + phosphorus reduction	<1	<5	<30	<10	<1	<0.1	<0.1
Sequencing batch reactor	<5	<5	<30	<5	<1	4-8	<1

Source: USEPA 2002; Crites & Tchobanoglous 1998; ARC's TP 58 (2004); Metcalf & Eddy 2006

Notes:

1) The level of TSS following an effluent outlet filter is dependent on the type of filter and hydraulic flow. Some literature indicates TSS following some filter types may be significantly higher, e.g. up to 70 g/m^3.
2) The percent reduction with intermittent sand filters is better than that achieved by recirculating filter systems, due to the single pass and lower loading rate.

D1.3 Treatment system effluent quality

The stages within a treatment unit can be engineered to achieve a range of treatment levels. To accommodate the development of new technologies, categorisation of treatment stages is associated with effluent quality only. The expected treatment quality for these stages (listed from left to right, in increasing order of treatment) is presented in Table 23. These concentrations should be used as a guide only. Specific wastewater concentration testing is recommended where concentrations may exceed typical domestic strength and/or where good understanding of influent quality characteristic is essential for on-site wastewater system design and/or operation. It is recommended that secondary treatment units be assessed:

- Through the OSET NTP[2] established by Water New Zealand SWANS-SIG, or
- By an accredited assessment body, as conforming to the Australian/New Zealand Standards (AS/NZS) 1546.3:2008, or equivalent robust data from an international assessment body.

[2] The OSET NTP (On-site Effluent Treatment National Testing Programme) is operated as a joint venture between Water NZ SWANS-SIG, Bay of Plenty Regional Council and Rotorua Lakes Council.

Table 23: Typical wastewater treatment unit stages and associated effluent quality

Treatment unit stage	Primary treatment	Secondary treatment	Advanced secondary treatment	Advanced secondary treatment with nutrient reduction [Note 2]	Advanced secondary treatment with disinfection [Note 3]
BOD_5 (g/m^3) [Note1]	100-140	≤20	≤10	≤10	≤10
TSS (g/m^3) [Note1]	30-70	≤30	≤10	≤10	≤10
Ammonia (g/m^3)	<30	<5	<5	<5	<5
Total nitrogen (g/m^3)	<100	<40	<40	<25	<40
Total phosphorus (g/m^3)	<20	<10	<10	<8	<10
E. coli (CFU/100 mL) [Note 4]	10^6 - 10^{10}	$<10^4$	$<10^4$	$<10^4$	≤200

Notes:

1) 90^{th} percentiles of the samples taken over three testing periods.
2) Enhanced and targeted nitrogen reduction is achieved by recycling nitrified wastewater through an anoxic zone and requires specific design and well-controlled operation.
3) Disinfection can be achieved by either UV or chlorination. The effectiveness of a disinfection system is affected by the wastewater characteristics. High quality of secondary treated effluent is required to ensure effective disinfection.
4) The alternative unit is MPN/100 mL.

D1.4 Primary treatment unit design

D1.4.1 Primary treatment units

Septic tanks are commonly used to provide primary effluent treatment prior to discharge via a land application system (Figure 4). They can also be used to provide primary treatment prior to a secondary treatment stage (Section D1.5.3). A septic tank collects greywater and blackwater and is a simple retention unit for settling of solids and flotation of oils, grease and fat (scum). The tank operates as a passive, low-rate digester, with wastewater passing through as plug flow. A stratification process separates solids depending on the density of the particles relative to water. Separation and biodegradation are natural processes that do not depend on additives. Stratification allows a clear zone, free of solids, to develop in the middle of the tank before being discharged.

The total capacity of a septic tank is divided into:

- Air space at the top and above the scum layer, which in the case of a pumped unit, includes capacity for 24-hours emergency storage volume above the high-water level alarm sensor
- The scum layer
- The clear zone or settling zone
- The sludge layer at the base.

Accumulated sludge in the base of the tank biodegrades and consolidates slowly under the action of facultative and anaerobic micro-organisms.

D1.4.1.1 Septic tank configurations

Septic tank configurations can vary based on specific designs and can be conventional or compartmented.

Conventional

A conventional septic tank is usually a single rectangular chamber (Figure 4). Where oval or circular tanks are used, it is recommended that their total surface area is at least the same as a rectangular tank, a minimum separation of 1.5 m between the inlet and outlet tee, and with their bulk centred at around half depth.

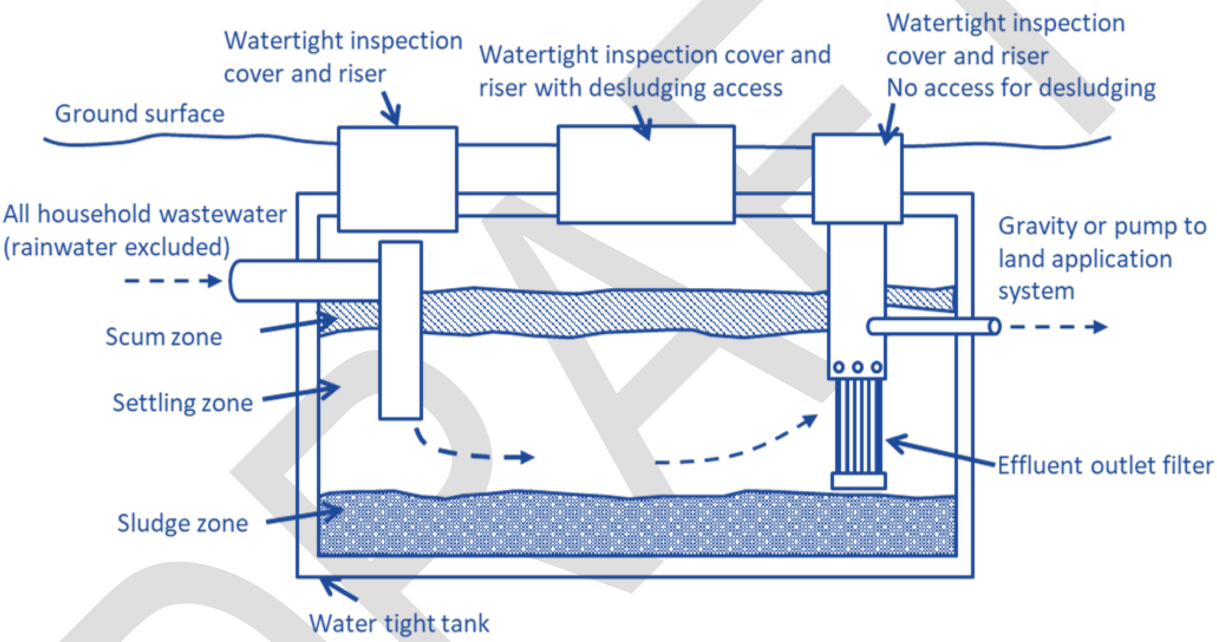

Figure 4: Conventional septic tank

Compartmented tank

Compartments separated by a partition wall are an optional configuration for the conventional septic tank (Figure 5). Partition walls divide the tank into two compartments in the ratio by volume of 2:1. Hydraulic buffering provided by the first compartment stabilises the flow through the second compartment and reduces potential carryover of solids into any later treatment stages and/or into the land application system.

Tanks with compartments may need to be desludged more frequently than conventional tanks of equal size because the bulk of sludge settles in the first compartment. While compartmented tanks may increase the volume of retained solids, those solids can still be re-suspended and discharged and still require an outlet filter.

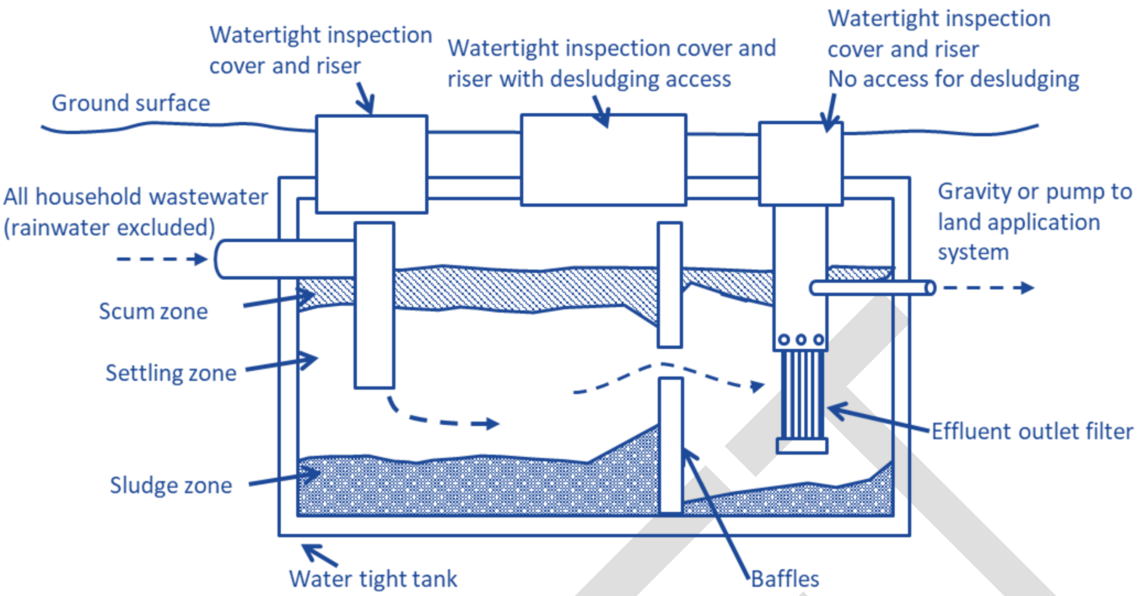

Figure 5: Compartmented septic tank

D1.4.1.2 Outlet filters

Outlet filters (also known as "outlet solids control devices" or "effluent outlet filters") are effective and low-cost items fitted to septic tank outlets, providing considerable improvement in the whole unit's performance. Their purpose is to capture the larger suspended solids that have not settled or have been re-suspended by hydraulic turbulence. They ensure that solids approximately 3 mm or greater are retained within the septic tank, rather than being discharged into the secondary treatment unit and/or to the land application system.

Different effluent filters are available including multiple mesh or slotted tubes or as a plate disc or disc dam module.

Mesh tube models can achieve a suspended solid concentration in effluent of 30 g/m^3 TSS, compared to 80 g/m^3 from a well-performing conventional septic tank, with only an outlet tee (Crites and Tchobanoglous, 1998). Mesh outlet filters can enhance both suspended solids and organic matter removal (e.g. BOD_5).

All single or two-stage septic tanks, or multi-chamber tanks, should be fitted with effluent outlet filters and allow for external access for maintenance.

D1.4.1.3 Conventional grease traps

Conventional grease traps are crucial for assisting with the removal of fat, oil and grease from wastewater. They are typically used in units serving restaurants, cafes, marae, laundromats, hospitals and institutions producing wastewater with a high fat, oil and grease content[3]. Only kitchen wastewater is discharged into the grease trap.

Grease traps are similar in design to a septic tank (Figure 6). Typically, the grease (dissolved in the hot influent water) cools and solidifies and traps oils by flotation. Clearer water is then removed from the central

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[3] For individual homes, the septic tank generally provides adequate control of grease, although it is important that grease from utensils and cooking are not discharged to the household wastewater system.

zone. To be effective, the grease trap must retain the fluid for sufficient time to allow grease cooling and flotation. For on-site systems, the grease trap volume should be a minimum of four times the kitchen flow volume.

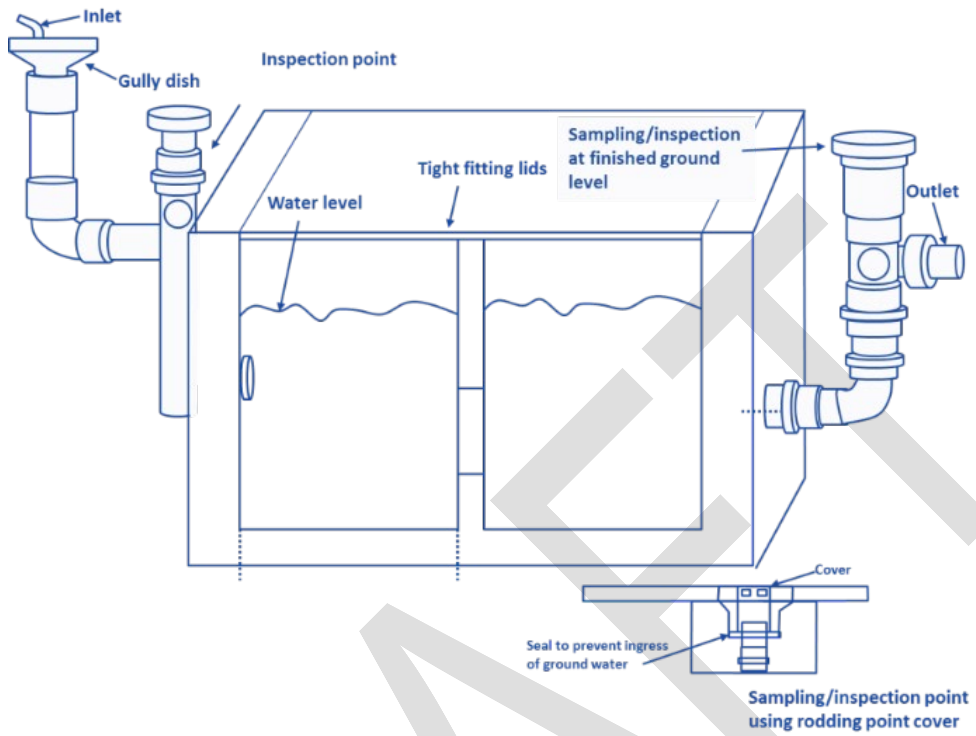


Figure 6: Illustration of a typical conventional grease trap

Key design and operation considerations

Design must comply with the Building Code. Additional design recommendations for grease traps are:

Sizing	• Storage capacity should be four times the kitchen average daily design flow volume, with at least one-day's retention for the peak wastewater flow discharging to it.
Location	• Locate outside the building and be accessible for maintenance or cleaning. Building Code Clause G13/AS2 provides acceptable configurations and locations.
Influent	• They do not perform well with high solids content in the wastewater; this leads to increased pump-out frequency. • Discharges containing high BOD (such as wine, milk, oils and grease) should be avoided. • High solid flows (such as from in-sink grinders) should bypass directly to the septic tank.
Filters	• Commercially available effluent outlet filters designed for grease interceptor tanks can improve effluent quality.
Additional design options	• In commercial kitchens, under-sink grease skimmers, prior to the grease trap, can provide additional oil and fat removal, with further treatment in the subsequent grease trap. • Under-sink grease converters with chemical addition for emulsification of grease components in the wastewater are never appropriate in an on-site wastewater system.

Maintenance	• Cleaning frequency is dependent on the facility's kitchen practices and must be based on observed accumulation. The depth of scum and sludge build-up requires regular monitoring. • Cleaning is needed when the grease is accumulated to 75% of the grease retention capacity (USEPA, 1980). For restaurants, depending on the capacity of the grease traps, pump-out frequency can vary between once a week and once every two to three months (USEPA, 1980).

D1.4.2 Primary treatment unit performance

The larger the primary treatment chamber, the better the bulk solids removal and separation of oil and grease. The following performance requirements apply:

Minimum combined total retention capacity	• Prior to secondary treatment: Three to five days of average flow volume, unless the supplier has verified that: ○ Sufficient final effluent quality is achieved in the secondary treatment process, to achieve the required secondary discharge standards specified in Table 26, and ○ Less than three days primary treatment is sufficient.
Overflows	• No potential for overflows or cross-contamination from the primary treatment chamber to any secondary treatment chamber (e.g. where the primary chamber is within the whole treatment plant unit, the walls of the primary chamber must be of full height and sealed).
Effluent outlet filter	• An effluent outlet filter must be installed at the primary treatment chamber(s) outlet to retain any solids with a particle size of 3 mm or greater and to prevent such solids entering the land application system or the aeration chamber of a secondary treatment unit. Ideally this should achieve a primary effluent TSS concentration of 20-50 g/m3 or less.

Performance of primary treatment units is affected by:

Retention time and tank capacity	• Essential to ensure settling of solids and scum flotation.
Influent composition and concentration	• Different facilities will have differing influent composition, e.g. households with in-sink grinders produce higher organic loads which can negatively impact the effectiveness of the septic tank unit.
Age of unit	• A septic unit can take up to six months to become fully operative. • The microbial biomass of the wastewater treatment unit should be allowed to reach equilibrium in this time with consistent, regular inflows.
Microbial health	• Facultative and anaerobic bacteria provide the majority of biological treatment processes and must be protected from inputs of chemicals and anti-microbial agents.
Climatic conditions	• In warmer climates, the microbial breakdown of solids and scum can almost be completed in the septic tank. • In cooler climates, the microbiological activity is restricted, and biological activity is less efficient (Hammond & Tyson 2004). Therefore, more frequent pump-outs may be required in cooler climates.

Common failures of septic tanks can result from:

Ingress of water	• Ingress of water from any surrounding groundwater results in hydraulic overloading of the wastewater treatment unit and land application system.
An overloaded unit	• These subsequently flush solids and grease from the septic tank into the land application system.
Tank too small	• Can result in overloading.
Sudden shock	• Septic tank units may fail if subjected to sudden shocks, such as changes in influent composition, chemical exposure, temperature changes, loss in microbial biomass etc.
Leaky tanks and components	• Including risers, pipe inlets and pipe outlets. Any leaks are viewed as crucial design failures.
Failure to maintain or infrequent maintenance	• Septic tanks require solids removal through pump-outs. • Pump-out frequency will depend upon solids production and tank volume. • Some of the sludge biomass material should be retained in the tank after pump-out to provide a biological 'starter' for a stable bacterial population.
Inappropriate inputs	• In-sink grinders should not be used in facilities discharging to septic tanks[4]. • Occupants and homeowners must be aware that inappropriate substances (especially chemicals, FOGs and antimicrobials) should not be discharged into the wastewater. Appendix G provides a list of alternative household chemicals.

Appendix I provides further information on improving septic tank performance and dealing with remedial actions.

D1.4.3 Septic tank sizing

Capacity requirements for single dwelling septic tanks are based around an allowance for settling volume plus accumulated scum/sludge storage volume between pump-out periods.

Settling volume allowances are based on	• All-waste tanks, 200 L/person • Blackwater tanks, 60 L/person • Greywater tanks, 120 L/person plus 33% flow buffering allowance of 40 L/person (total 160L/person).
Scum/sludge storage allowances based on	• All-waste tanks, 80 L/person/year • Blackwater tanks, 50 L/person/year • Greywater tanks, 40 L/person/year.

[4] If owners insist on the provision of in-sink grinders, then special design, monitoring and maintenance provisions are required.

Septic tank capacity is based on providing a minimum settling volume equivalent to a total daily flow allowance of 200 L/person plus sludge and scum storage at 80 L/person/year over seven years. This provides a minimum settling time of 24 hours when the sludge/scum volume reaches storage capacity, at which time, the tank will require pump-out.

Table 24 provides GD06 requirements for septic tank capacities for dwellings. It should be noted that:

- The settling volume allowance of 200 L/person for all-waste tanks is equivalent to the per-capita daily flow allowance for standard households (Item B Table 18) and will need to be increased for Item A Table 18 households. Excess settling capacity available for households with lower per-capita flow production provides some beneficial hydraulic buffering
- For greywater, the 120 L/person settling volume design capacity increased by 33% to compensate for the same flow intensities as the larger all waste tanks
- The minimum all-waste tank size of 4,500 L is based on a four-bedroom dwelling accommodating up to six persons. For a larger dwelling, or for increased occupancy over six persons, the tank size should be increased accordingly or alternatively, the tank should be pumped out more frequently
- All septic tanks must be fitted with an effluent outlet filter, including all waste, blackwater and greywater tanks
- The above flow and scum/sludge allowances make no provision for the installation of an in-sink grinder.

Table 24: Septic tank capacities for dwellings based on number of bedrooms

Type of wastewater	GD06 minimum capacities	
	No. of bedrooms	
	1 to 4	5 to 6
Tank capacity	**(L)**	**(L)**
All wastewater	4,500	6,000
Blackwater only	2,500	2,500
Greywater only	3,300	4,000

A design example determining septic tank capacity requirements in on-site wastewater systems serving commercial accommodation facilities is provided in Table 25.

Table 25: Capacity criteria – institutions and commercial septic tanks

Type of wastewater flow	Settling volume allowance (L/person)	Sludge/scum accumulation capacity allowance/person (L/person/year x 5 years)	Total settling volume capacity (L/person) [Note 1]
24-hours settling volume allowance			
All wastewater	200	80 (400 L/person/5 years)	600
Blackwater [Note 2]	60	50 (250 L/person/5 years)	310
Greywater 32-hours settling volume allowance			
Greywater [Note 3]	160	40 (200 L/person/5 years)	360
Commercial food premises [Note 4]	Requires specialist design and more frequent pump-out		

Notes:

1) All-waste septic tanks: 24-hours settling volume at a capacity allowance of 200 L/person/day, plus 80 L/person/year allowance for scum/sludge accumulation over five years.
2) Blackwater septic tanks: 24-hours settling volume for daily blackwater flows at a capacity allowance of 60 L/person/day, plus 50 L/person/year allowance for scum/sludge accumulation over five years.
3) Greywater septic tanks: 32-hours settling inclusive of hydraulic buffering volume at a capacity allowance of 160 L/person/day, plus 40 L/person/year allowance for scum/sludge accumulation over five years.
4) Trade waste tanks (e.g. for restaurants) require more frequent pump-out and additional specialist design considerations over and above the requirements of the domestic type flow component. Therefore, there is no trade waste sizing criteria listed in this document.

D1.5 Secondary treatment units

Secondary treatment refers to an aerobic biological process in which micro-organisms absorb suspended and dissolved organic matter while growing under aerobic conditions. The resulting biological sludge solids are then removed by settlement and/or filtering processes. The performance of secondary treatment processes in removing BOD and TSS is set out in Table 22.

The two main types of secondary treatment units are suspended growth and fixed film activated sludge systems (Section D1.5.3) and packed bed media filled reactors (Section D1.5.4).

D1.5.1 Selection of secondary treatment process

D1.5.1.1 Key factors of consideration

Key factors include:

- Performance in terms of effluent quality (including consistency and available data)
- Frequency and cost of maintenance (including power costs)
- Aesthetics (including noise and odour)
- Site-specific constraints (e.g. intermittent wastewater loading)
- Water tightness
- Number and size of tanks
- Power requirements
- Installation for difficult sites.

A three to five-year performance guarantee that the unit will consistently meet effluent quality parameters should be provided by the supplier. The parameters are typically only BOD_5 and TSS, unless the on-site wastewater system is specifically required to decrease faecal coliform levels and/or nutrients. In this case, further analyses for these parameters should be undertaken and checked against the manufacturer's specifications. The tests should be continued weekly (Section F1.3.1.2) until the discharge quality analyses are within the manufacturer's design specifications for at least three consecutive samples.

During the performance guarantee period, the manufacturer or designer should undertake quarterly effluent quality assessments. Consistent effluent quality results are needed to demonstrate the long-term effectiveness under all types of loading situations.

D1.5.1.2 Operational and maintenance considerations

Secondary units require regular inspection by an experienced operator. Six monthly inspections are the recommended minimum necessary to achieve consistent performance, except for the most stable influent flow and type of plant. Operation and maintenance servicing contract arrangements are important and must be maintained for the system's life. Servicing will include checks on the dissolved oxygen level in the effluent as well as periodic analysis of BOD_5 and TSS levels.

Removal of scum/sludge via pump-out of the septic tank/primary treatment compartment will also be required at intervals based on operating observations and experience.

D1.5.2 Key performance requirements for secondary treatment units

Key performance requirements are presented in Table 26. Actual performance depends on correct operation and maintenance which needs to be verified according to the system's Operation and Maintenance Plan and Section F, as well as information provided in Appendix I. Some key criteria may be adjusted if other components of the unit are sized or designed to compensate for any variance.

Table 26: Key performance requirements for secondary treatment units (for both wastewater and greywater treatment)

Treatment system (components)		Performance requirements
Secondary treatment system	Secondary treatment	• 90% of ten or more consecutive weekly samples taken over three testing periods (refer to Section F1.3.1.2),should have a $BOD_5 \leq 20$ g/m^3 with no sample > 30 g/m^3. • 90% of samples should have a TSS ≤, 30 g/m^3 with no sample > 45 g/m^3. A minimum of three consecutive weekly samples are necessary to verify compliance for commissioning. • Where wastewater treatment units cannot meet these criteria, the supplier should provide evidence of what criteria their system can realistically achieve.
	Advanced secondary	• 90% of ten or more consecutive weekly samples taken over three testing periods (refer to Section F1.3.1.2), should have a $BOD_5 \leq 10$ g/m^3, with no sample > 20 g/m^3. • 90% of samples should have a TSS ≤ 10 g/m^3 with no sample > 30 g/m^3. (A minimum of three consecutive weekly samples are necessary for commissioning purposes to verify compliance.)
	Advanced secondary with nutrient reduction	• 90% of ten or more consecutive weekly samples taken over three testing periods (refer to Section F1.3.1.2), should have a $BOD_5 \leq 10$ g/m^3 with no sample > 20 g/m^3. • 90% of samples should have a TSS ≤ 10 g/m^3 with no sample > 30 g/m^3. • Required levels of total nitrogen and total phosphorus determined based on nutrient loading constraints or limitations identified during the site and soil evaluation stage.
Other components	Disc filter	• If a drip irrigation system is designed for land application of treated effluent an effective disc filter (or a screen or a mesh filter with constant backflush) must be: ○ Fitted between the discharge point from the treatment process and the irrigation lines ○ Designed to retain all solids > 130 µm within the wastewater treatment unit. • The supplier is required to provide verification that the wastewater treatment unit will consistently achieve the specified treated wastewater quality parameters. • The cleaning frequency of outlet disc filters should be more frequent than the routine three-monthly contracted maintenance frequencies.

Treatment system (components)		Performance requirements
	Alarm system	• A malfunction alarm system should be installed to activate in the event of aeration equipment failure or other electrical/mechanical malfunction, and/or in the event of a high water level in any chamber within the wastewater treatment unit and/or in the pump chamber. • An audible alarm unit, as well as a visual alarm unit, should be located in a prominent place.
	Safety components	• There must be a sealed and durable lid on the on-site wastewater system that prevents ingress of surface water. The system should be secured to prevent access by unauthorised personnel yet be readily accessible for maintenance or replacement. • All risers must be watertight.
	Emergency storage	• A minimum emergency storage volume of at least 24-hours capacity above the alarm trigger level is required in the pump chamber. Otherwise, a combination of the equivalent emergency storage must be provided within the whole on-site wastewater system, with automatic overflow between sections. • Excess wastewater must not have access to the clarifier chamber, or otherwise lead to cross contamination of other sections.
	Electrical equipment	• All electrical connections and components in the on-site wastewater system must be in accordance with NZ Standards (i.e. AS/NZS 3000:2018 and AS/NZS 3820:2009).
Additional criteria	Noise	• The maximum noise level with all equipment (except the alarm) operating should be 40 dB (equivalent continuous level) at a distance of 1 m from the noise emitting equipment.
	Service life	• The design life of a secondary treatment unit and associated fittings should be a minimum of 15 years.
	Other relevant design standards	• Systems must be manufactured to the Standards in AS/NZS 1546.3:2008, "*On-site domestic wastewater treatment units, Part 3: Aerated wastewater treatment systems*", particularly in terms of the design requirements specified in Section 2.4 and must also be in accordance with the other relevant design criteria specified in this document, whichever is the more stringent. • The key criteria that must be noted within AS/NZS 1546.3 are design flows and loads (the average influent quality the plant must be designed to handle), and design considerations (a variety of additional design provisions that must be included within the wastewater treatment unit). • AS/NZS 1546.3 provides standards for the design of tanks and fittings, tank construction, emergency storage capacity, materials selection, mechanical equipment, electrical equipment, effluent pumps, alarm systems, and disinfection criteria.

D1.5.3 Activated sludge

A typical activated sludge treatment unit will incorporate a primary treatment compartment (or septic tank) with the overflow transferred to the aeration compartment by an outlet tee that may incorporate an outlet filter.

Air is supplied by either a blower and sparge pipe, or a rotating impeller/aspirator unit, and provides aeration of the reactor tank and suspension of activated sludge solids. The overflow from the aeration compartment is then passed to a settling compartment for suspended solids recovery and return of settled biological sludge to the aeration compartment. Some settling compartments may incorporate settling plates to assist recovery of solids. Some units replace the settling compartment with an outlet filter to pass final effluent from the aeration chamber direct to the pump well. Final treated effluent enters a pump well for distribution to a land application system.

Blower-driven aeration systems also provide air for air-lift pumps to transfer recovered biological sludge back to the aeration compartment and transfer excess sludge to the primary compartment (or septic tank). A skimming device on the settling compartment may also be used to return floating scum/sludge back for treatment in the septic tank. Impeller/aspirator aeration units may have a small solids pump to recycle sludge to the aeration compartment and to dispose of excess solids to the septic tank.

The aeration compartment in modern units often contains modules of submerged plastic media to assist in developing a submerged fixed film (Figure 7) with the objective of providing better biological stability to the treatment process. Air for dissolved oxygen supply is provided either by an external blower or a submersible pump-powered venturi. Air may be released below the media or into the water outside the media in a manner that causes the aerated water to flow down through the media.

Biological growth on the submerged media results in lower sludge production volumes than in an activated sludge aerated wastewater treatment system (AS-AWTS) without media. Media may also provide stability to the treatment process, which is a particular advantage for dwellings with intermittent or seasonal occupancy

Among the variations of AS-AWTS units, the extended aeration process is widely used by pre-fabricated plants for residential or small communities. This process operates under an endogenous respiration mode, which requires low organic loading rate and longer aeration time.

Another common variation of the AS-AWTS applied for on-site wastewater treatment is the sequencing batch reactor which operates in a fill-and-draw operational mode with recycling to achieve both biological treatment of organic matter as well as nutrient stripping of nitrogen products, specifically nitrates.

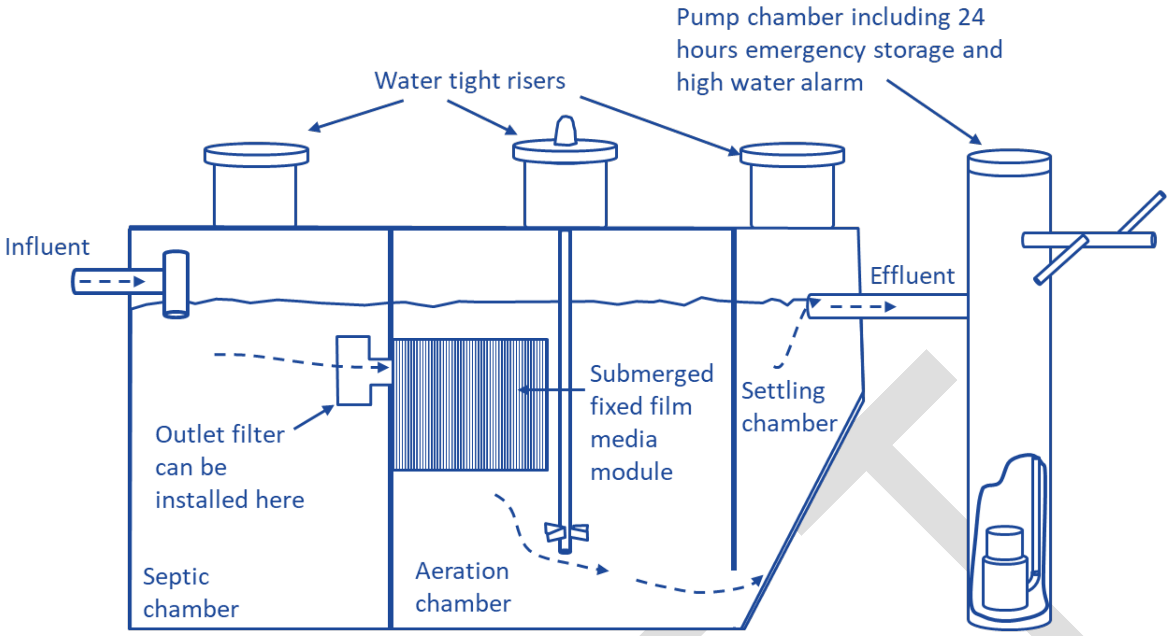


Figure 7: Typical activated sludge aerated wastewater treatment unit with submerged media

Depending on specific configurations of the selected unit, design criteria may vary significantly, including biomass concentration, typical food-to-microbe ratio, hydraulic retention time, sludge recycling rate, and sludge retention time. For instance, a typical organic (BOD_5) loading rate for a complete mix AS-AWTS is in the range of 0.8 to 2.0 kg BOD_5/m^3 day, with a typical hydraulic retention time of 3 to 4 hours. For extended aeration units, the typical organic loading rate is in the range of 0.08 to 0.24 kg BOD_5/m^3 day, with a hydraulic retention time of 18 to 36 hours.

Shock loads, large variances in the organic load and flow, insufficient flows and/or significant temperature variations can all adversely affect biological performance and discharge quality. To perform well, the following aspects of the design and operation need to be appropriate for each unit and site:

- Sludge return rates
- Control of the mixed liquor suspended solids concentrations
- Aeration controls
- Anti-foaming measures
- Provision for scum and grease removal from the final clarifier
- A means for the continuous removal of accumulated sludge from the final effluent chamber.

Good performance relies on adequate retention time in the final clarifying chamber and an appropriate sludge return rate. Exact design criteria for these depend on the combined design of all features within the unit.

This document does not provide guidance on the typical sizing required for various activated sludge processes since these units are typically designed, manufactured, installed and maintained by specialised companies. They exist in a wide variety of configurations and sizes. Materials and structural performance criteria of the assembled tanks should meet relevant tank specifications in AS/NZS 1546.1:2008. Due to the high biomass concentration within an AS-AWTS unit, the final settling/clarification stage following the aeration tank is crucial to ensure a satisfactory effluent quality.

AS-AWTS units are more susceptible to failure from flow and mass loading variation than some alternative wastewater treatment units (e.g. attached growth biological processes such as packed-bed reactors etc.). Reported BOD_5 and TSS output from well-operated units may be in the range of 10 to 50 g/m^3 for BOD_5 and 15 to 60 g/m^3 for TSS. Lower discharge quality may occur as a result of surge flows, variable loading and inappropriate operation or maintenance (USEPA, 2002). Excessive solids carry-over may occur due to:

- Insufficient retention time within clarification chamber
- Poor settling of biomass (e.g. filamentous growth)
- Fluctuating wastewater load and flow
- Under-design.

All AS-AWTS effluent must pass through an additional filtration step before being discharged to the land application system. Although the actual filtration requirements are dependent on the drip line supplier's recommendations, a disc filter with aperture size of 120 to 130 μm is generally recommended.

Disc outlet filters in AS-AWTS require increased operation and maintenance; the filter needs to be checked and cleaned regularly (refer to Table 26 and also Appendix G1.5).

D1.5.4 Packed-bed reactors

Packed-bed reactors are generally filled with media including textile, foam, rock, slag, plastic, and sand or modules or sheets formed with plastic or textile. They are normally operated in down-flow or up-flow mode with either continuous or intermittent dosing. Media materials can be arranged either continuously or in multiple stages. Designs differ by their media characteristics and inlet/outlet flow distribution and collection.

Advantages include:

- Sand/textile filters can produce a consistently high-quality wastewater as long as they are well designed, installed and the influent volume and strength is within design parameters
- Very low operator input is required
- Very low operational costs compared to traditional wastewater treatment units
- Very low sludge production from the sand/textile filters
- Can be expanded with additional modules/sectors
- Unit can be remotely managed and monitored via an internet connection
- Are more stable than AS-AWTS under variable hydraulic loading
- Have low operation and maintenance requirements compared with AS-AWTS
- Are capable of consistently producing a nitrified effluent with low BOD_5 and TSS compared with AS-AWTS.

Disadvantages include:

- Sand filters have a relatively large footprint
- Sand filters can be difficult to renovate if overloaded and clogged by biological sludge. May require sand replacement (textile filters more readily renovated)
- Sourcing suitable sand with the correct grading curve.

Most packed-bed reactors do not have a clarification stage involving biological sludge settling. Organic matter in the inflow is converted to biomass which accumulates within the pores of the media where it undergoes endogenous respiration as it ages and decays. If excess biomass growth occurs due to system under-design or over-load, this may result in flow blockage which will require remedy via media flushing.

Table 27 provides a summary of the key design characteristics and performance standards of the various filter units available. Appendix L provides a discussion on sand and textile filter timer dose loading.

Table 27: Summary of key characteristics of packed bed reactor filter units

Sand filters/packed-bed reactors		
Filter system	**Characteristics**	**Treated wastewater quality**
Intermittent sand filter (Refer Figure 8)	• Single pass • Suitable for lower strength wastewater • Hydraulic loading rate typically 40 - 100 mm/day • Biochemical loading rate typically 0.0025 - 0.01 kg $BOD_5/m^2/day$ • More suited to individual dwellings than large systems • Large footprint compared to multiple-pass systems • Usually open and therefore subject to rainfall infiltration • Produce extremely small sludge volume • Must be timer dose loaded.	• Reduces faecal coliform levels from 10 million CFU to less than 10,000 CFU/100 mL • Some systems claim to achieve less than 400 CFU/100 mL • Nitrified effluent averages 30 g/m^3 nitrate • Little reduction in phosphates • Biochemical oxygen demand less than 10 g/m^3 • Total suspended solids less than 10 g/m^3.
Recirculating sand filter (Refer Figure 10)	• Multiple pass (i.e. wastewater is pumped onto sand filter 3 to 4 times) • Treated wastewater mixed with primary treated wastewater causing dilution and reduced strength • Dilution allows use of higher loading rates • High loading rates reduce sand filter footprint • Typical hydraulic loading rates of 120 to 240 mm/day (typically 200 mm/day) • Organic loading rate is also very important and typically 0.01 to 0.04 kg $BOD_5/m^2/day$ • The even split of treated effluent and recirculation is very important for successful operation • Must maintain recirculation even when there is no wastewater inflow into the unit • Must be timer dose loaded • Usually open and therefore subject to rainfall infiltration • Produce an extremely small sludge volume.	• Very effective at reducing faecal coliform level but not to the same extent as intermittent sand filters – expect a 99% reduction • Nitrified effluent averages 30 g/m^3 nitrate • Little reduction in phosphates • Biochemical oxygen demand less than 10 g/m^3 • Total suspended solids less than 10 g/m^3.

Sand filters/packed-bed reactors		
Filter system	**Characteristics**	**Treated wastewater quality**
Recirculating textile filters (Refer Figure 9)	• Sand is replaced by an engineered fabric as sheets, foam cubes or chips • Some use vertical sheets of fabric and others have textile blocks placed in layers • They are multiple pass • Textile has a much larger surface area for biological growth than sand and therefore a higher hydraulic loading rate is possible • Hydraulic loading rates range from 1,100 to 2,100 mm/day, but are typically less than 1,700 mm/day • Significantly smaller footprint than sand filters • Contained in watertight modules • Textile can be easily maintained in the event of excess biological growth • Produces an extremely small sludge volume • Must be timer dosed.	• Very effective at reducing faecal coliform level but not to the same extent as intermittent sand filters – expect a 99% reduction • Nitrified effluent averages 30 g/m³ but significantly better N reduction is possible with nutrient reduction cycle • Little reduction in phosphates • Biochemical oxygen demand less than 10 g/m³ • Total suspended solids less than 10 g/m³.

Additional design considerations are provided in Table 28.

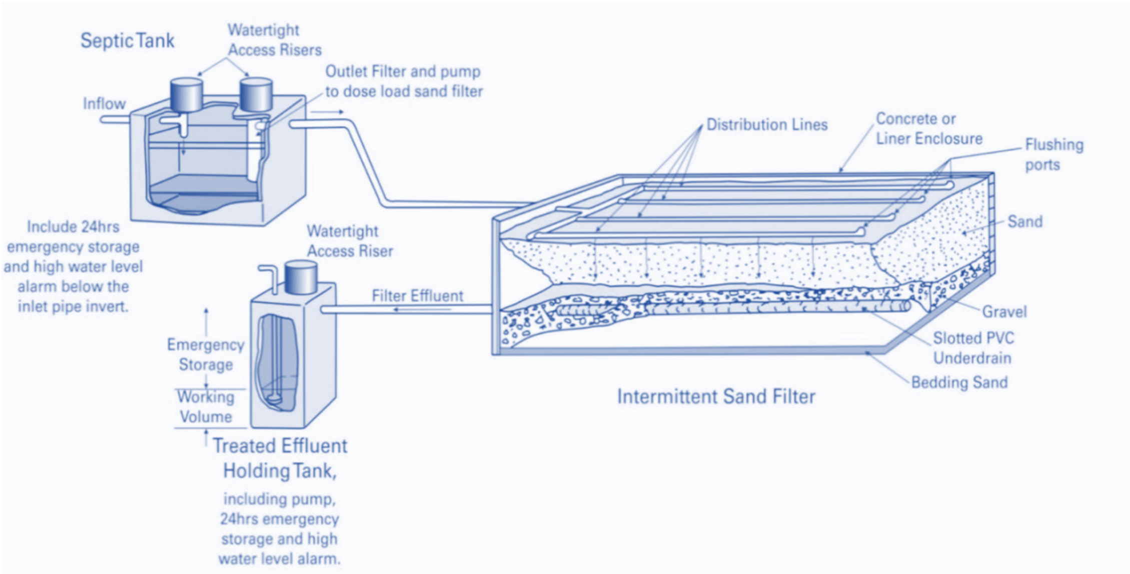
Table 28: Design considerations

Parameter	Consideration
Pre-treatment for all packed bed reactors/filter units	• Septic tank and outlet filter to reduce total suspended solids
Wastewater loading to filter	• Must buffer wastewater flows over 24 hours by using timer-controlled dosing • Wastewater must be timer pump dose loaded onto sand/textile filter as a series of small doses over 24 hrs/day • Flood dose loading is not appropriate as it results in uneven distribution across sand filter surface and produces saturated flow rather than thin film flow • Distribute onto sand/textile filter by pressure pipe network • Typical dosing frequency 48-120 doses per day for recirculating sand filters • Further details in Appendix L
Sand media	• Sand must be specifically graded • Sand must be clean and free of fines

Parameter	Consideration
Important criteria for successful operation	• Stormwater and groundwater infiltration into the on-site wastewater system must be excluded to minimise the filter area and maintain peak design flow • If influent design BOD_5 is exceeded significantly on a regular basis, there is a very high risk that the sand filter will clog, or textile filter surfaces blind off with excess biological growth • Timer-controlled dose loading of wastewater is important for optimum consistent treatment quality. This results in many small doses over 24 hours to maintain a thin film flow through the filter, rather than plug flow • On-demand dose loading undesirably results in the wastewater being discharged onto the sand/textile filter at the time of wastewater production and concentrated at breakfast, lunch and dinner peaks • Wastewater must be distributed evenly across the entire surface for consistent treatment quality • Wastewater pumped onto the filter must be low in total suspended solids to prevent clogging of the infiltration surface.

Intermittent sand filter

Typical schematic



(Adapted from Auckland Council's Technical Publication 58)

Description

- Intermittent sand filter units are designed to treat the wastewater in a single pass and are generally best suited for treating flow volumes and strengths typical of wastewater flows from single or multiple households.
- Once the design flow volume increases, so too does the total footprint required for the intermittent sand filter unit and they become less cost effective compared to recirculating sand filter units.
- A pumped dosing system is needed to achieve even distribution, with timer dose loading providing optimal performance.
- Effective at reducing bacteria BOD_5 and suspended solids.

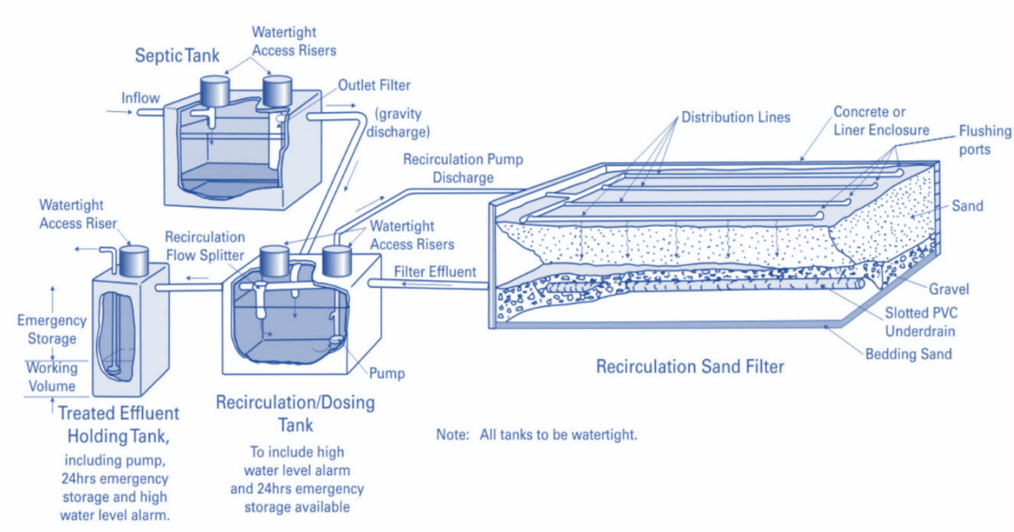
Design considerations

- Conservative design parameters should be used
- Hydraulic loading: 40 - 100 mm/day (typically, 80 mm/day)
- Organic loading: 0.0025 - 0.01 kg BOD_5/m^2/day
- Dosing frequency: 12 - 48 times/day
- Effective media size: <0.25 - 0.75 mm (clean and fines free)
- Depth: 600 - 900 mm
- Recirculation tank volume: 24-hour emergency storage + working volume.

Figure 8: Intermittent sand filter

Recirculating sand filter

Typical schematic



(Adapted from Auckland Council's Technical Publication 58)

Description

- Recirculating sand filters or multi-pass sand filters treat effluent by recycling wastewater through the sand filter three to five times, based on forward flow from the septic tank, prior to discharge to the land application system.
- Used to treat higher flow volumes (e.g. >3000 L/day) from large institutions or from cluster housing in subdivisions. They are also used to treat high-strength wastewater (with elevated organic loads), e.g. from restaurants.
- They are also particularly effective in treating intermittent wastewater flows, such as that from schools, that are subject to extended rest/no flow periods, as the recirculating nature of the unit maintains a healthy biomass population within the reactor.
- A recirculating sand filter unit comprises:
  - A water-tight septic tank with an effluent outlet filter
  - A recirculation tank into which primary septic tank wastewater is discharged, which mixes with treated wastewater that has already passed through the sand filter
  - An open sand filter to allow free air flow (not soil covered or sealed).

Design considerations

- Wastewater flow must be free of gross solids
- Must be timer dosed
- Hydraulic loading: 120 -o 200 mm/day (typically, 160 mm/day)
- Organic loading: 0.01 - 0.04 kg BOD_5/m^2/day (typically, < 0.025 kg BOD_5/m^2/day)
- Dosing frequency: 48 - 120 times/day
- Effective media size: <1-5 mm (typically 2.5) (clean and fines free)
- Depth: 450 - 900 mm
- Recirculation tank volume: 0.5 - 1.5 x daily flow + 24-hour emergency storage.

Figure 9: Recirculating sand filter

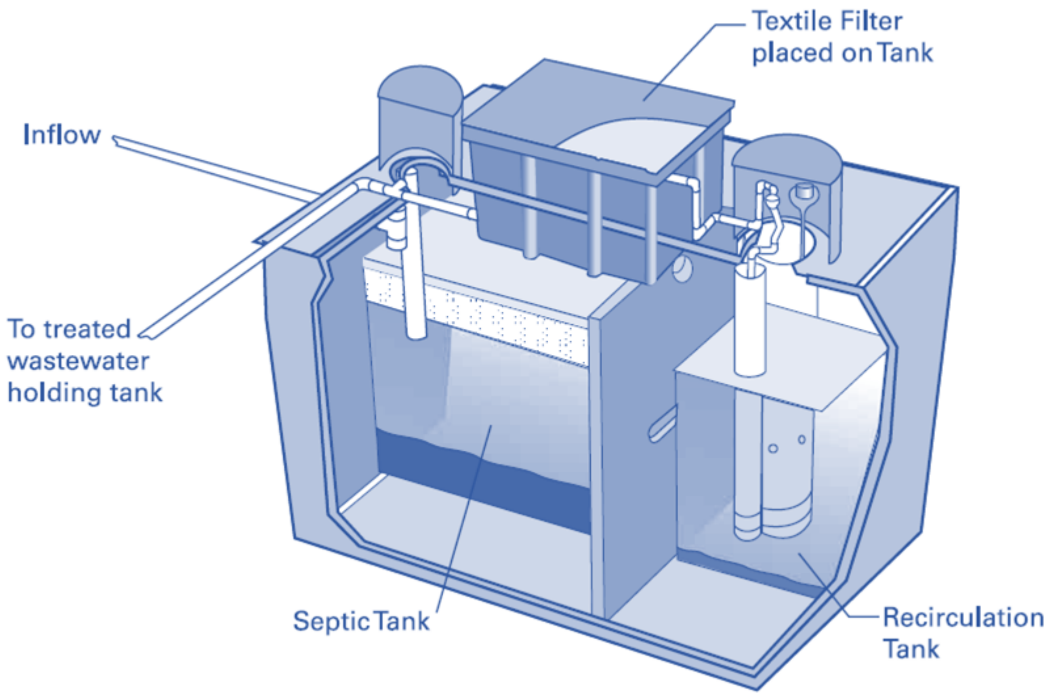
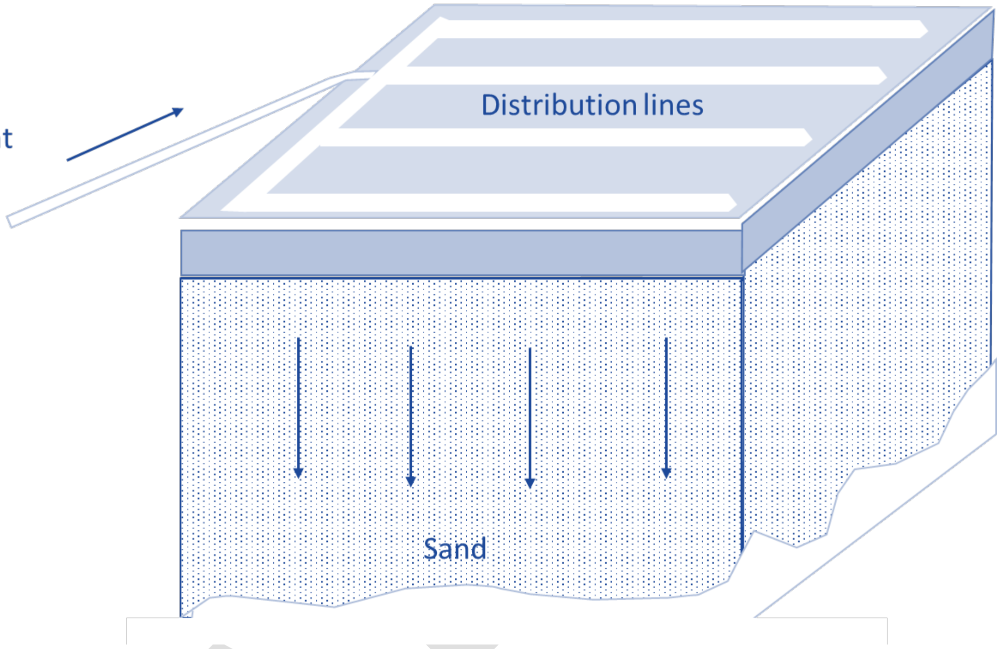
Recirculating textile packed-bed reactor	
Typical schematic	 (Source: Auckland Council's Technical Publication 58)
Description	• The recirculating textile packed-bed reactor (rtPBR) (also referred to as fixed film textile filter) is an alternative to the sand filter. Textile provides a significant surface area for biomass attachment. • Two key designs use textile packed-bed reactors or fixed film filters in a smaller footprint than sand filters. • They are designed to operate by recirculating the treated wastewater through the filter 3 to 5 times, based on forward flow from the septic tank, prior to discharge to the land application system. • The most recent rtPBR technology may achieve a relatively high effluent quality (e.g. advanced secondary treatment). • Available as textile packed-bed reactors with chips or sheets. • Lightweight, compact and watertight.
Design considerations	• Buffer wastewater over 24 hours • Timer pump dose loaded in small doses • Hydraulic loading: typically, 1,000 mm/day • Dosing frequency: 48 - 120 doses/day.

Figure 10: Recirculating textile packed-bed reactor

Bottomless sand filters (Figure 11) are combined treatment and land application systems (refer Section E1.1.3.1)

Bottomless sand filter

Typical schematic



(Adapted from USEPA, 2002)

Description

- Similar to the intermittent sand filter but without basal lining and collection system.
- The base of the bottomless sand filter is open to the underlying sand and doubles as the land application system.
- Bottomless sand filters are used following at least primary treatment. Wastewater is timer dose loaded onto the filter via a pipe distribution network to ensure even coverage of the entire distribution area.
- Can be built either above ground or below ground within a walled contained unit.

Design considerations

- Sand media should be 0.25-1.0 mm with uniformity coefficient <4.0.
- Size of filter horizontal surface area based on loading rate into subsoil beneath the filter as follows:
    - Soil category 1: Gravel and coarse sand – 50 to 70 mm/day (900 mm sand filter depth)
    - Soil category 1: Medium sand – 35 to 50 mm/day (min 600 mm sand filter depth).

Figure 11: Bottomless sand filter

D1.6 Disinfection

D1.6.1 Overview

Disinfection of treated wastewater usually refers to pathogen deactivation following secondary treatment. Unlike sterilisation, disinfection does not kill all micro-organisms within the wastewater but results in damage to the micro-organism cell (cell wall or the cell's nucleic acids) resulting in death or prevention of replication. Disinfection consists of the selective reduction of disease-causing bacteria, parasites and viruses and is typically achieved by chlorination, UV or ozone dosing.

Wastewater characteristics (including TSS, organic content measured by BOD_5 and COD, pH, and hardness) can impact on disinfection effectiveness. Other factors include contact time, concentration of the disinfectant, temperature and concentration of the micro-organisms.

For disinfection to be effective, the wastewater must first be treated to a consistently high quality (Advanced Secondary: 10 g/m^3 BOD_5, 10 g/m^3 TSS) and be clear. Wastewater high in BOD_5 and TSS requires a greater level of disinfectant dosage (i.e. higher doses of chlorine as chlorine demand) or it reduces the performance of UV disinfection due to the low UV transmissivity.

Recycling of wastewater should only occur where the treatment and disinfection system can be closely monitored to ensure that the required recycled water quality can be achieved and maintained. Further discussions on design considerations for recycling of treated wastewater are presented in Section D1.8.

D1.6.2 Chlorine disinfection

D1.6.2.1 General information

Chlorine is the most commonly used disinfectant as it is effective and inexpensive, easily monitored for the effective chlorine residual, and relatively easily maintained.

However, chlorine treatment of treated wastewater may result in the formation of disinfection by-products as the chlorine interacts with organic matter in the wastewater. Some of these disinfection by-products may have adverse effects on the receiving environment or have potential human health impact if public contact occurs. Excess residual chlorine can also have a toxic effect on micro-organisms in the receiving soils or waterbodies. These risks decrease if the disinfected wastewater is sufficiently de-chlorinated prior to discharge.

The required degree of chlorination will depend on intended reuse of the wastewater, sensitivity of the environment and the volume and quality of the wastewater to be disinfected. Chlorination may be used for reuse purposes but is not appropriate for disinfection prior to discharge to the environment.

D1.6.2.2 Chlorination performance requirements

In general, the design criteria for treated wastewater chlorination should follow the specifications within AS/NZS 1546.3:2008.

Chlorination systems require regular addition of chlorine and ongoing monitoring to ensure the necessary chlorine residual is maintained. A design minimum Ct value (concentration x contact time) to achieve the required chlorination will need to be specified. To be effective, a final chlorine residual in the disinfected wastewater should be at least 0.5 g/m^3 free available chlorine, with a minimum contact time of 30 minutes. Monitoring should ensure that the chlorine residual is maintained.

Effective chlorination prior to wastewater reuse should achieve a median *E. coli* level of ≤10 MPN/100 mL, with 80% of samples containing fewer than 20 MPN/100 mL and maximum *E. coli* level of 100 MPN/100 mL.

Section D1.8.3. provides further information on chlorine disinfection systems and their use in disinfecting treated wastewater prior to reuse, primarily for toilet flushing.

D1.6.3 Ultraviolet (UV) disinfection

D1.6.3.1 Overview

UV disinfection uses UV radiation to penetrate the cell walls and disrupt nucleic acids. Table 29 outlines advantages of UV compared to other disinfection options. Its effectiveness depends on wastewater characteristics, UV light intensity, length of time the micro-organisms are exposed to the UV light, and reactor configuration.

UV is most effective where there is low colloidal and particulate material in the treated wastewater. Treated wastewater should have very low turbidity, otherwise bacteria can be shielded and not receive an effective dose. It is for this reason that untreated greywater, with its often-high suspended solids and high turbidity levels, is unsuitable for UV disinfection. Consequently, all wastewater subject to UV treatment should be advanced secondary treated.

UV units require regular maintenance to ensure the tube surfaces are clean and UV transmission intensity is not reduced. Key maintenance requirements for typical UV systems installed for wastewater treatment units are provided in Section F3.

D1.6.3.2 Advantages and disadvantages of UV disinfection

Some advantages and disadvantages of UV are presented in Table 29.

Table 29: Advantages and disadvantages of UV disinfection

Advantages of UV	Disadvantages of UV
• It is effective at inactivating most viruses, spores and cysts.	• Low doses may not effectively inactivate some viruses, spores and cysts.
• It is a physical process rather than a chemical disinfectant, eliminating the need to generate, handle, transport or store toxic or hazardous chemicals.	• Micro-organisms can sometimes repair and reverse the destructive effects of UV through mechanisms of photo-reactivation (with light) or dark repair (in the absence of light).
• No residue that can be harmful to the environment or humans is produced.	• Preventative maintenance is crucial to control tube fouling. Automatic maintenance (e.g. wiping system) is preferable.
• It is user-friendly for operators.	• High turbidity and TSS in the wastewater can render UV disinfection ineffective.
• It has a shorter contact time than other disinfectants (in the order of 20 to 30 seconds with low-pressure lamps).	• UV disinfection (particularly using low-pressure lamps) is not as effective on wastewater with TSS levels above 30 g/m^3.
• It requires less space than other methods.	• It is not as cost effective as chlorination, but costs become comparative when de-chlorination is practised, and chlorine handling costs are considered.

Source: United States Environmental Protection Agency (USEPA), 1999

D1.6.3.3 Components of a UV system

In UV treatment systems, the wastewater can flow either perpendicular or parallel to the direction of the lamps, and the lamps can be in either a horizontal or vertical configuration. There are two types of UV disinfection units:

- **Contact types:** A series of mercury lamps are enclosed in quartz sleeves (or Teflon tubes) to minimise the cooling effect of the wastewater (Figure 12)
- **Non-contact types** (less common): The UV lamps are suspended outside a transparent conduit, which carries the wastewater to be disinfected.

In both types, the ballast (control box) provides a starting voltage for the lamps and maintains a continuous current.

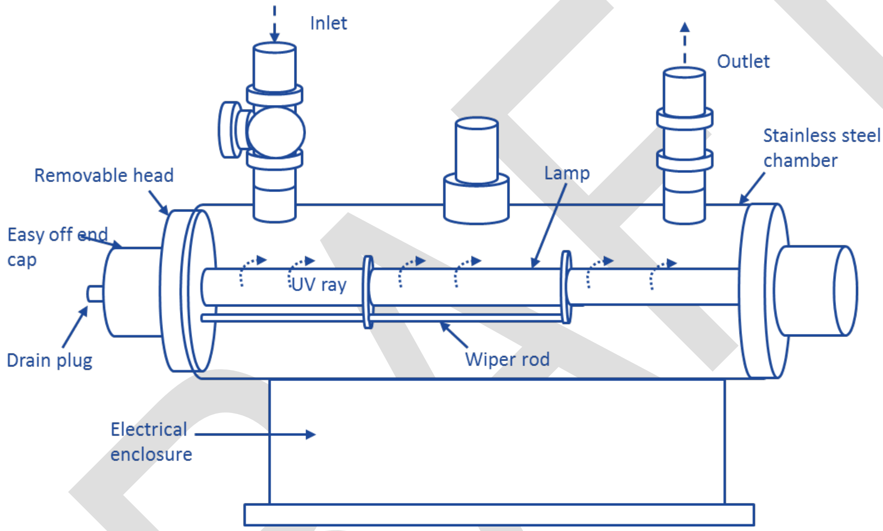


Figure 12: Example of UV disinfection unit

The most common UV system used for small on-site wastewater systems is a low-pressure, low-intensity system (handling wastewater flow less than 0.4 m^3/s). The low pressure of the mercury in the lamp is typically 13.8 Pa. Standard low-pressure, low-intensity lamps typically have a power of 65 W. The optimum UV wavelength is in the range of 250 to 270 nm. The intensity of the radiation emitted by the lamp dissipates as the distance from the lamp increases.

Low-pressure lamps limit monochromatic light at a wavelength of 254 nm. The low-pressure, low-intensity lamp typically has 40% of its output at 254 nm, which is within the ideal range for inactivating bacteria. Standard lengths of the low-pressure lamps are 0.75 m and 1.5 m with diameters of 15 to 20 mm.

The ideal lamp wall temperature is between 35 and 50°C (USEPA, 1999). This type of system can be configured vertically or horizontally, to fit available space. Health and safety factors must be considered when installing and maintaining UV systems (including the potential release of mercury from lamp bulbs).

D1.6.3.4 Factors affecting UV effectiveness

The following factors need to be addressed at the design stage to ensure UV treatment achieves the level of disinfection necessary; these are key considerations when designing a UV system and determining lamp strength and exposure time (USEPA, 1999):

Wastewater flow within the reactor	• It is important that the UV system has a uniform flow with enough radial mixing to maximise exposure of any micro-organisms to the radiation. • The reactor must be designed to eliminate short circuiting and/or dead zones.
Radiation intensity	• UV intensity is affected by the lamp age (see Section D1.6.3.5), lamp fouling, and their configuration and placement. • Lamps can take some time to warm up. During this time, any discharge should be assumed to be untreated. • Where disinfection is crucial, a control system may be needed to ensure there is no discharge without disinfection.
Wastewater quality	• UV effectiveness is dependent on wastewater's suspended and colloidal solids content, micro-organism density and flow rate. These factors determine how much UV radiation reaches the target micro-organisms. • Other parameters that affect UV effectiveness include: ○ Water hardness (which affects the solubility of metals that can absorb UV light or carbonates that can precipitate on the UV tubes) ○ pH (affects metal solubility and carbonates) ○ Humic materials and iron (have high absorbency for UV radiation) ○ Colloidal or particulate BOD_5.

D1.6.3.5 UV disinfection design criteria

A UV disinfection system usually consists of mercury-arc lamps, a contact vessel and ballasts. Several wastewater characteristics must be evaluated before selecting the UV disinfection including:

Flow rate	• Peak hourly flow rate is used as the design flow rate because wastewater flow can vary daily and seasonally, affecting the required size of a UV disinfection facility. • The applied UV dosage is a function of UV intensity and the duration of exposure; the dosage rate achieved is directly proportional to flow rate.
UV transmittance	• UV transmittance is a measure of the quantity of UV light at the characteristic wavelength of 254 nm transmitted through wastewater per unit depth. • A 50% UV transmittance is accepted as the minimum transmittance for which UV disinfection is practical. • High turbidity and/or high concentrations of BOD_5, certain metals, TDS, TSS, and colour may decrease transmittance, lessening the effectiveness of UV radiation.

Gravity flow	• On-site wastewater systems using an aerobic household wastewater treatment unit (producing advanced secondary effluent quality) are usually installed at, or below, grade level and the effluent pipe may be as much as 60 cm below grade. • The UV unit must be below grade and must have very low flow resistance to maintain gravity flow. • Components of underground UV systems must be easily accessed for service and low voltage used for safety during construction.
Microbial composition in the wastewater	• Different pathogenic micro-organisms have different UV sensitivities. • Viruses are typically the most resistant to UV disinfection, followed by spore-forming bacteria, non-spore-forming bacteria, and protistian cysts (Cryptosporidium oocysts and Giardia cysts).

Table 30 provides typical design parameters of the dose requirements for effective UV treatment.

Table 30: Typical UV system design parameters

Design parameter	Typical design value
UV dosage (= UV intensity x exposure time)	20-140 mW-s/cm (or mJ/cm^2)
Contact time	6-40 seconds
UV intensity	3-12 mW/cm^2
Wastewater UV transmittance	50-70%
Wastewater turbidity	Less than 2 NTU (24-hr average), less than 5 NTU (at all time)
Wastewater velocity	5-40 cm/s

Source: USEPA (2002)

D1.7 Alternative treatment options

D1.7.1 Overview

Alternatives are available for both wastewater treatment units (Section D1.7.2) and toilet systems (Section D1.7.3). They include waterless toilet systems such as composting toilets, and other alternative wastewater treatment units such as vermiculture (worm) systems, wetlands and peat bed treatment systems.

Other alternative systems such as dewatering toilets, incinerating toilets, liquid chemical toilets, and vault toilets are briefly summarised below but are not discussed in detail in this document. The design of alternative systems must be done by a qualified person and an appropriate operation and maintenance plan in place and adhered to.

D1.7.2 Alternative treatment systems

Vermiculture	
Description	• Vermiculture uses earthworms to digest waste material (kitchen and garden waste as well as human waste) as well as low temperature composting (below 35°C). • The process relies on both worms and soil microbes for the decomposition process (rather than heat-tolerant microbes present in regular composting).
Design considerations	• Vermiculture must be installed by professionals and only operated and/or owned by people who understand and will comply with the maintenance requirements that are undertaken in accordance with the required safety precautions. • Proprietary devices are generally assessed on a case-by-case basis. • Worms need to be protected from harmful chemicals and supplied with a regular food source. Since worm casts are not heat-treated during the biodegradation process, it must be assumed that the pathogen content is higher than in composted material and should be handled as a hazardous substance. • There is a public health risk and potential for direct contact with waste when composted and partially composted solid material is removed for burial. The solid material must be collected by a commercial waste collection contractor who can dispose of it off-site in an authorised manner. All the risks covered in Appendix E also apply to vermiculture. • Wherever the design wastewater flows are reduced due to the inclusion of a vermiculture toilet, the land application system reserve allocation should be increased by an additional 40-50%.
Peat bed treatment	
Description	• Peat is used as a filter material (built in a similar way to intermittent sand filters) and can produce effluent to a secondary quality standard suitable for irrigation. • Primary effluent is dosed intermittently over the peat bed, with treated effluent either passing through the base of the peat module or collected in a slotted pipe for dispersal to a land application area. Intermittent timer dosing is preferred to ensure the peat bed is not overloaded. • Peat beds can achieve significant reductions in suspended solids, BOD5, nitrogen, phosphorus and faecal coliforms with minimal maintenance (Patterson, 2004). • Phosphorous saturation of peat can occur. The effluent quality from peat beds is suitable for land application and water can be reused in landscaped areas via drip irrigation.
Design considerations	• Advanced primary septic tank effluent quality (with effluent filter) is required prior to entry into the peat bed systems. • Filter size and design and the type of peat used need careful consideration for sufficient treatment. Design loading rates across a peat bed should be between 35 to 50 mm/day, dependent on peat quality. The peat filter depth should be 0.5 m. • Estimated life expectancy of the peat bed fibre is cited by commercial producers of modular peat bed systems in North America as 10 to 15 years. However, based on experience in Australia and New Zealand, systems designed and supervised by specialist designers and operated and maintained appropriately, can have a life expectancy of up to 30 years. • Design and construction of peat beds should allow for ease of removal and replacement of the peat. These systems require monitoring and reporting to demonstrate design assertions.

Constructed subsurface flow wetland	
Description	• Constructed subsurface flow wetlands consist of a shallow gravel media bed, lined with an impermeable membrane or clay layer, in which septic tank effluent flows horizontally below the media surface between inlet and outlet structures. • The gravel media is planted with selected emergent wetland species, and secondary treatment of the primary treated effluent is accomplished by physical, chemical and biological processes within the media and the plant root systems. • Wetland systems for on-site wastewater management include surface and subsurface flow constructed wetlands Further design guidance can be found in NIWA's (2011) Guideline for the use of horizontal sub-surface flow constructed wetlands in on-site treatment of household wastewaters. • Generally, vertical flow wetlands perform better than horizontal flow wetlands.
Design considerations	• Long HRTs are possible. • Climate and seasonal conditions affect performance. • Surfacing effluent should be avoided to reduce public exposure and insect issues. • There are low energy costs and potential aesthetic/ecological benefits. • The design, installation and operation and maintenance criteria for subsurface flow wetland wastewater treatment units are outside the scope of GD06. For detailed design specifications, refer to the Gisborne District Council 'Guideline for the use of horizontal subsurface-flow constructed wetlands in on-site treatment of household wastewaters' (Tanner, Headley, & Dakers, 2011). • The need for expert, site-specific design means that assessment of wetland designs is done on a case-by-case basis. • Planting should follow the New Zealand Constructed Wetland Planting Guidelines (Tanner, Champion, & Kloosterman, 2006).

D1.7.3 Alternative toilet systems

Other methods for reducing pollutant mass loading to a single on-site wastewater treatment unit include segregating toilet waste flows from sink, shower, washing machine, and other waste flows. Some alternative types of toilet systems can provide separate handling of human faecal material and associated products such as toilet paper.

Significant quantities of suspended solids, BOD_5, nitrogen, and pathogenic organisms can be eliminated from wastewater flows by segregating human effluent from the wastewater stream using composting or incinerator toilets. This approach may be more cost effective for new homes, homes with adequate crawl spaces, or mobile or modular homes. Retrofitting existing homes, especially those with concrete floors, can be expensive.

Waterless toilets can reduce a household's wastewater volume by 20% to 40% depending on toilet system flush volumes and water reduction fixtures. Where blackwater is treated separately, all greywater must be collected and treated according to its intended end use. Further discussions on reuse or recycling of treated domestic wastewater are presented in Section D1.8.

Composting toilet

Description

Composting toilets are designed to store and compost, by aerobic bacterial digestion, only the toilet waste (but may also include kitchen food scraps, depending on the design). Other carbon sources may be required to enhance the digestion, (such as grass clippings, wood chips, coarse saw dust, etc.). The greywater from bathing facilities, sinks and washing machines must be collected and treated separately. The main components of a composting toilet include:

- A composting chamber connected to one or more toilets
- An exhaust system (often fan-forced)
- Ventilation (aeration) system
- Drainage/collection of excess liquid and leachate
- Mixers (automatic or manual)
- Access for mixing and removal of end-product.

Design considerations

- Composting toilets need to be located and operated in such a way that no public health hazard or odour nuisance arises. Homeowners should not remove the composted residual wastes; these should be handled by licensed septage (hazardous) waste transporters only. Further details are provided in Appendix E.
- Factors that need to be considered:
  - Number of individuals who use the composting toilet
  - Kind of use (residential, day-use, public facility, etc.)
  - Designed environmental factors (temperature, aeration control, etc.).
- Important sizing assumptions may include:
  - Daily waste production rate: Urine: 1.3 L/person/day; faeces: 0.6 L/person/day or 200 grams/person/day
  - Population equivalent definition: 1.2 faecal events and 4 urine events/person/day
  - Ratio of urine to faeces: 3:1 - 4:1 (residential); 10:1 (public facility).
- The solid end-product should not produce any objectionable odour immediately after removal from the composting toilet.
- The moisture content of the solid end-product should be ≥ to 65%.
- Faecal coliform level should be ≥ 200 MPN/gram.
- Vector management considerations are required.

Incinerator toilet

Description

- Incinerator toilets accept human waste in a chamber where the waste is burned.
- These chambers have limited capacity and require electricity or fuel to burn the waste. Ash must be periodically removed and disposed of appropriately.
- Incinerator toilets may routinely produce objectionable odours at the start of each incineration cycle.
- As incinerators produce hazardous materials, there may be additional requirements under the regulation of National Environmental Standards for Air Quality (Ministry for the Environment, 2004).

Design considerations	• The number of users or uses per day of the designed incinerator toilet should be identified according to the manufacturer's specifications. • Access ports should be sized and located to facilitate the installation, removal, sampling and maintenance of the incinerator toilet. • The setback distance from the exhaust stack to the nearest property boundary or other inhabitable buildings should be at least 150 m.
Chemical and recirculating chemical toilets	
Description	• Chemical toilets generally include a toilet seat located above a vault, which contains chemicals to disinfect and control odours from the wastewater. • Recirculating toilets apply chemicals with the toilet flushes. Usually, the waste is separated from the liquid phase and stored in an internal holding tank. The chemical liquid may be reused for additional toilet flushing. • Because of the incomplete disinfection of the waste and presence of chemicals in the liquid, the residual waste or spent chemical liquid in these toilets needs to be periodically removed by a licensed hazardous waste transporter.
Design considerations	• Only proprietary devices available, therefore no specific design parameters are available. • Proprietary devices should be assessed on a case-by-case basis.
Vault toilets	
Description	A vault toilet may consist of the following components: • A toilet above a water-tight storage chamber for human waste • A mechanism for sewage waste pumping/overhauling/collection followed by off-site discharge/disposal.
Design considerations	• There should be one vault for each toilet riser. The vault must be capable of withstanding any anticipated structural, hydraulic, or buoyant forces. • The vault interior should be water-tight, with a proper vent pipe. • Vault sizing is determined by the amount of use. The depth of the vault should be less than 1.5 m. • Access ports should be sized and located to facilitate the installation, removal, sampling and maintenance of the toilet. • Vault toilets cannot be installed in areas prone to flooding or surface water ponding.
Pit toilets	
Description	• A pit toilet consists of a toilet structure on top of an excavation where human waste is permanently deposited.
Design considerations	• Pit toilets cannot be installed in soils of medium - coarse sand. • Pit depth should be at least 3 m deep. • Complete separation (or isolation) is required to prevent accidental human, animal, or vector access. • Pit toilets cannot be installed in areas prone to flooding or surface water ponding.

Holding tanks	
Description	• A wastewater storage tank or holding tank which requires regular pump-out of all contents (solids and liquids) and disposal off-site. It can provide a temporary solution (e.g. for a failed system) but is generally not a cost-effective long-term solution. • Long-term dependence on a holding tank is outside the scope of this document.
Design considerations	• Must control against uplift during emptying. • Should be sized for seven day's storage. • Requires water reducing fixtures. • Must be fitted with a high-level alarm (recommended set at 80% of capacity level) and be accessible for pump-out. • In such circumstances, the pump may be driven by an electric generator-powered motor or directly by an internal combustion engine.

D1.8 Reuse of treated wastewater

D1.8.1 Overview

Using treated greywater[5], referred to here as reclaimed water, can reduce demand for potable water supply and the treated wastewater discharge volume. However, wastewater system design must include greywater volumes to ensure the land application area is appropriately sized.

The Ministry of Health strongly advises against the domestic use of treated wastewater for the following reasons (Sinclair, 2004):

- Greywater can have a high microbial and BOD_5 contaminant load
- On-site wastewater treatment units are often not sufficiently reliable to ensure consistent wastewater quality thereby raising an avoidable and real hazard
- The risk of cross-connection between reclaimed wastewater and potable water is significant
- System maintenance may not be sufficient to ensure consistent wastewater quality.

As a minimum, advanced secondary treatment and disinfection is required where greywater will be used for toilet flushing.

The following sections provide a summary of the minimum requirements for any wastewater reuse system.

[5] Only treated greywater sourced from bathroom washbasin, shower, bath and from laundry (excluding kitchen sink flows) is considered acceptable as reclaimed water for reuse.

D1.8.2 Options for domestic use of treated wastewater

Reclaimed water may be suitable for:

- Flushing toilets (must be disinfected)
- Subsurface irrigation of gardens, including fruit trees and bushes, but not root crops
- Filling ornamental ponds where there is no direct human contact.

The Ministry of Health advises against reclaimed wastewater being used where there is any potential for human contact or contact with stormwater drains (Sinclair, 2004). This includes:

- Manual watering of lawns and gardens by sprinkler or handheld hose
- Garden hoses, washing cars, walls, windows etc.
- Construction purposes.

Reclaimed water must never be used for:

- Drinking
- Cooking or kitchen purposes
- Personal washing such as baths, showers and hand basins
- Washing clothes
- Household cleaning
- Swimming pools, spas
- Recreation (e.g. playing under sprinklers)
- Spray irrigation for crops that are eaten raw or unprocessed.

D1.8.3 Reuse requirements for on-site wastewater units

D1.8.3.1 Treated effluent quality requirements

Minimum treatment system requirements are an advanced secondary level of treatment (refer to Section D1.3 or D1.5.2 for the effluent quality of advanced secondary treatment), followed by an appropriate disinfection system (in accordance with the specifications described in Section D1.6). UV disinfection is applicable for initial disinfection of treated wastewater. However, effective free chlorine residual is always required if any indoor reuse of treated wastewater (including treated greywater) is proposed. Detailed requirements on chlorination systems can be found in Section D1.6.

Treated disinfected wastewater should meet the following quality prior to reuse for toilet flushing:

- Microbiological: <10 *E. coli* MPN (or CFU)/100 mL
- Turbidity: <2 NTU (24-hour average) and <5 NTU (at any time)
- Free available chlorine ≥0.5 g/m^3 or pH adjusted equivalent
- pH: 6.5 - 8.5.

D1.8.3.2 Disinfection requirements for reclaimed water use

D1.8.3.2.1 Liquid chlorination

Treated effluent must be disinfected prior to domestic indoor reuse (i.e. for toilet flushing). The preferred method is chlorination using automated flow-proportionate chlorine dosing with continual on-line monitoring by redox probe to ensure chlorine doses are sufficient and that the required 0.5 ppm chlorine residual is maintained. Key components include:

- A chlorine contact tank
- Chlorine supply
- An automatic proportional flow chlorine dosing system with a redox probe to maintain effective free available chlorine at >0.5 g/m^3 (with pH 6.5 - 8.5)
- Alarm system (audible and preferably visible) if the free available chlorine goes outside set limits, or if the chlorine supply is low. Automatic notification to a maintenance contractor is required for any decentralised system or system serving public toilets or other facilities
- A separate chlorinated wastewater holding tank.

Signage and plumbing considerations are discussed in Section D1.8.4.

D1.8.3.2.2 Alternatives to liquid chlorine disinfection methods

A tablet chlorinator usually consists of a basin where the tubes containing a stack of chlorine tablets are placed. The chlorine tablets that are used for wastewater are usually made of calcium hypochlorite ($Ca(OCl)_2$). They dissolve in the wastewater and release hypochlorite, which then becomes hypochlorous acid (the primary disinfectant). The top of the tubes should extend above the ground and be protected by a cap. The bottom tablet in the tube contacts with the wastewater flowing through the basin. As that tablet dissolves and/or erodes, the next tablet falls by gravity to replace it.

A tablet can dissolve quickly or slowly, depending on the volume and flow of wastewater coming into contact with it, tablet properties, and length of contact time. If the contact time is too long, the wastewater becomes over-chlorinated and the tablets are consumed rapidly; if the contact time is too short, the wastewater is not disinfected sufficiently. UV disinfection may be applicable, when combined with an appropriate chlorine dose to maintain chlorine residual.

D1.8.3.2.3 Monitoring and maintenance

The performance of the chlorine disinfection system should be monitored to ensure free available chlorine remains above 0.5 g/m^3. This monitoring includes:

- For household systems: A simple swimming pool chlorine concentration test is useful on a daily basis until there is certainty that the chlorination system is stable and thereafter, testing should occur on a weekly to fortnightly basis
- For public toilet reuse systems: Continuous on-line chlorine monitoring, with an alarm to the maintenance contractor
- Daily or weekly home test kit tests for pH, turbidity and free available chlorine

- Periodic analysis of microbiological concentrations, pH, turbidity and free available chlorine at a registered laboratory
- Regular calibration and cleaning of the redox probes: Sensor probes must be cleaned each service, at least six monthly or more frequently for systems serving flows larger than from a single household (probes are a consumable item, and most will foul and need to be replaced within approximately 12 months).

Testing frequency should be increased whenever results show disinfection has been inadequate and continued until remedial action is taken and the testing results are satisfactory.

D1.8.4 Other reclaimed water use precautions

Signage	• Place notices in public areas where effluent is recycled to warn users that the toilet cistern water is non-potable.
Cross-connection precautions	All practical steps should be taken to prevent any future cross-connection, including: • If potable water is used for top-up requirements, it must be delivered via a backflow preventer • Pipes for redistribution of reclaimed water must be a different colour to those for water supply and those for raw and disinfected treated wastewater. Each pipe must be labelled separately as not being potable water • Reclaimed water reticulation must be separated from all potable water lines in the home and from sewerage pipes (they should be in different trenches and, where practicable, separated by at least 300 mm) • Non-standard taps and fixtures must be used, which do not allow garden hoses or other equipment to be attached to the reclaimed water system. Preferably, there should not be any taps connected to the reclaimed water system • The only reused water outlets within buildings should be toilet cisterns and there should be no tap connections providing any forms of reuse water outlets.

Further information on the operation and monitoring of chlorine disinfection systems is provided in Section D1.6.2 above.

D1.8.5 Design of greywater systems

D1.8.5.1 Greywater composition

Greywater comprises wastewater from all other domestic sources within a household other than toilets. It is estimated to constitute around 60 to 80% of total in-house water usage.

Grey water for reuse is sourced from bathroom and laundry wastewater flows and excludes kitchen sink and garbage grinders. Such reuse has traditionally been considered relatively safe and cheap due to its lower organic content and perceived low microbial concentrations compared to toilet wastewater (blackwater). However, greywater can have high concentrations of faecal indicator bacteria (Silyn Roberts, 2002; Converse, 2004; Sinclair, 2004) as well as high concentrations of strong household washing and cleaning chemicals. Typical greywater constituents are summarised in Table 31, in comparison to the typical blackwater constituents.

Table 31: Typical raw greywater composition

Parameter	Greywater range	Greywater typical	Blackwater typical
BOD_5 (g/m^3)	250-550	360	267
COD (g/m^3)	400-700	535	533
TSS (g/m^3)	30- 180	40	200
TN (g/m^3)	10-17	13	67
TP (g/m^3)	3-8	5.4	15
Total coliform (CFU/100 mL)	10^2-10^6	10^5	10^4-10^7
E. coli (CFU/100 mL)	10^2-10^6	10^4	10^4-10^7

Source: Nolde, 1995 and Bullermann *et al* 2001

This document does not differentiate between the effluent quality classification for greywater treatment systems and regular wastewater treatment units. The potential greywater treatment options, along with their suitable greywater sources and acceptable effluent disposal/reuse methods, are summarised in Section D1.8.5.4 below.

D1.8.5.2 Greywater reuse system

In general, greywater recycling/reuse systems should fulfil four criteria:

- Hygienic safety
- Environmental tolerance
- Economic feasibility
- No loss of comfort to users.

Where separation of greywater and its reclamation for reuse for domestic purposes is proposed (e.g. toilet flushing), the greywater needs to be treated to achieve the equivalent of advanced secondary treatment effluent quality, followed by chlorine disinfection. Disinfection needs to be undertaken in accordance with the guidelines in Section D1.8.3.2 and further precautions provided in Section D1.8.4.

Less treatment may be allowed if the reuse of laundry waste is for manual irrigation purposes.

D1.8.5.3 Design flow

Designers are required to refer to the flow allowances specified in Section C for adequate sizing of the greywater treatment systems. Where practicable, it is recommended that the greywater treatment and land application systems be sized as if the blackwater is also discharged into the wastewater treatment unit.

D1.8.5.4 Performance requirements and effluent discharge/reclaimed water recycling methods

Due to greywater's potentially high contaminant levels, the design and sizing of a greywater treatment unit should be based on that for normal domestic wastewater (Sections D1.4 - D1.4.3). There are several different systems (Table 32); the most efficient systems for greywater treatment are biological, in combination with physical/mechanical processes. The discharge or reclaimed water use options of treated greywater are also listed in Table 32.

Table 32: Summary of greywater treatment options and related design requirements

Greywater system	Greywater effluent quality	Applicable greywater sources	Design requirements	Land application of treated effluent	Suitability of treated effluent for indoor use
Primary treatment units only (i.e. septic tanks)	[Note 1]	All greywater sources (including kitchen sinks)	Design method and performance requirements same as traditional all-waste septic tanks.	Same as applicable primary effluent for all-waste septic tanks: • Trenches and beds • Mounds • Deep bores • LPP/LPED. Corresponding design loading rates apply (refer Section E1.3). Corresponding setback distances apply (refer Section B5.4).	N/A
Greywater diversion system only (No treatment) [Note 2]	[Note 1]	Bath, shower and washing machine only, (excluding kitchen sinks)		• Trenches and beds • Mounds • Deep bores • LPP/LPED. Corresponding design loading rates for primary effluent apply (refer Section E1.3). Corresponding setback distances for primary effluent apply (refer Section B5.4).	N/A

Greywater system	Greywater effluent quality	Applicable greywater sources	Design requirements	Land application of treated effluent	Suitability of treated effluent for indoor use
Secondary treatment	Same as secondary treated effluent quality as defined in Table 23: • 20/30 (BOD_5/TSS 90%ile) • 30/45 (BOD_5/TSS max).	All greywater sources	Design requirements vary according to the selected biological/physical treatment processes.	Same as applicable secondary effluent for all-waste on-site wastewater treatment systems: • Pressure compensating drip irrigation • LPP/LPED • Trenches and beds • Mounds • Bottomless sand filter • Deep bores Corresponding design loading rates apply (refer Section E1.3). Corresponding setback distances apply (refer Section B5.4).	N/A
Advanced secondary treatment	Same as advanced secondary treated effluent quality as defined in Table 23 with additional requirements below (as per D1.6.2.2 and D1.8.3.1): • 10/10 (BOD_5/TSS 90%ile) • 20/30 (BOD_5/TSS max).	All greywater sources	Design requirements vary according to the selected biological/physical treatment processes.	Same as applicable advanced secondary effluent from all-waste on-site wastewater treatment systems: • Pressure compensating drip irrigation • LPP/LPED • Trenches and beds • Mounds • Bottomless sand filter • Deep bores Corresponding design loading rates apply (refer Section E1.3). Corresponding setback distances apply (refer Section B5.4).	N/A

<table>
<tr><th>Greywater system</th><th>Greywater effluent quality</th><th>Applicable greywater sources</th><th>Design requirements</th><th>Land application of treated effluent</th><th>Suitability of treated effluent for indoor use</th></tr>
<tr>
<td>Advanced secondary with disinfection [Note 4]</td>
<td>Same as advanced secondary with disinfection effluent quality as defined in Table 23:
<table>
<tr><th>Parameter</th><th>Values</th></tr>
<tr><td>BOD_5</td><td>10 g/m³ (90%ile)</td></tr>
<tr><td>TSS</td><td>10 g/m³ (90%ile)</td></tr>
<tr><td>Turbidity</td><td>2 NTU (average)
5 NTU (maximum)</td></tr>
<tr><td>pH</td><td>6.5 - 8.5</td></tr>
<tr><td>E.coli</td><td>10 MPN (or CFU)/100 mL (median)
20 MPN (or CFU)/100 mL (80%ile)
100 MPN (or CFU)/100 mL (max)</td></tr>
<tr><td>Free available chlorine residual</td><td>0.5-1.0 g/m³</td></tr>
<tr><td>Colour *</td><td>Non-detectable</td></tr>
<tr><td>Odour *</td><td>Non-detectable</td></tr>
<tr><td>Oily film and foam*</td><td>Non-detectable</td></tr>
</table>
* Colour, odour, oily film and foam analysis should be undertaken with diluted sample (i.e. effluent composite sample diluted 1: 1000 with deionised water).</td>
<td>All greywater sources</td>
<td>Design requirements vary according to the selected biological/physical treatment processes.</td>
<td>Same as suitable land application systems for advanced secondary with disinfection effluent from all-waste on-site wastewater systems:
• Pressure compensating drip irrigation
• Surface irrigation
• Spray irrigation
• LPP/LPED
• Trenches and beds
• Mounds
• Bottomless sand filter
• Deep bores.
Corresponding design loading rates apply (refer Section E1.3).
Corresponding setback distances apply (refer Section B5.4).</td>
<td>Toilet or urinal flushing only [Note 3]</td>
</tr>
</table>

Greywater system	Greywater effluent quality	Applicable greywater sources	Design requirements	Land application of treated effluent	Suitability of treated effluent for indoor use
Physical soap and lint filtration with disinfection [Note 4]	Effluent quality should be assessed against the categories as defined in Table 23.	Bath, shower and washing machine only, excluding kitchen sinks	Various proprietary devices are available in New Zealand and should be assessed on a case-by-case basis.	Suitable land application methods should be selected based on the effluent quality classification above.	Toilet or urinal flushing may be allowed if the effluent quality meets the criteria for advanced secondary with disinfection [Note 3].

Notes:

1) Effluent quality may vary.
2) The system may contain some coarse screens and a surge tank with no storage of diverted greywater for longer than 24 hours.
3) Any greywater indoor reuse must include the following components:
    - Backflow prevention devices
    - Colour-coded pipework for indoor recycled water plumbing
    - An appropriate back-up potable water supply
    - An automatic valve to divert the effluent to the designed blackwater treatment system in the event of system malfunction, power failure, system blockage, or when the tank is full.

Liquid chlorination (rather than tablet chlorination, D1.8.3.2.2) is the preferred disinfection for any indoor recycling system. If UV disinfection is used, an additional chlorine dosing system is required to maintain a free available chlorine residual level of between 0.5 and 1.0 g/m^3 within the system.

E Design of land application systems

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Tables

E1.0 Design of land application systems

The land application area receives treated effluent from the wastewater treatment unit and provides further treatment by several processes that include physical filtering, chemical reactions and biological breakdown as the effluent passes through the soil. The resulting carriage water is dispersed via:

- Assimilation through the soil matrix for eventual plant uptake of soil moisture via transpiration
- Evaporation
- Percolation through the soil matrix for eventual assimilation with groundwater.

This section provides design specifications and guidance on the selection and design of land application systems, as well as construction and operation, and discusses:

- The choice of land application systems (including shallow irrigation, conventional and non-conventional systems)
- Design loading/irrigation rates, including the long-term acceptance rate
- Sizing and placing the land application area
- Design of dosing and distribution systems
- Recommended planting to improve nutrient uptake and evapotranspiration.

E1.1 Land application systems

With shallow soakage or irrigation systems, organic matter in the effluent is taken up by aerobic micro-organisms and vegetation within the well aerated upper soil layers. This occurs at a faster rate than in anaerobic conditions which predominate in deeper or saturated soil. The “KISS” (“keep infiltration systems shallow”) principle utilises this upper, aerobic soil layer.

Land application areas, including proposed reserve areas, should not be located within:

- Any geotechnical hazardous area (soil warning, geotechnical constraint zoning, etc.) without specialist design
- Any areas earth worked, stockpiled, or compacted by heavy machinery
- Proximity of any contaminated land
- The 5% AEP (1 in 20 year) floodplain.

Land application systems should be designed for a loading rate less than the estimated long-term acceptance rate for the soil conditions. The long-term acceptance rate represents the steady-state infiltration rate over time, following full development of the biological clogging mat (which builds up on infiltrative surfaces under continuous use with the application of treated effluent). This may take several weeks or months to develop for a new system. The design loading rates should be set below the estimated long-term acceptance rate so that seepage or ponding does not occur once the clogging mat has developed and should maintain the soil’s infiltration capacity.

Shallow land application systems (Section E2.0) can be vented to help maintain long-term acceptance rate values and is essential in all subsurface distribution systems unless aerobic conditions are maintained in the lines (as in pressure compensating drip irrigation [PCDI] and shallow low pressure effluent distribution [LPED] systems) where effluent is pumped.

Long-term acceptance rates can be improved by treating the effluent to a higher quality. The suggested design loading rates or design irrigation rates for soakage systems (or irrigation systems) are provided in Section E1.2.

Design details for the most commonly designed shallow irrigation and conventional land application systems are provided in Section E2.0 and Section E3.0 respectively.

E1.1.1 Shallow irrigation systems

Shallow irrigation systems are well suited to moderate draining soils. In slow draining and fast draining soils, an adequate overlying topsoil depth is needed, and environmental requirements must be met.

Common shallow irrigation systems are summarised in Table 33. The distribution of treated effluent in shallow irrigation systems is usually designed based on areal[1], rather than basal[2] loading. The areal loading rate is determined according to soil characteristics and environmental constraints with lower rates appropriate for sites having environmental limitations, including poorer soakage characteristics. Recommended irrigation rates for a range of soil categories are provided in Section E1.2.

Refer to Section B5.4 for requirements for shallow irrigation system setback distances.

Table 33: Shallow irrigation land application systems (using areal loading for design area calculation method)

General description	Effluent quality requirements	Reference section
Pressure compensating drip irrigation (PCDI) systems:		
• Used for distribution of secondary quality effluent, or better, via pressure-dosing into land application areas. • They provide for equal wastewater flow from each emitter and the lines do not need to be level. Spacing of 1 m for the line/emitter is generally applied. • For systems using fine drip, a 120 µm disc filter is usually required prior to the irrigation field. • For systems using coarse drip, it is potentially feasible to operate with a coarse filter (e.g. 40 mesh) for effluent quality less than secondary treated. • All driplines must be installed according to the manufacturer's specifications.	Secondary treated	E2.2

[1] Typically applied for shallow irrigation systems, where the loading application area comprises the entire irrigation area including the area between the distribution lines. This is further defined in Section E1.3.2

[2] For conventional land application systems, the design land application area only comprises the basal area of the trench, bed or mound excluding the area in between. This is further defined in Section E1.3.3

General description	Effluent quality requirements	Reference section
Other low pressure irrigation systems (LPED and LPP):		
The low-pressure pipe (LPP) and low-pressure effluent distribution (LPED) systems are low-pressure and non-pressure compensating shallow subsurface irrigation systems, designed to retain and further treat wastewater in the topsoil for evapotranspiration and to reduce seepage into the subsoil. • Due to large discharge pipe and orifice diameters (in comparison to those in PCDI systems), they can be used for the application of either primary treated or secondary treated wastewater. For primary treated effluent, a 3 mm septic tank outlet filter must be installed. • LPP irrigation systems comprise a series of shallow and narrow distribution media filled trenches laid within the topsoil, above the shallow subsoil layer and are pressure-dosed by small diameter perforated plastic pipe laterals. • LPED irrigation systems also comprise a series of shallow and narrow distribution media filled trenches, and work by pump dose flooding of the laterals enclosed within a draincoil line through widely spaced perforations in the dose line. LPED allows for more effective distribution of treated wastewater along the length of the trench during each dose than LPP, avoiding the spot-loading effect associated with LPP. As both the LPED and LPP systems are non-pressure compensating, they have a greater potential for uneven distribution throughout the system (in comparison to PCDI systems). • The LPP/LPED systems are not recommended to be installed on sites with a slope greater than or equal to 8.5° (15%). Pipes for LPED systems should be laid in 200 x 200 trenches in distribution media (aggregate) of 20 - 40 mm, clean and free of soil or organic matter. The dosing system should consist of a 25 - 30 mm perforated pipe installed in an 80 - 100 mm distribution pipe or draincoil line. • Final details of perforated dose line pipe size and squirt hole size in the LPED system should be confirmed by hydraulic design (refer Section E2.3). It is preferable to use an automatic sequencing valve system for even distribution.	Primary treated (with effluent filter) Secondary treated	E2.3 & E2.4

E1.1.2 Conventional land application systems

Conventional land application systems include trenches, beds and mounds (Table 34) and were historically the system of choice before more advanced evapotranspiration systems were developed. Conventional adsorption systems may be used in well-drained soils with low groundwater tables, although some site issues (such as high groundwater level, periodical flooding/inundation, inadequate permeable soil depth or shallow distance to bedrock, etc.) may restrict their suitability.

Table 34: Conventional land application systems

	General description	Effluent quality requirements	Design area calculation method
Trenches (Section E3.1)	• A trench system is a system of narrow trenches partially filled with aggregate in which a distribution pipe is laid. Two common types of absorption trench field layouts are: ○ A distribution box connected to parallel laterals for flat or minimally sloped sites, and ○ A drop box connected to parallel successive trenches along a slope on sites with 5.7° (10%) or greater slopes. • The required basal area of absorption trench is dependent on the daily design flow rate and soil category (Table 35). The maximum length of absorption lines used in conjunction with gravity distribution should be 20 m. The maximum length of absorption lines, used in conjunction with pressure distribution or dosing, should be 30 m. • The preferred material for covering the distribution aggregate is permeable non-woven geotextile.	Minimum: Primary treated with an effluent outlet filter	Basal loading or sidewall loading (deep trench)
Beds (Section E3.2)	• Conventional bed systems are a second-best alternative to trenches and should only be used where the slope and site area is too restrictive for trench installation. • Conventional beds function via basal seepage only. Beds have a limited sidewall area compared to trenches and their design loading rate is reduced as the low ratio of sidewall to base area reduces their operational factor of safety. • ETS systems are appropriate for use in Category 3 to 5 soils to utilise both subsoil soakage and assist plant evapotranspiration to achieve a more effective application than that achieved by conventional beds. • In an ETS bed, the sand layer overlying the distribution media draws liquid via upward capillary action to feed both water and nutrients to stimulate plant growth and evapotranspiration.	Minimum: Primary treated with an effluent outlet filter	Basal loading
Mounds (Section E3.3)	• Mound systems have applications where conventional trenches are unsuitable due to shallow soils overlying a hardpan or rock, or where water quality protection is required for a high water table in permeable soils. • The mound provides for the distribution of effluent onto a layer of sand of at least 600 mm depth to ensure renovation before entering natural soil and diffusing into the surrounding soil above the hardpan or water table. • The design and construction details provided in Section E3.3 are based on the Wisconsin Mound System. Refer to Appendix N1.0 for a worked example.	Minimum: Primary treated with an effluent outlet filter	Basal loading

E1.1.3 Combined treatment and land application systems

E1.1.3.1 Bottomless sand filters

Bottomless sand filters (Figure 13) are only to be used in Category 1 gravel and sandy soils. The bottomless sand filter (refer Section D1.5.4 and Figure 13) is the same design as an intermittent sand filter but without a basal lining and effluent collection system. They are normally used following pre-treatment by septic tank and outlet solids control filter. Wastewater is usually timer-controlled dose loaded onto the filter via a pipe distribution network to ensure even coverage of the entire distribution area (using a basal design area calculation). Sand media should be 0.25 -1.0 mm with uniformity coefficient <4.0.

The size of filter horizontal surface area is based on the loading rate for distribution into the underlying subsoil. For gravel and coarse sand subsoil, the DLR is 50 to 70 mm/day 900 mm sand filter depth. For a coarse to medium sand subsoil, the DLR can be 35 to 50 mm/day (min 600 mm sand filter depth). Note that bottomless sand filters should be designed and installed by experienced practitioners.

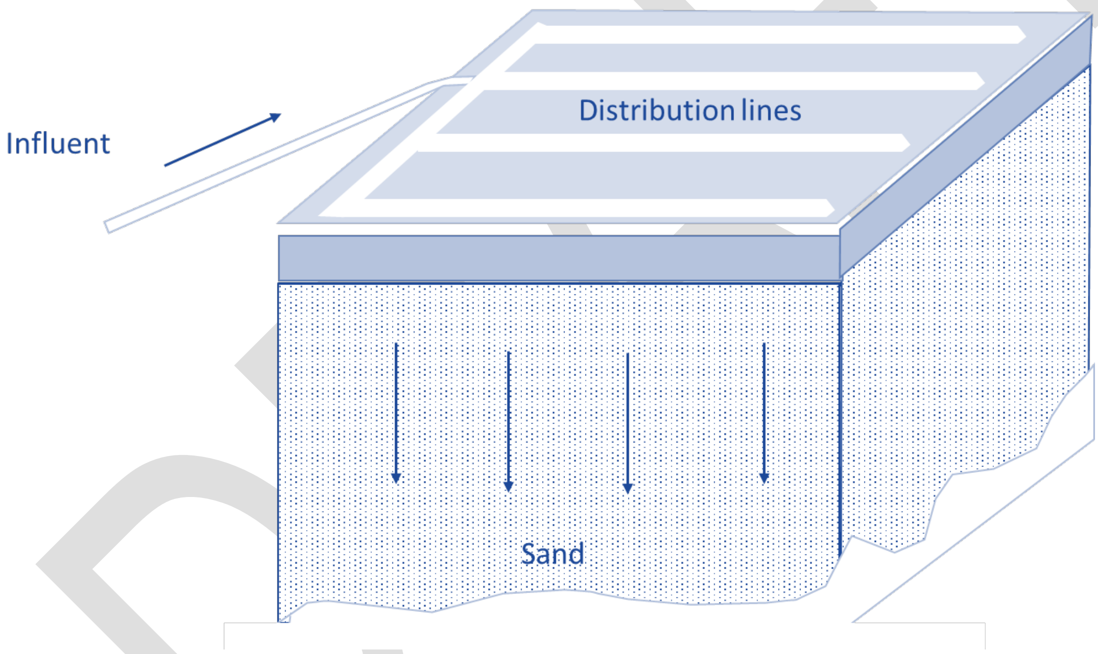


Figure 13: Example of bottomless sand filter

(Adapted from USEPA, 2002)

E1.1.3.2 Textile wrapped pipe and sand filter system

This proprietary combined treatment and dispersal system consists of primary treatment via a septic tank with effluent outlet filter followed by secondary treatment and distribution through a textile wrapped pipe system within sand filled trenches or beds (Figure 14). Specialist design sizing, sand specification and installation procedures are required using supplier-trained installers.

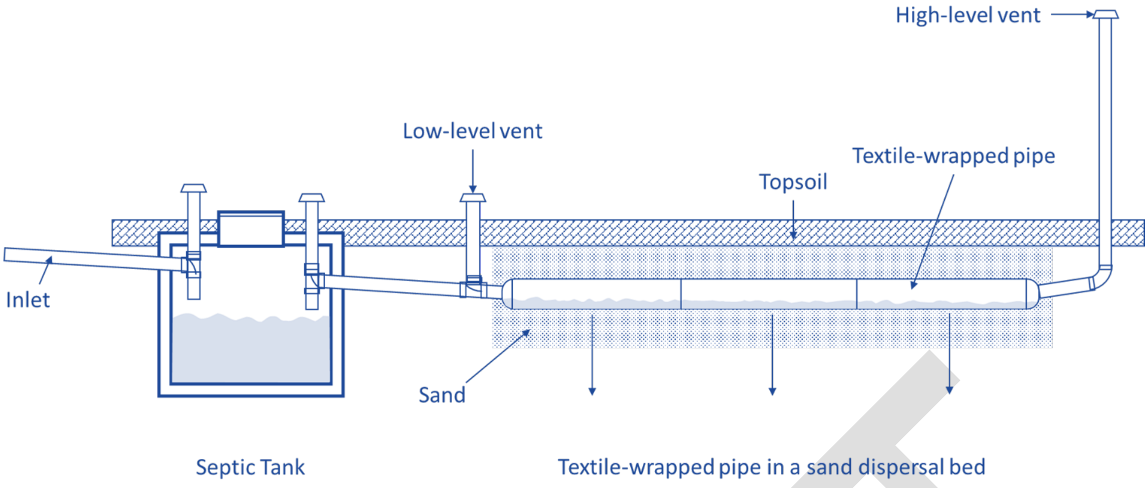


Figure 14: Example textile wrapped pipe and sand filter system

(adapted from installers information)

E1.1.4 Non-conventional land application systems

Design details for non-conventional land application systems are not provided in this document but are summarised here for reference. Non-conventional systems require specialist design and installation by an experienced on-site wastewater practitioner.

E1.1.4.1 Deep bores

Deep bores (Figure 15) are a method of wastewater disposal where there are restrictive soils near the surface, e.g. poorly draining clays overlying more permeable subsoil layers. They are a disposal mechanism only and provide no treatment. Deep bores are typically no deeper than 6 m and are a high-risk method for disposal of because it is difficult to determine the impact on groundwater or surface waters.

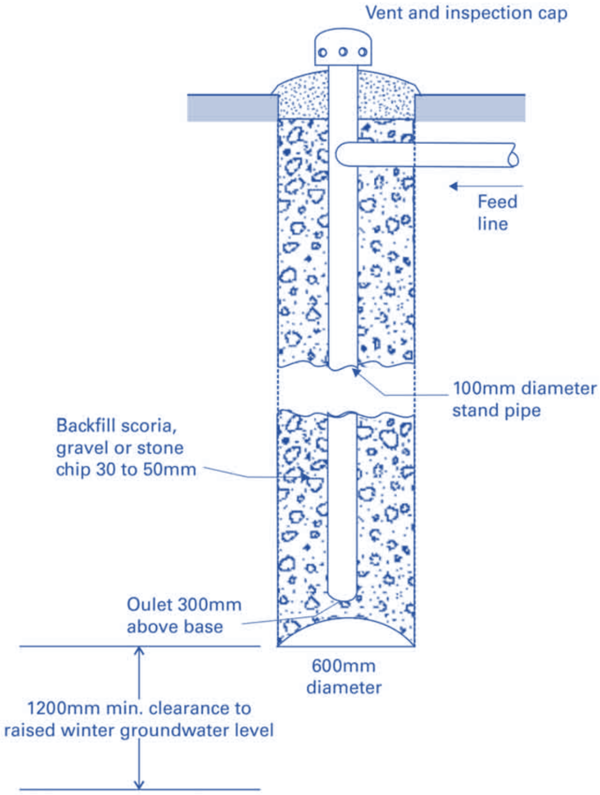


Figure 15: Example of deep bore

E1.1.4.2 Spray irrigation

Irrigated effluent is advanced secondary treated and disinfected prior to being sprayed by sprinklers over soil or a vegetated area. Effluent is sprayed at a low rate and generally relies on evaporation to enhance the system's treatment ability. Stringent bacterial effluent quality standards apply to spray-irrigated wastewater.

Spray irrigator heads are no greater than 500 mm above the finished irrigation surface and wetted diameters for each spray head are no greater than 2000 mm. Spray irrigation systems are not recommended due to their higher environmental and public health risks. Extreme care is required when determining the areal loading rate and where to locate the irrigation area to avoid runoff to surface water or contamination of cultural sites. Other design considerations include:

- Wet weather storage to manage irrigation during rainfall
- Wind exposure, aerosol formation and spray drift
- Setback distances from property boundaries
- Exclusion of public access to the irrigation area.

E1.2 Design loading rates and design irrigation rates

The recommended maximum design loading rates (DLR) or design irrigation rates (DIR) are provided in Table 35 and are dependent on soil and site constraints, and the quality of treated effluent (i.e. it is recognised that secondary effluent may be loaded at higher rates than primary treated effluent as for a given soil the long term acceptance rate is improved via the higher quality effluent). Table 35 is not to be used for detailed design; it is provided as an aid to design planning and selection of a land application system ahead of detailed design.

A conservative approach should be used when designing the land application area, and the maximum recommended loading rates should only apply where there are no soil and site constraints.

Recommended DLR and DIR values for use in detailed design are provided in the following sections:

Trenches	Section E1.3.2 and Table 51
Beds	Section E3.2.1 and Table 52
ETS beds	Section E3.2.2 and Table 53
Irrigation (PCDI)	Section E2.2.2.1 and Table 44
LPED	Section E2.3.2 and Table 48
Mounds	Section E3.3.2 and Table 54
Bottomless sand filters	Section E1.1.3.1

Table 35: Soil categories and recommended maximum design loading rate (DLR) or design irrigation rate (DIR) for treated wastewater land application

Soil category [Note 9]	Soil texture	Soil structure	Indicative permeability K_{sat} (m/d)	Recommended maximum design loading rate (DLR) or design irrigation rate (DIR) – mm/day								
				Trenches [Note 7]		Beds [Note 8]		ETS beds and trenches	Subsurface and surface irrigation (e.g. PCDI)	LPED irrigation	Mounds	Bottomless sand filter
				Primary treated effluent	Secondary treated effluent	Primary treated effluent	Secondary treated effluent					
1	Gravels and sands	Structureless (massive)	>3	20 [Note 1]	25 [Note 1]	16 [Note 1]	20 [Note 1]	Not advised	5 [Note 4]	Not advised	24	70
2	Sandy loams	Weakly structured	>3	20 [Note 1]	25 [Note 1]	16 [Note 1]	20 [Note 1]	Not advised	4 [Note 4]	4	24	Not advised
		Massive	1.4 – 3	15	30	12	24		4 [Note 4]	3.5	16	
3	Loams	High/moderate structured	1.5 – 3	15	30	12	24	15	4 [Note 3]	3.5	16	
		Weakly structured or massive	0.5 – 1.5	10	30	8	24	12	4 [Note 3]	3.5	16	
4	Clay loam	High/moderate structured	0.5 – 1.5	10	30	Not advised	15	12	3.5 [Note 3]	3	Not advised Note 2	
		Weakly structured	0.12 – 0.5	6	20		Not advised	8		3		
		Massive	0.06 – 0.12	4	10		Not advised	5		3		

Soil category [Note 9]	Soil texture	Soil structure	Indicative permeability K_{sat} (m/d)	Recommended maximum design loading rate (DLR) or design irrigation rate (DIR) – mm/day								
				Trenches [Note 7]		Beds [Note 8]		ETS beds and trenches	Subsurface and surface irrigation (e.g. PCDI)	LPED irrigation	Mounds	Bottomless sand filter
				Primary treated effluent	Secondary treated effluent	Primary treated effluent	Secondary treated effluent					
5	Light clays (non-swelling)	Strongly structured	0.12 – 0.5	5 [Note 2]	12 [Note 2]	Not advised	Not advised	8	3 [Note 3]	2.5 [Note 5]		
		Moderately structured	0.06 – 0.12	Not advised	10 [Note 2]			5		2.5 [Note 5]		
		Weakly structured or massive	<0.06		8 [Notes 2 & 6]			5 [Note 6]		2.5 [Note 5]		
6	Medium to heavy clays. Swelling clays.	Strongly structured	0.06 – 0.5	Not advised	Not advised	Not advised	Not advised	Not advised	2 [Note 4]	Not advised		
		Moderately structured	<0.06									
		Weakly structured or massive	<0.06									

(Adapted from: AS/NZS 1547:2012)

Notes:

1) Conventional trenches or beds are not advisable for Category 1 to 2 soils when indicative permeability is greater than 3 m/d. The land application systems in these soils require design by a suitably qualified and experienced person, using special distribution techniques such as discharge control trenches and beds (Section E3.1.3).

2) Special design requirements and distribution techniques or soil modification may be necessary to allow use of these soils for wastewater land application. The effluent loading rate should be based upon soil permeability testing results.

3) PCDI systems should be installed at a depth of 100-150 mm into good quality *in situ* or imported topsoil of depth 250 mm for all soil categories. Alternatively, these may be pegged to the ground in areas of densely established vegetation and covered with leaves or mulch.

4) For Category 1 soils, recommended PCDI design irrigation rate (DIR) is 5 mm/d, into 250 mm good quality topsoil. If further groundwater protection is required, the DIR may be reduced to 4 mm/d or 3 mm/d as a risk reduction measure. For Category 2 soils the drip irrigation system should be installed within an adequate depth of topsoil (minimum 250 mm of *in situ* or imported topsoil) to slow the soakage and assist with nutrient reduction.

   For Category 1, 2 and 6 soils, drip irrigation systems should be installed at a depth of 100-150 mm, within good quality topsoil.

5) For Category 5 soils, the LPED irrigation system requires a minimum depth of 250 mm good quality topsoil. Covering of tree roots should be avoided where surface trickle irrigation is used and topsoil has to be imported.

6) If K_{sat} < 0.06 m/d, a full water balance for the land application should be used for sizing trenches or beds (refer to AS/NZS1547:2012 Appendix Q for the indicative methodology of water balance calculation).

7) The listed figures in these columns are recommended maximum DLR for trenches, including conventional trenches, discharge control trenches, shallow trenches and deep trenches.

8) The design loading rate for beds is recommended to be approximately 75 - 80% of the trench DLR due to limited sidewall to bottom area ratio for beds.

9) Refer to Section B4.4 Soil category selection for design.

E1.3 Calculating the land application area

Table 36 indicates the methods used for calculating the area requirements for commonly installed land application systems.

Table 36: Summary of design area calculation methods

Land application system	Design area calculation method
Pressure compensating drip irrigation (PCDI)	Areal loading
Low pressure pipe (LPP) / Low pressure effluent distribution (LPED) irrigation systems	Areal loading
Beds (conventional / ETS)	Basal loading
Mounds [Note 1]	Basal loading
Shallow trenches	Basal loading
Discharge control trenches [Note 2 & Note 4]	Basal loading
Deep trenches [Note 3]	Sidewall loading

Notes:

1) Mound design loading includes design loading rate for the distribution area on top of the sand media as well as the design loading rate for the basal area for the sand media on the natural ground surface.
2) Discharge control trenches to be used for Category 1 soils.
3) Deep trenches are only suitable for Category 2 soils.
4) Conventional trenches are not suitable for Category 1, 5 and 6 soils.

E1.3.1 Sizing of land application area

For conventional land application systems, trench and bed lengths are calculated using (Equation 1) below. The horizontal bottom (basal) area must be used to determine the length of trench or bed required. Note that the width does not include the sidewall area (sidewall area loading is only used for deep trenches).

$$L = Q/(DLR * W) \quad \text{(Equation 1)}$$

Where:

L	-	The trench or bed length (m)
Q	-	The design daily flow (L/d)
W	-	The width of the trench or bed (m)
DLR	-	The design loading rate (mm/d) indicated in Table 51 and Table 52

For shallow irrigation systems, the irrigation area is calculated using (Equation 2). The three loading area determination methodologies (i.e. areal loading, basal loading and sidewall loading) are detailed in Sections E1.3.2 to E1.3.4.

$$A = Q/DIR \qquad \text{(Equation 2)}$$

Where:
- A - The area of irrigation land where the driplines or LPED lines are to be installed (m^2)
- Q - The design daily flow(L/d)
- DIR - The design irrigation rate (mm/d) determined in Table 44 (PCDI and Table 48 (LPED)

Note: The design irrigation rate is an areal loading rate over the entire land application area. The actual loading rate at the individual points of discharge (drip emitters or LPED lines) will be considerably higher than the design irrigation rate.

E1.3.2 Areal loading

The areal loading concept comprises the entire irrigation area including the area between the distribution lines and within the topsoil to maximise evapotranspiration and seepage. The aim is to distribute treated wastewater over the entire area available for assimilation by the soil. Areal loading is used to calculate land application area requirements for PCDI systems and low pressure pipe (LPP & LPED) irrigation systems (Section E2.2 to E2.4).

The land application area and linear length of lines can be calculated as outlined in Table 37. Note that the designer must adjust area and/or linear length of irrigation lines where the irrigation line spacing is not equal to 1 m.

Table 37: Areal loading area calculation

Areal application area calculation				
Design land application area (m^2)	=	Maximum daily wastewater flow (L/day) / Design irrigation rate (DIR) (mm/d)		
Design example				
Design land application area of 140 m^2	=	700 L/d / 5 mm/d		
Linear length of lines required for 140 m^2 land application area at 1 m centres				
Lines at 1 m centres (within a 140 m^2 application area)				
140 linear metres	=	140 m^2/1 m	=	140 linear metres
Lines at 0.5 m centres (within a 140 m^2 application area)				
280 linear metres	=	140 m^2/0.5 m	=	280 linear metres
This is twice the linear length to achieve the 5 L/m^2/day areal loading rate				
Lines at 1.5 m centres (requires a 210 m^2 application area to achieve the minimum of 140 linear metres of line)				
Effective irrigation area	=	140 m^2 x 1.5	=	210 m^2
140 linear metres requires an area of 210 m^2				

The zone of influence (or loading area) is taken as 500 mm either side of the dripline, with emitters spaced at 1 m intervals. For each metre of line, a 1 m^2 area is provided to absorb and infiltrate the daily dose of effluent. A more effective coverage of the soil absorption area can be achieved by decreasing the dripline spacing to 500 mm, thereby doubling the dripline length required and this doubling the number of emitters covering the design area (with the daily flow per emitter thus halved).

Where driplines are installed on sloping ground, the zone of influence is taken as 1 m downslope from each line. It is normal practice to allow greater dripline spacing on steeper slopes to allow for downslope seepage of effluent between lines, particularly during rainfall events. Spacing of 1.5 m is typical. Given the zone of influence is only 1 m, then the overall area within which the driplines are installed is increased by 50%. Design irrigation rates may be decreased for sloping ground to ensure adequate effluent uptake within topsoil and plant root system.

E1.3.3 Basal loading

The design land application area only comprises the basal area of the trench, bed or mound, excluding the area between the trenches/mounds/beds. The design loading rate is based on the soil category and site constraints (refer to Table 51 [trenches], Table 52 [beds], Table 54 [mounds] and Section B5.1). The land application area required for basal loading is calculated according to Table 38.

Table 38: Basal loading area calculation

Basal application area calculation		
Basal application area (m^2)	=	Maximum daily wastewater flow (L/day) / Design loading rate (DLR) (mm/d)
Design example		
Basal application area 70 m^2	=	700 L/d / 10 mm/d

E1.3.4 Sidewall loading

Sidewall loading is only used for the design of deep trenches within free-draining Category 2 soils (Section B5.1 and Table 39) where there is a winter groundwater separation of at least 1.2 m below the base of the trench. The design soakage area only includes both sides of the trench.

Table 39: Deep trench sidewall loading area calculation

Deep trench sidewall loading design		
Sidewall area required (m^2)	=	$\frac{\text{Maximum daily wastewater flow (L/day)}}{\text{Design loading rate (DLR) (L/m}^2\text{/d)}}$
Total trench length required	=	$\frac{\text{Sidewall area (m}^2\text{)}}{\text{Available sidewall depth (m) x 2}}$
Design example		
Sidewall area required 35 m^2	=	$\frac{\text{700 L/d}}{\text{20 L/m}^2\text{/d}}$
Total trench length required 17.5 linear metres	=	$\frac{\text{35 m}^2}{\text{1 m x 2}}$

Note: The trench depth is multiplied by 2 because both sides of the trench provide an infiltrative surface and therefore halving the total length of trench required.

E1.4 Design of dosing and distribution systems

Following treatment, wastewater is discharged to surface and subsurface land application systems either by a pressurised (on demand or controlled) distribution method in doses or by a gravity (uncontrolled) distribution method. The dose loading, distribution options and common system components are summarised in Table 40, with detailed information for each component provided in the following sections.

The key performance requirement for the distribution system is that it be designed to accept the discharge from the wastewater treatment unit and to convey it securely and evenly to the land application area (AS/NZS 1547:2012).

The selection of the most appropriate method for discharging wastewater from the wastewater treatment unit to the land application system can be determined from Sections E1.4.1 - E1.4.2.

Table 40: Common dose loading and distribution methods

Dose loading method	Distribution method				Common distribution system components
	PCDI (pressurised distribution) [Note 1]	LPED (pressurised distribution) [Note 2]	Distribution box (non-pressurised distribution)	Drop box (non-pressurised distribution) [Note 3]	
Controlled Pump • On demand • Timer-controlled [Note 4] Siphon • On demand Floating outlet • On demand	Pressure compensating drip emitters are welded within small diameter plastic pipelines. All driplines must be installed according to manufacturer's specifications. Refer to Section E2.2 for detailed design and construction methodology and criteria for PCDI systems.	LPED is widely used for free-draining soils. A perforated small diameter pipe is inserted within standard drain coil distribution lines in trenches. Use of timer-controlled pressure dosed automatic sequencing valves ensures uniform loading of the distribution pipe network. To ensure even distribution across all lateral pipework, refer to Section E1.4.2.3 and Appendix M for the calculation methodology for sizing and spacing the discharge orifices. All distribution lines should be capped to allow maintenance flushing.	This becomes a flood distribution method when tipping bucket, floating outlet chamber, pumps or siphons are utilised for wastewater loading. Treated effluent is pressure-loaded (by either a pump or a siphon) into a distribution chamber (distribution box), followed by gravity flowing onto various sections of the land application area. Usually, the manifolds are at the same level; so that each trench or bed lateral receives a relatively equal loading. General design settings: • Dosing frequency: 5-6 doses/day • Maximum length of distribution laterals: 12-15 m • Diameter of distribution pipes:100 mm.	Used on sloping sites (>5.7° or 10%) so that treated effluent can be directed to the distribution pipes parallel to site contours. Can be pump- or siphon-loaded if the top drop box is up-slope of the wastewater treatment unit. Due to the fact that downslope application areas only receive wastewater load when the uphill section is flooded, this distribution method causes uneven loading and has a higher potential of overloading uphill sections and may destabilise the uphill soil. Some designs can mitigate this by providing inlets controls to enable resting of uphill trench sections and using downhill trenches on an alternating basis.	Automatic sequencing valve Distribution manifold Distribution box Manual diversion valves Drop box Serial loading pipework (superseded by drop box loading) Distribution pipework • PCDI • LPP • LPED • Perforated PVC drain line • Drain coil Distribution aggregate Gravelless systems • Proprietary polyethylene • PVC vault • Textile wrapped distribution pipes
Uncontrolled On demand Trickle gravity (Note 5]	Not applicable	Not applicable	Applicable	Applicable	

Notes:

1) Only secondary treated effluent, or better, followed by a disc filter (minimum 120 µm) can be applied with PCDI systems to prevent blockage. Dripline products are available which are designed to handle more contaminated water but require more maintenance.
2) LPED is preferable for dose loading trench systems in Category 1 soils (discharge trenches) and Category 2 soils (conventional trenches), where the indicative permeability K_{sat} > 3 m/d.
3) Drop box loading supersedes serial distribution. As a method of uneven distribution applied on sloping sites, serial distribution is currently not considered best practice.
4) Timer-control involves incorporating a programmable timer to activate the pump on a timed basis to distribute wastewater doses equalised over an entire day.
5) Refer E1.4.1.1.

E1.4.1 Dosing methods and devices

E1.4.1.1 Uncontrolled trickle loading

Uncontrolled trickle flow by gravity is to be avoided wherever possible in modern on-site wastewater practice. Dose loading is by far the preferred method. However, gravity trickle loading may be used where there is insufficient head difference between the septic tank and the land application area for a floating outlet or siphon to operate and where there is no power for a pump. The disadvantage of gravity trickle loading is that wastewater may not be distributed across the entire design area and in well-drained soils the application of septic tank effluent can result in creeping[3] failure.

E1.4.1.2 Controlled dose loading

Methods for operation of a controlled dosing device are either on-demand or timer-controlled; timer-control is the most effective and preferred method.

On-demand dosing systems are siphon-operated, floating outlet-operated, or pump-operated by float switch. In all cases, wastewater doses to the land application system are concentrated around the time of wastewater production when the wastewater level has built up in the treated wastewater dosing tank. On-demand dose loading may potentially result in saturated conditions and inferior treatment.

Timer-controlled dose loading allows the discharge of an equal volume at pre-set time intervals over 24 hours. Wastewater produced at peak production times during the day is buffered and discharged evenly over the day. This allows more effective control of unsaturated conditions in the infiltrative surface and underlying soil, thus reducing the rate of infiltrative surface clogging and improving in-ground treatment (USEPA, 2002).

[3] Creeping failure" occurs when gravity trickle loading results in progressive "clogging" of infiltration surfaces from build-up of biomat slime growths. This may be managed by alternating loading and resting cycles amongst the individual trenches.

E1.4.1.3 Controlled dose loading methods and devices

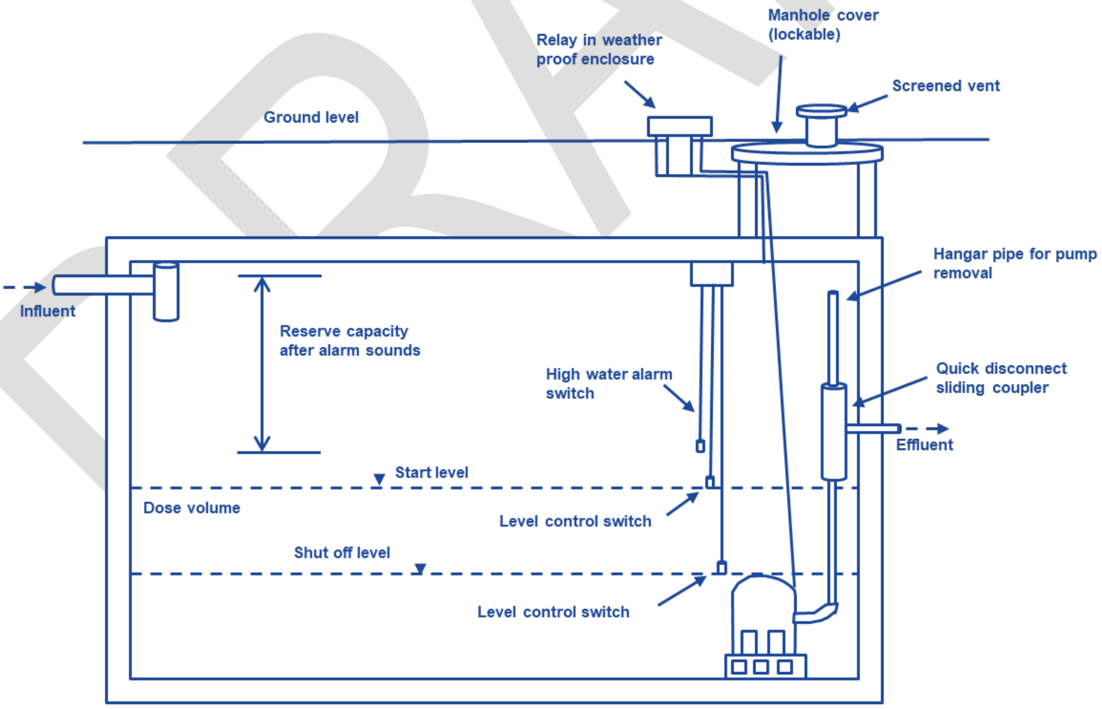
Discharging a controlled dose volume, by pump or siphon, allows for the wastewater to be distributed along the entire length of the distribution line and across the entire infiltrative area with each dose. This allows for more effective treatment by utilising the entire infiltrative surface and not overloading a small area of it, which could result in creeping failure. Additionally, the greater the number of doses, and the more evenly they are spread over a 24-hour period, the more evapotranspiration and renovation of wastewater by the receiving soils will be enhanced. In free-draining soils, dose loading can limit the potential for development of creeping failure commonly associated with gravity-trickle loading. The advantages of dosed systems outweigh the perceived disadvantages of additional mechanical devices (USEPA, 2002).

Pump-controlled loading

Pump-controlled dose loading is preferable to siphon-dosed loading as the volume and timing of the dose can be readily controlled to best suit the distribution and land application system.

Pump chamber

A typical layout of a dosing chamber with pump is shown in Figure 16. Any pump chamber associated with a septic tank, aerated treatment plant, sand filter dosing chamber, recirculation tank or treated wastewater holding tank, should include 24 hours of emergency storage above the high-water level alarm. Emergency storage is required to provide sufficient time to rectify a problem in the event of mechanical or electrical failure. Failure to provide sufficient emergency storage can result in an unauthorised overflow of wastewater.



Note:

1. Pump chambers shall be sized to provide a minimum of one day's design flow storage above the alarm level or duplex pumping system with audible or visual alarms shall be used in lieu of a single effluent pump and one day's reserve capacity.
2. Pump chamber shall be equipped with an audible and visual alarm to indicate malfunction. Alarm should be in an accessible and conspicuous location in the home.
3. The use of manually operated siphons or pumps is not acceptable.

Figure 16 Typical dosing chamber with pump

(Source: National Small Flows Clearinghouse 1998)

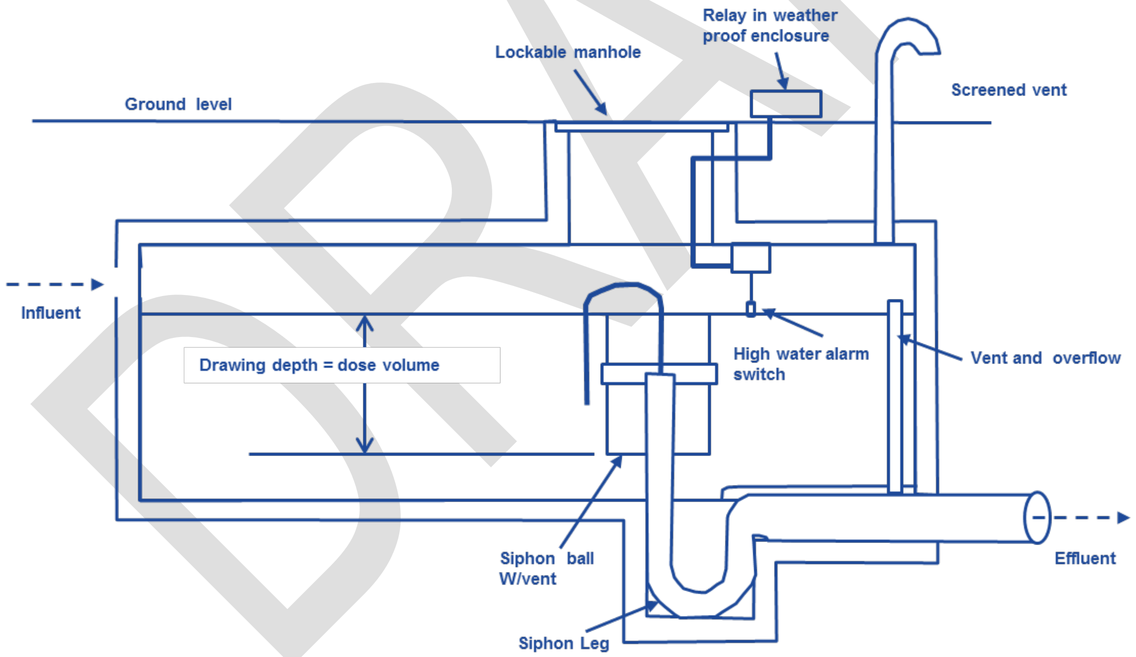
An acceptable substitute to emergency storage in an individual pump chamber is the provision of gravity overflow to another chamber, which contains additional emergency storage capacity.

Pump chamber alarm systems

All pump chambers should include a high-water level alarm, which activates in the event of the water level rising above the design working volume in the pump chamber. There are several float switches or probe systems available to activate alarms. The alarms may be audible or visual. Audible alarms have the advantage that they are noticed and acted upon at an early stage whereas visual alarms can be easily missed, resulting in a concentrated discharge from the chamber.

Siphon-controlled loading

Siphon-controlled loading is suitable where there is sufficient height difference between the tank outlet and highest line of the downslope land application system for the siphon to operate. A typical layout of a dosing chamber with siphon is shown in Figure 17. Siphon-controlled dose loading provides for a set volume of treated wastewater to be discharged to the land application system. However, treated wastewater can only be dosed on demand and can still result in overloading of the land application system infiltrative surface. Where sufficient head is available to operate a sequencing valve, the impacts from siphon-controlled demand dose loading can be reduced by sequentially loading a series of beds or trenches.



Note:
1. Dosing is recommended for all systems as it promotes better treatment of wastewater and system longevity.
2. Use of manually operated siphons or pumps is not acceptable.
3. The volume of effluent in each dose should be 5 to 10 times the volume in the pipe network
4. The siphon chamber must be equipped with an audible/visual alarm to indicate malfunction. The alarm should be in an accessible and conspicuous location.
5. Pipe for siphon dosing is sized to conform with the volume of the dose.

Figure 17: Typical dosing chamber with siphon

(Source: National Small Flows Clearing House, 1998)

Controlled flood distribution by pump, siphon or floating outlet

Controlled flood loading comprises of dosing by siphon, pump or floating outlet discharge to a distribution box, for subsequent gravity flood flow to all, or to selected, sections of the land application area.

To be effective, the siphon or floating outlet chamber or the pump sump should be sized to break the daily design maximum flow into a minimum of at least five to six doses per day. The distribution box should be designed to handle flow volumes delivered with each dose, and to ensure effective loading of the whole or selected sections of the land application system.

The length of the subsurface distribution lines should be limited to ensure even distribution and to prevent potential for the dose cycle to overload the front sections of the land application system and under loading of the end sections. Maximum suggested distribution line lengths are 12 to 15 m for effective loading and should provide reasonable distribution where 100 mm perforated distribution lines are used. Hydraulic characteristics for both siphons and pumps will be available from the manufacturers to assist with equipment selection and system design.

E1.4.2 Distribution methods and components

Where alternating effluent loading is proposed (into either individual sections of a land application system, or into duplicate systems on a load and rest cycle), then proprietary automatic or hand-operated units are available to switch flow between sectors in accordance with the management plan for the system.

E1.4.2.1 Alternation of loading and resting

The use of distribution boxes or diversion valves, in either gravity or pressurised application systems, enables sections of the land application system to be rested, as required, by diverting flow to portions of the system on an alternating basis. This will temporarily overload the loaded section of the land application area resulting in an elevated daily loading rate, unless the system has been designed with excess capacity to allow for alternating loading without a daily exceedance of the design application rate.

The resting of a section of a subsoil soakage land application system (such as trenches and beds) will only benefit the system’s long-term acceptance rate if the rested section fully drains and dries out during each rest period. The rest period in a free-draining system will enable rejuvenation of the infiltrative surfaces by aerobic action and drying. On resumption of loading, the system will then operate at higher infiltration rates than before the rest period. These infiltration rates will then progressively, but slowly, decrease over the next operational period as clogging slimes build up again on the infiltrative surfaces.

Resting has no value in non-free draining soils that remain waterlogged or only slowly drain during the rest period. Not only is resting not applicable in such situations, but the type of land application system and/or loading rate should be reconsidered (refer to Section B5.1 for discussion on constraints of subsoil types on land application system selection). Systems using soakage and evapotranspiration rather than purely subsurface soakage application systems are more appropriate in such conditions.

Subsoil soakage systems, which are designed to operate without periodic resting and rejuvenation, do so at a long-term acceptance rate associated with continuously flooded conditions. In slow draining soils, such systems could benefit from having duplicated land application areas (each designed for 100% of design flows) where resting may take place on 6-month or 12-month cycles.

E1.4.2.2 Common distribution system components

Distribution manifolds

Distribution manifolds are utilised for pressure-dosing of laterals feeding individual lines or sectors of a land application system. Careful design of both the manifold and the laterals is required to ensure that uniform dose loading of the system is achieved (see Section E1.4.2.3 below).

Automatic sequencing valves

Where sufficient head and flow rate from pump- or siphon-controlled dosing is available, automatic sequencing valves can replace distribution manifolds, ensuring equal flow distribution is achieved to a set of parallel trenches or beds. The hydraulic design of distribution manifolds has to be supported by careful installation and fine-tuning during commissioning testing to confirm equal loading of all elements of the system. Automatic sequencing valves, by their design and operation, provide an advantage over reliance on distribution boxes.

Sequencing valves with two, four, or six outlets, switch automatically at pump start-up, or under build-up of siphon discharge flow pressure. This allows each distribution line or sector to be dose loaded separately and in sequence, with a predetermined dose volume. Division of controlled doses to each sector allows for better control over dose volumes allowing for smaller doses to a number of sectors instead of one large sector and therefore the use of smaller pumps as the volume per dose is reduced.

Head and minimum flow rate requirements, needed to trigger sequencing valve rotation, should be confirmed with the manufacturer or supplier. Depending on the sequencing valve spring pressure, a head of 4 to 6 m is likely to be required in addition to the distribution system pump head. A full-scale operational trial should be undertaken with clean water (i.e. cold commissioning) during construction and installation, to confirm sequencing performance of the unit. An important design requirement for siphons is that the feed line from the siphon outlet to the sequencing valve has a capacity at least equal to the dose volume. If not, flow may back up in the discharge line and interrupt siphon action before the dose cycle is completed, prompting the siphon to cease dosing operation and trickle continuously.

Distribution boxes

There is a range of layouts for gravity loading (trickle or flood). For gravity trickle distribution, or pump-dosed distribution, various proprietary fittings are available to enable the adjustment of outlet levels to ensure even distribution to each line.

Drop box

The drop box method only works on sloping sites greater than or equal to 5.7° (10%) as it operates based on incremental loading via gravity flow to a series of trenches or beds. It is generally less favoured due to the preferential loading of the uppermost trench, potentially leading to creeping failure of the system. The preferred method of loading is pressure-dosing via pump through sequencing valves or manifolds to ensure even distribution over the full design surface (see Section E1.4.1.3 above).

The top drop box can be either gravity-fed (direct from the wastewater treatment unit), or pump-loaded (where the land application area is located up-slope of the wastewater treatment unit). Controlled dose loading is the preferred method to feed treated wastewater to the drop box. The inverts of all outlets within each drop box should be at the same elevation to ensure even distribution and should be at least 50 mm above the bottom of the drop box to reduce solids carryover and prevent short-circuiting.

Each section of the land application system (either trench or bed) is kept flooded at a predetermined level at the system's long-term acceptance rate. In relatively free-draining soils with higher long-term acceptance rate values, this means the top section of the land application area can be maintained under continuous load for long periods. Other sections downhill do not come into operation until overflow takes place from the uphill section. The land application system can be modified to cope with seasonal variations in subsoil soakage rates and evapotranspiration rates by increasing the number of downslope sections of the land application area during the winter wet periods, and subsequently reducing the proportion of the area used during summer drying conditions. The drop box configuration allows shutdown of any section of the land application area (e.g. trench or bed) for resting, and it is thus practical to rest the upper section during summer while bypassing flows to the lower portions, which are least frequently in operation.

A reserve area should be provided downslope of the land application area to enable extension of the drop boxes and land application area as required, and then resting the original upslope land application system.

E1.4.2.3 Distribution pipes

The pipe work in a surface or subsurface distribution system will generally comprise sealed feed lines leading from the distribution system to connect to the perforated distribution lines within the land application area. Careful design and installation of the whole land application system is crucial to ensure that the design area is uniformly loaded.

It is important that sealed feed lines are not constructed through trenches or beds, since this provides a potential channel for short circuiting of effluent from upslope areas to downslope sections of the land application system and the lower end of the main distribution pipe trench. All distribution pipes should be end fed as shown in Figure 18.

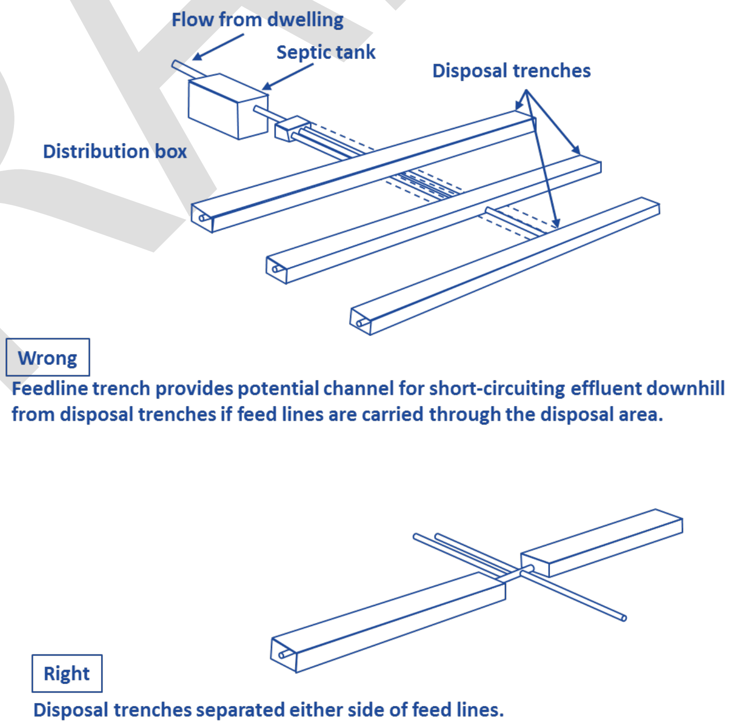


Figure 18: Effluent distribution

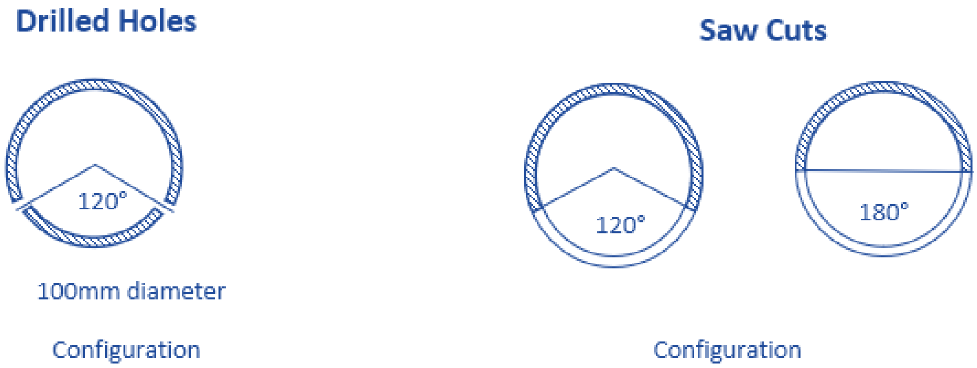
The performance of a trench or bed land application system is controlled by the effectiveness of the distribution system.

Pressure compensating drip emitter distribution

Proprietary drip emitter systems are a favoured method for both surface and subsurface irrigation distribution (as discussed in Section E2.2).

Perforated PVC drain lines

Perforated rigid PVC pipe is used as an alternative to drain coil, and for many authorities is the preferred distribution method for gravity trickle/flood loading. Perforations may be either drilled holes or saw cuts. Figure 19 gives details of sizes to meet a 2% surface area requirement[4].



Size	Spacing
12 mm diameter	35 mm
20 mm diameter	100 mm
25 mm diameter	150 mm

Width	Spacing	
6 mm	100 mm	150 mm
8 mm	130 mm	200 mm

Figure 19: Perforation details for distribution lines in rigid PVC

Low-pressure pipe loading (LPP & LPED)

In situations where flood loading is neither practical nor suitable (e.g. in Category 1 and 2 soils), a perforated pressure line system loaded by pump or siphon is an alternative for spreading effluent evenly over the full design area. This method is suitable for both free-draining and slow-draining soils. LPP (low pressure pipe) and LPED (low pressure effluent distribution) are essentially the same. The difference between the two is that a LPED pressure line is inserted (nested) within the draincoil distribution line and an LPP line is not, the LPP line consisting of a single pressure line laid within the distribution aggregate.

LPED was originally developed for distribution in free-draining soils where LPP provides ineffective loading of the design basal area due to the spot loading that occurs at each perforation (squirt hole). In converting LPP into LPED by nesting the LPP dose line within the draincoil, the discharge from each squirt hole is then “sloshed” along the draincoil invert to spread relatively evenly along the length of the line. This avoids the spot loading effect of LPP and provides for more effective effluent distribution over the full design basal area.

LPP and LPED are also used as the distribution system for subsurface irrigation of septic tank or secondary treated effluent via LPP subsurface irrigation, LPED subsurface irrigation and LPED surface trickle irrigation (Section E2.3).

[4] The 2% surface area requirement was adopted by an earlier NZ Standard in 1982.

Design of the distribution lines

Distribution lines should be laid within the distribution aggregate along the full length of the land application system element (such as a trench length). To achieve effective distribution, the discharge rate from each orifice must be approximately equal, requiring careful balancing of the head loss and flow rate in each distribution line along with selection of appropriate line diameter, orifice (squirt hole) size and spacing. The base of the land application system must be accurately levelled to avoid low areas where dosed flow could overload and/or pond.

Some designers advocate clay or concrete dams at intervals along the land application system length to counteract any inaccuracies in construction and installation. In any case, a clay or concrete dam is required at the start of each line to prevent short circuiting via the transport line trench.

Sizing the dose volume

The distribution system can be loaded by either of the following methods:

- The entire land application system loaded with each dose via a distribution manifold; or
- Each lateral loaded individually via a sequencing valve.

The size, number and spacing of discharge orifice in each distribution lateral cannot be designed by a 'rule of thumb' if the laterals are to be evenly loaded. When determining the pressure within each lateral, the outlet orifice spacing, and the outlet orifice diameter are crucial for the effective operation of a whole LPP or LPED system. However, the land application system will only load evenly when it is fully pressurised, resulting in overloading of the lowest lateral during pressuring and draining parts of the cycle. Where the land application system is on sloping ground, with each line laid to a different contour, then in addition to a control valve from the manifold to each line, a check (non-return) valve is needed after each control plate to prevent backflow into the main header line and overloading of the lowermost trench. Distribution lines should always be located along the site contours; this is essential in non-pressure compensating and conventional land application systems.

A non-conservative formula for sizing the dose volume is using a minimum dose of ten times the volume capacity of the distribution manifold and laterals. This is required to build up adequate pressure in the distribution system to achieve adequate 1.5 m squirt height from each orifice and thereby uniform wastewater distribution throughout the application field. When determining the pressure within each lateral, the outlet orifice spacing, and outlet orifice diameter is crucial for the effective operation of an LPP or LPED system (Section E2.3).

Where it is proposed to dose load the LPP or LPED system by siphon, the main transport line from the siphon should be sized to ensure open channel flow and maintained as straight as possible. This minimises the potential of an airlock in the transport line and overloading a section of the land application system. The main transport line should also have sufficient volume to prevent backing up of discharge water to the siphon.

If discharge water backs up to the siphon while discharging, it can trip such that trickle discharge occurs and wastewater is concentrated into the distribution trench at the lowest point in the irrigation system resulting in overloading and wastewater breakout.

In situations where the land application system is dose loaded by pump then the operating pressure within each distribution line can be determined using standard hydraulic calculation procedures. Input date for the calculation includes:

- The duty rating of the pump to be used;
- The elevation of pump relative to distribution lines;
- The difference in elevation of each line; and
- The size and friction factors of the feed lines, manifold, distribution lines and squirt holes.

The diameter of distribution laterals is based on the requirement that there is more than a 10% variation in flow between one end and the other. The spacing of squirt holes and the longest lateral length must be determined before selecting the lateral diameter.

Some designers have adopted 5 mm, 4 mm or 3 mm diameter squirt holes. It is important that a squirt height of 1.5 m is achieved at each squirt hole orifice to maximise self-scouring. The hydraulic calculations should be undertaken by design specialists. Commercial computer software programmes are available for such calculations (a worked example is provided in Appendix M). Where the entire lateral network is dose loaded, it is important that each lateral is loaded equally, and the discharge is not concentrated into the lowest trenches. This can be achieved by placing a flow control plate at the start of each lateral. The orifice size can only be calculated when the height of each lateral, length and number of orifices are known to achieve even loading although individual trenches may be of variable length and elevation. A non-return valve at the start of each line ensures the higher elevation laterals do not drain to the lowest laterals between doses and overload the lower lines.

As an alternative to manifold pressure distribution, either each lateral can be loaded individually via an automatic sequencing valve (Section E1.4.2.2), so long as sufficient head is available to trigger rotation, or the entire lateral network can be loaded with each dose. The dose volume for an individual lateral can be based upon the total daily flow divided by the number of laterals. With on-demand pumping controlled by float switches set to the daily dose volume for each lateral, each sector of the land application area (such as an individual trench) receives a single daily dose.

Commissioning

Once the lines are installed, and before they are covered, the distribution system must be fully tested with clean water so that the effectiveness of the dosing system, orifice spacing, and lateral lengths can be determined. Any variation in distribution can then be field-adjusted by altering the hole diameter or spacing, or by adjusting the manifold valves. This is particularly important on sloping sites with several distribution lines at different elevations.

Maintenance

All distribution lines must be capped, or screw plugged with removable end pieces to enable maintenance in case of line blockage. Any growth, which could clog perforations, can be dislodged by scouring using high velocity flow to discharge through the uncapped end and the spent cleaning mixture disposed into a soakhole. The use of oxidising agents, such as bleach, has a detrimental effect on soil bacteria and should only be used as a last resort. Checking for blockage of the orifices can be undertaken by checking the pump pressure at the end of each line. This should be undertaken regularly during the life of the land application system, particularly in response to problems involving uneven loading.

Draincoil

PVC draincoil is manufactured for land drainage purposes. Its use for effluent distribution via circumference drainage slots is the exact reverse of its intended use. It does, however, offer many perforations per unit of surface area, enabling effective distribution of effluent throughout its length. Where sediment blocks any slots, there are ample additional openings; it has been used successfully as an alternative to field tiles since 1976. Proprietary brands of draincoil meet the 2% area requirement for perforations. Some agencies are not satisfied that draincoil is an appropriate distribution method; in such cases use of perforated PVC rigid pipe would be the preferred distribution method.

E1.4.2.4 Trench and bed distribution aggregate

Graded aggregate (granular media) comprising durable material is required to support distribution lines and enable spread of the treated effluent over the design surface area within the land application system.

AS/NZS 1547:2012[5] (Standards Australia/New Zealand, 2012) recommends 20 mm to 40 mm aggregate size. The design loading rates recognise that the aggregate itself creates a shadow effect on both the bottom area and sidewalls where individual aggregate elements rest against the soil. Hence the design infiltration area is effectively reduced by the coverage of the soil surface by aggregate with only exposed portions of the soil enabling direct infiltration. This reduction in infiltration surface area is taken into account via the redundancy built into the DLR values.

If the aggregate size is smaller than the standard, the biofilm (bacterial slime generated by soil bacteria interaction with the organic matter in the effluent) can clog at depth into the media. Distribution aggregate must be totally free of fines or dust that can coat the base of the design area and reduce the soil infiltration capacity. Aggregate should be of high quality and washed before placement.

5 AS/NZS 1547:2012 Australia/New Zealand Standard *On-Site Domestic Wastewater Management*

E1.4.2.5 Gravelless trench systems

Vaulted trench distribution

Polyethylene vault systems, which provide airspace over the horizontal infiltrative surface have either slotted sidewalls that shelter the effluent distribution slots from surrounding soil or have a surrounding aggregate backfill to protect against potential soil blocking of the openings.

Inspection ports enable access to determine development of clogging mats on the horizontal infiltration surface and with careful design, sections can be removed to allow access for raking the infiltrative surface. Gravity trickle loading into vault systems can lead to progressive failure in free-draining soils; hence controlled loading via the LPP or LPED line should be installed within the vault. In other soils, loading by pump or siphon can ensure that incoming flows are routinely distributed fully over the infiltrative area.

PVC vaults

An alternative to vaulted trench distribution is a large rigid PVC pipe cut in half lengthwise, placed in the trench and covered over with soil. Treated wastewater is distributed along the trench within the PVC vault by the LPP method.

Other proprietary systems

Textile-wrapped gravelless pipe systems are also available. These need to be designed and installed according to manufacturer's instructions. A combined treatment and dispersal system (E1.1.3) utilises a textile wrapped pipe designed to provide in-pipe treatment prior to infiltration through sand trench or bed into the subsoil.

E1.4.3 Water diversion

Groundwater and surface water flows should be diverted away from land application areas. Groundwater cut-off drains should be of an adequate depth to control groundwater movement. Care is needed to avoid subsurface short-circuiting of wastewater into the groundwater cut-off drain. Surface water collectors should be either grassed swales or half tiles which capture overland flow and divert it away. However, limitations imposed by perched water tables or poorly drained soils may not be solved through the installation of subsoil groundwater cut-off drains.

E1.5 Planting

It is essential to select appropriate plant species for land application and reserve areas. Plants should be selected that can cover the entire land application area with maximum transpiration capacity and be tolerant of moist conditions. Planting should consider the following:

- Intensive planting for land application and reserve areas located on slopes
- The effects of roots from plants on wastewater distribution pipe networks/emitter lines in land application systems. This is particularly relevant to large tree species
- Planting plans should accommodate future maintenance needs of the area including pruning, vegetation removal, mowing, etc.

- In many instances, grasses will provide sufficient evapotranspiration for a well-designed land application system (Table 41). Other plant options are provided in Table 42 and Table 43.
- All native plants should be ecosourced to the correct Auckland ecological district.
- Any non-native plants selected should not be classified as a pest or unwanted organism.
- In all cases, consideration should be given to the size of any species at maturity and should only be used only in spaces where their root systems will not impact the function of the on-site wastewater system.

Table 41: Grasses (non-native)

Botanical name	Common name	Notes
Paspalum dilatatum	Paspalum	Short, stout rhizomes which join grass together in dense clumps, tolerant of extreme wet and dry conditions.
Cynosurus critatus	Crested dog tail	Thrives in a variety of soils.
Holcus lanatus	Yorkshire fog	Suitable if wet regularly, tolerant of a variety of soils and temperatures.
Schedonorus arundinaceus *Schedonorus phoenix*	Tall fescue	Large, rhizomatous, grows in wet and tolerates drying.

Table 42: Ground covers and other plants (native)

Botanical name	Common name	Notes
Carex	Maurea	Grows in naturally in damp, wet areas and prefer light shade. They are vigorous in moist conditions. The following species have been identified for their suitability: • *C. dissita:* Tolerates swampy habitat and also noted to grow on drier soils • *C. flagellifera:* Prefers damp soils and full sun, can thrive in boggy conditions • *C. geminata:* Thrives in a range of wet habitats. Suitable for a larger area • *C. lessoniana:* Robust and vigorous spreading species suitable for a larger wet area • *C. secta* (purei, makura): Grows up to 3 m tall, widespread in swampy areas. • *C. virgata:* Does well in swamps, drain margins, seepages and wet pastures.
Austroderia fulvida (Formerly Cortaderia)	Toetoe kākaho	Branching from the base and forming a clump to 4 m high. Prefers good drainage and semi-shade. Will struggle to compete if dried out in summer.
Cyperus ustulatus	Coastal cutty grass upokotangata	Vigorous leafy sedge growing to 1 m in open damp places. Tolerates immersion in standing water within a range of habitats from seepage to wetlands.
Dicksonia squarrosa	Whekī	Tree fern up to 7 m tall that exhibits tolerance of wet open ground, and floods. Useful applications to streambank and seepage habitats.

Botanical name	Common name	Notes
Elatostema rugosum	Parataniwha	Herbaceous plant up to 0.5 m tall that spreads by rhizomes. Bronze coloured foliage with serrated edge. Grows on moist sites in light to heavy shade. Will not tolerate drying or full sun.
Parablechnum minus	Swamp kiokio	Robust fern growing to 0.5 - 1 m; hardy species that tolerates most conditions, prefers a moist site in either full sun or full shade.
Phormium tenax	Harakeke kōrari	Fast growing clump-forming flax with large leaves. Full exposure and sun. Moist to wet conditions. Does not have deep or wide roots.

Table 43: Trees and shrubs

Botanical name	Common name	Notes
Brachyglottis repanda	Rangiora	Typically grows to 3-4 m high.
Carpodetus serratus	Putaputawētā (Marbleleaf)	Lowland forest tree typically grows 3-5 m tall.
Cordyline australis	Tī kōuka (Cabbage tree)	Typically grows between 4 and 8 m tall, widely branched and tall straight trunk.
Coprosma areolata	Aruhe (Thin-leaved coprosma)	Grows to 4 m tall. Low drought tolerance, with medium to high fertility needs.
Coprosma robusta	Kāramuramu (Shining karamu)	Shrubs or small trees which can grow above 3 m. Hardy plant.
Geniostoma ligustrifolium	Hangehange	Grows to 2-3 m. Looks best in sunny position where it retains a bushy habit. Prefers well-drained soil; not for the wet feet in evaporation bed.
Hebe stricta	Koromiko	Shrub or small tree growing to 2-5 m in height. Plant in full sun. Tolerates exposure.
Leptospermum scoparium	Mānuka	Shrub or small tree which can grow over 4 m in height. Provides shelter for other plants. Quick growing and hardy. Prefers full sun and tolerant of difficult conditions, including waterlogging and drought.

Detailed design for land application systems

E2.0 Shallow irrigation systems design

E2.1 Overview

Shallow irrigation systems maximise the evapotranspiration potential of soil and vegetation and are well suited to moderate to slow draining soils, where clay-type soils underlying topsoil have limited soakage capacity at depth. The following shallow irrigation methods are discussed in this section:

- Pressure compensating drip irrigation (PCDI) for secondary treated effluent
- Low pressure effluent distribution (LPED) irrigation for both primary and secondary treated effluent
- Low pressure pipe (LPP) subsurface irrigation for both primary and secondary treated effluent.

Shallow irrigation systems can be effective in all soil categories provided there is adequate overlying topsoil depth. These systems are limited by the most restrictive soil horizon and depth to groundwater. Typically, the overall area enclosing an irrigation field will be larger than the area required for a subsurface trench system for the same site and soil conditions.

E2.1.1 Pressure compensating drip irrigation (PCDI)

PCDI systems are used for the distribution of secondary (or better) quality effluent (usually from AS-AWTS or PBR-AWTS[6]) via pressure-dosing into (subsurface drip) or onto (covered surface drip) land application areas. PCDI systems are in general, much more economical to construct than conventional lower technology LPED and LPP irrigation systems and significantly more economical than conventional shallow land application alternatives such as ETS beds. PCDI achieves the most even distribution throughout the land application area and, in combination with a secondary wastewater treatment unit, is the recommended method of land application in most soil types, particularly in moderate to poor soakage Category 4 and 5 soils.

Commercial companies that market specific types of dripper irrigation lines generally provide guidance on system design, layout and operation. Section E2.2 provides details on the function and application of these systems together with their design, drip-line installation and maintenance.

E2.1.2 Low pressure effluent distribution (LPED) and low-pressure pipe systems (LPP)

Low pressure effluent distribution (LPED) and low-pressure pipe (LPP) systems are low pressure subsurface irrigation systems. LPED can also be utilised as a surface irrigation system (E2.3.3). Their advantage over PCDI systems is that they can distribute primary treated effluent (treated via a large septic tank with an effluent outlet filter), due to the larger diameter pipes and wider emitter holes.

[6] Activated Sludge – Aerated Wastewater Treatment System (AS-AWTS), Packed Bed Reactor – Aerated Wastewater Treatment System (PBR-AWTS)

As both the LPED and LPP systems are non-pressure compensating, they have a greater potential for uneven distribution throughout the land application system (in comparison to PCDI systems). They require very careful design considerations and installation test trials to achieve near-even distribution throughout the irrigation field. Pumped or siphon dosing is essential to achieve distribution along the entire length of each trench lateral of the land application area.

Section E2.3 provides design for both surface and subsurface LPED systems while Section E2.4 provides design details for LPP systems. Because of the overlap in design between the two systems, most design considerations are contained in the LPED section. Users should refer to this section first when considering LPP design.

A topsoil depth of at least 250 mm must be included in the design. If this topsoil depth is not available, additional topsoil should be imported to the irrigation area and/or lower application rates should be used. Topsoil depth is important both in terms of assimilating the hydraulic load and the nutrient load and becomes even more essential when receiving primary treated wastewater. These systems are at risk of failure when used in Category 4 and 5 soils without the necessary topsoil depth or if topsoil is dense. The underlying soil structure should also have good structure and texture to slow, but not restrict, soakage and to avoid preferential flow paths.

Advantages[7]:

- Reliance on passive in-soil treatment (assuming adequate topsoil)
- Shallow, narrow trenches reduce site disturbance during construction and thereby provide more protection against soil compaction and loss of permeability
- Periodic cycles of dose and rest assist in maintaining aerobic conditions in the land application area
- Pumped or siphon dose loading provides uniform distribution
- Pumped or siphon systems increase flexibility in siting the land application system on the lot
- Pumping allows construction of land application systems on sloping sites unsuited to gravity-fed systems
- The shallow systems have lower material costs compared to alternative subsurface systems (less distribution aggregate required)
- Less power and pump dependent than a secondary wastewater treatment unit.

Further advantages specific to LPED:

- The nested pipe allows for improved distribution over a larger soil surface area than LPP systems
- The longitudinal distribution of dosed effluent is more effective in achieving low levels of effluent to soil contact than LPP systems or conventional gravity-trickle distribution methods.

[7] Adapted from USEPA National Small Flows Clearinghouse (NSFC) fact sheet on LPP systems, 1998

Disadvantages:

- May not be suitable for many sites due to insufficient topsoil depth, soil type, steeper slopes, well vegetated areas and space availability for land application
- Distribution perforations on the pumped laterals may become blocked by solids if an effluent outlet filter is not fitted to the septic tank outlet (particularly if effluent is only treated to primary quality) and/or where there is insufficient pressure within the lines, or perforations become blocked by roots
- There is limited storage in the immediate shallow trench aggregate because of the very small trench size
- It is difficult to predict effective soakage beyond the immediate vicinity of pipe work at the design stage
- Wastewater is not evenly distributed throughout the entire land application area, with areas between irrigation lines frequently ineffective. This problem is worse for LPP than for LPED systems, providing less even distribution compared to properly installed drip irrigation systems
- Unsuitable for use in dense soil as effluent does not move laterally into the soil resulting in breakout
- Regular monitoring and maintenance of the system is required, including checks for even distribution throughout the field - a lack of maintenance can be a precursor to failure
- Systems will not operate effectively in Category 4 and 5 soils without adequate topsoil depth. They should not be used in Category 6 soils
- Lines need to be laid parallel to the land contours, which may not be possible on some sites.

E2.2 Pressure compensating drip irrigation

E2.2.1 Overview

Pressure compensating drip irrigation is the most appropriate land application option wherever wastewater is treated to at least a secondary standard. Treated secondary effluent[8] typically enters a load-dosing system which may consist of a treated wastewater dosing tank and a dosing pump with adequate reserve capacity and control mechanisms (Figure 19).

Typically, the control mechanisms may include flow regulation, filtration, and field flushing, zone selection and alarm systems. Design details of dosing systems and operations are provided in Section E1.4.

PCDI systems need to be installed in good quality topsoil (around 250 mm), which may need to be imported (and scarified) where on-site soil is inadequate. Shallow irrigation via PCDI achieves the best results by dispersing treated effluent into the topsoil at low application rates. This enhances evapotranspiration and minimises infiltration into the subsoil. PCDI irrigation is therefore applicable for use in all soil categories from Category 1 sands to Category 5 clays. Its use in Category 6 soils require specific design considerations and should be assessed on a case-by-case basis.

[8] Usually provided by AS-AWTS or (PBR-AWTS

Two types of drip irrigation emitters are available: pressure compensating and non-pressure compensating. These systems comprise small diameter pressure pipes with in-line effluent discharge emitters built into the pipes at a typical spacing of 0.3 m to 1 m.

Pressure compensation provides for relatively equal wastewater flow from each emitter and the lines do not need to be level. Dripper irrigation lines are typically installed in parallel lines on the contour and buried at depths in the order of 50 to 200 mm within the topsoil zone. Pressure compensating drip irrigation lines should be buried whenever practicable. Irrigation lines can be placed on, and pinned to, the ground surface within areas established in trees, or other vegetation, and covered over with leaf fall or mulch where practical. The irrigation area should be fenced where irrigation lines are on the ground surface in areas where there is potential for human access. If not, they must be well covered and pinned in place. Lines should not be left exposed to direct light or the elements. It is recommended that irrigation lines be buried wherever possible.

Modern pressure compensating drip lines can purge debris within the dripper and prevent siphon-suction. This prevents the drawback of solids into the line via the emitters, in response to suction forces developed when lines drain back to the lowest topographical point. It also allows for rapid pressurisation at the beginning of each dosing cycle. The disadvantage is that a higher head capacity pump is required for some brands of emitter than would be necessary for standard pressure compensating drip irrigation.

In addition to lower installation costs, the technical advantages of PCDI over alternative shallow irrigation systems (including LPP, LPED and spray irrigation) and other conventional land application methods, (including trench, bed and mound systems) include:

- Subsurface slow rate irrigation allows wastewater to be discharged into a specific soil horizon and provides slow rate land treatment using the topsoil as a biofilter
- The driplines do not need to be level to maintain an even distribution of wastewater between individual emitters and over the area of the land application system
- PCDI allows more flexible use of a site than traditional systems, taking advantage of natural or modified landscape conditions
- Timer dose loading optimises land treatment within the biologically active topsoil
- Wastewater can become a valuable resource for reuse to sub-irrigate lawns and gardens, reducing potable water requirements
- Lines can be placed on the ground surface within vegetated (bush covered) areas without the requirement for trenching and damage to root systems
- Allows widespread low application distribution minimising wetting of the ground surface while utilising evapotranspiration assistance of vegetation
- Allows ongoing access to lawn areas, which would be less accessible where bed or mound systems are installed. However, care is required where sub-irrigation of lawns is proposed particularly under high traffic areas.

E2.2.2 Design of PCDI system

Key information for proper design of a PCDI land application system includes design effluent flow rates, effluent quality, and the findings of the detailed soil and site evaluation. Some manufacturers provide easy-to-use computer programmes to assist with the design process. This, however, does not replace the need for professional evaluation services provided by qualified designers.

Key steps required for designing the PCDI field and the dosing system include:

- Determining the daily treated wastewater effluent flow volume
- Determining the design irrigation rate (areal loading rate) based on the findings of the soil and site evaluation
- Calculating the size of the land application area
- Selecting line and emitter spacing and calculation of the total line length
- Selecting emitter flow rate and calculation of the total emitter flow rate based on the total line length and emitter spacing
- Determining the number of zones and calculation of total irrigation flow rate per irrigation zone
- Determining the length of the lines – the manufacturer/supplier will set out maximum length requirements based on inlet pressure and emitter discharge rates
- Determining dose rates and dosing cycles
- Pump sizing and treated wastewater dosing tank design.

E2.2.2.1 Areal loading rates for PCDI

The areal loading rate is determined according to soil characteristics and environmental constraints with lower rates adopted for sites having environmental constraints, including lower soil assimilation capacity. The areal loading rate should consider the influences of rainfall, site aspect, exposure to sun and wind, as well as the soil category and its infiltrative capacity.

Recommended loading rates for PCDI systems in different soil categories are provided in Table 44. The variation in loading rates recognises the capacity of the underlying soil to manage that portion of the wastewater that infiltrates below the topsoil layer.

Table 44: Drip irrigation design criteria summary

Parameter	Design criteria	
Line spacing	Variable (typically 0.3 m - 1 m) [Notes 1 & 2]	
Emitter spacing	Variable (typically 0.3 m - 1 m) [Notes 1 & 2]	
Emitter rates	Typical rates 1.2, 1.6, 2, 2.3, 3.5, or 4 L/hr	
Design areal loading rates [Note 6]		
Soil category	1	5 mm/day [Note 3]
	2 and 3	4 mm/day [Notes 4 and 5]
	4	3 - 3.5 mm/day
	5	2 - 3 mm/day
	6	Special design precautions required: 1 - 2 mm/day
Depth of lines	100 mm to 150 mm or pinned to ground surface and may be covered with mulch or bark	

Notes:

1) When the line spacing is decreased below 1 m, the total application area must not be proportionately reduced. The ‘effective’ land application area along each line decreases to the setback distance between the lines, consequently, the linear length of irrigation lines required must be increased proportionately (Tennessee Valley Authority, 2004). If the line spacing is increased above 1 m, then the effective area remains at 1 m area along each line, for the purposes of determining the total effective land application area, with the additional space beyond the 1 m between lines classified as buffer area i.e. the total length of lines remains the same, but the total land application area increases due to the additional buffer areas.
2) Effective distribution in lawns is best achieved using closely spaced lines and emitters (0.3 m x 0.3 m) with use of very conservative loading rates based on the soil category underlying topsoil.
3) For Category 1 soils, recommended PCDI design irrigation rate (DIR) is 5 mm/d into a minimum of 250 mm good quality topsoil. Dripline and emitter spacing of 300 mm x 300 mm should be adopted. If further groundwater protection is required, the DIR may be reduced to 4 mm/d or 3 mm/d, as a risk reduction measure or the treatment level should be increased.
4) For Category 2 soils (free to good drainage characteristics), the drip irrigation system should be installed within an adequate depth of topsoil (in the order of 150 to 250 mm of *in situ* or imported topsoil or mulch) to slow the soakage and assist with nutrient reduction.
5) Where PCDI lines are placed within Category 3 type topsoil, overlying Category 2 soils, the Category 3 areal loading rate is to be applied (dripline and emitter spacing of 0.3 m x 0.3 m is also recommended).
6) Design irrigation rate may be decreased for sloping ground to ensure adequate effluent uptake within the topsoil and plant root system.

Lines are generally designed at spacings of 0.3 m, 0.5 m or 1 m centres; however this can be varied according to the site conditions. For example, closer line spacing may be appropriate where wastewater is reused in fast draining soils, while wider line spacing can be appropriate within slow draining soils.

When the irrigation line spacing is reduced to less than 1 m, the effective land application area is the same as for a 1 m line spacing to maintain the areal loading rate (as expressed in litres per m^2 per day). Where irrigation lines are placed at more than 1 m centres, the designer must increase the land application area by the equivalent amount to accommodate the linear length of lines that would be required for irrigation lines at 1 m centres.

An appropriate areal loading rate is determined based on the land use of the proposed land application area. Subsurface pressure compensating dripper land application systems are best installed within infrequently accessed planted areas. Landscaped or bush areas are the most appropriate area for surface irrigation. Lawn areas can be used for subsurface dripper irrigation. However, careful design is required to avoid soil pugging. This risk can be reduced by using a conservative areal loading rate and reduced irrigation line and emitter spacing (e.g. 0.3 m x 0.3 m). PCDI should not be used under lawns where alternative irrigation areas are available on the site. Any areas potentially accessed by the public need signage stating the area is used for wastewater irrigation. Extreme care is required when digging in the area to avoid cutting the lines.

Figure 20 shows an example of a common PCDI system irrigation pipe layout (with a worked example in Table 45).

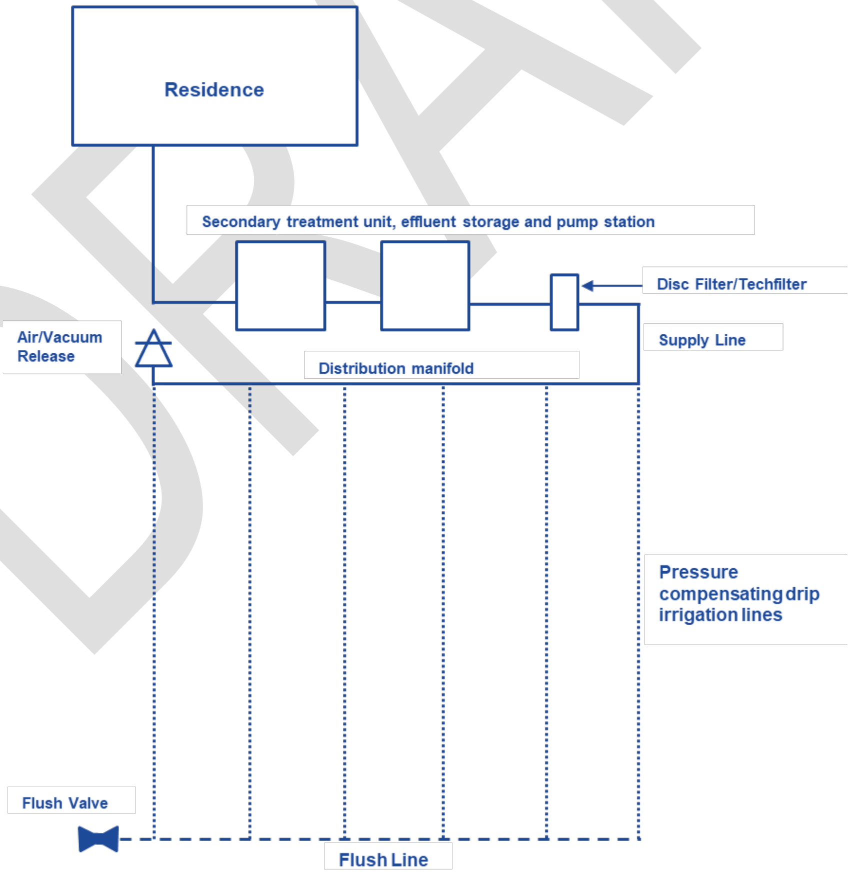


Figure 20: Typical PCDI system components layout

Source: Netafim NZ Land Application Design Guide 2007

Flush taps should be placed in a 'valve box' to allow easy access during maintenance, or alternatively, the lines can be taken to a single discharge point.

Table 45: Example of calculations for PCDI irrigation area

PCDI design examples	
Peak daily effluent production	900 L/day
Soil category	3
Areal loading rate	4 L/m²/day or 4 mm/day
Design land application area	225 m² [Note 1]
Land application area dimensions	9 m x 25 m
Line spacing – 1 m centres Linear length of line required	225 linear metres
Line spacing – 0.5 m centres Linear length of line required	450 linear metres [Note 2]
Reserve land application area (50%) [Note 3]	113 m²
Total area required	113 m² + 225 m² = 338 m²

Notes:

1) Land application areas exclude any setback requirements.
2) The design land application area must remain the same 250 m² to achieve a 4 mm loading rate and therefore, the length of line required is twice that for 1 m spacing.
3) The reserve area requirements are specified in Section B5.5.

E2.2.2.2 Dose loading

The dosing control design should ensure that the entire application field is adequately utilised and evenly distributed across the whole day (also discussed in Section E1.4). The function and complexity of the dose control system is determined by the flow demand and limitations of the soil. Depending on the selected dosing mechanisms, the electronic control system should be capable of scheduling/operating the dosing cycles and may also control the flushing and backwash operations. The dosing cycle time and dosing volume should be based on specific system and site requirements. Additionally, the minimum pump flow rate required is to be calculated to ensure the entire PCDI field is loaded evenly.

Generally, an effective minimum dose is approximately four to six times of the entire drip laterals' capacity. Some agencies recommend the minimum dose at 10 times the system volume capacity (see sizing the dose volume in E1.4.2.3 above).

It is very important that all pressure head losses are considered when determining the pump head capacity required for the dose loaded irrigation system. Insufficient pressure head will result in premature pump failure and uneven distribution of wastewater through the irrigation network. Table 46 provides a worked example for head loss calculations.

Table 46: Head loss calculation example

Component	Head loss (m)	Comments
Emitter	12	Minimum pressure required
Lateral	0.0	Head loss insignificant for short run
Submain	1	Using proprietary submain
Main	0.6	Using 25 mm LDPE x say 17 m (depends on distance from treatment plant to irrigation system)
Filter	3 to 5	For a semi-blocked (3 m) to blocked (5 m) filter
Tank depth	2 or actual depth	Actual depth of pump to be used if more than 2 m
Water meter	0.5 – 1.5	Depends on type of water meter being used
Elevation: upslope or downslope	metres + 0.0 m	Height difference to uppermost point of irrigation area Downslope [Note 1]
Total	20.1 m + 10% =	22.1 m [Note 2]

Notes:

1) Include anti-siphoning measures at pump station when pumping downhill.
2) Based on Irrigation Technology Services "*Drip Irrigation Effluent Disposal Fields Design Manual*" for standard pressure compensation irrigation lines. ITS 2001 and Netafim design guidelines. For the use of alternative pressure compensating irrigation systems, the design/installer is to confirm the manufacturer's recommended head loss guideline values.

A minimum of 5 m head should be allowed at the end of each dripline lateral when determining the dripline lateral length.

Where the land application system is located downslope of the pump, it is important to ensure the system does not empty the tank by uncontrolled siphoning. Where the system is uphill of the pump, the difference in elevation between the top of the pump and the highest point of elevation (static discharge head) must be added to the head loss calculation.

When pumping upslope ensure a non-return valve is installed above the pump to prevent the header line draining back to the treated effluent tank.

E2.2.2.3 Multiple PCDI application zones

Multiple application zones should be used when there are topographic or other site constraints (e.g. steep slopes with a risk of backflow drainage between doses). Design considerations for zones include ensuring:

- That each drip field zone is not too large to manage, and the fill-up time of each zone is reduced
- Dosing of different zones to be alternately dosed or flushed, allowing field resting (Section E1.4.2)
- Sufficient system capacity for field flushing
- Reduction of pump size, valves, filter, and main drip lines
- Varying application areas and loading rates depending on soil or vegetation across a site.

E2.2.2.4 Requirement of treated effluent quality

Drip irrigation lines must be installed according to the manufacturer's specifications including wastewater quality requirements. Fine filtration is needed (e.g. 120 µm disc filter) between the secondary treatment plant and the land application area. Regularly maintained filters following aerated wastewater treatment plants can reduce the maintenance requirements of irrigation lines. Screen filtration is not an acceptable alternative because pump pressurisation can force solids through the screen, unless the screen has constant flushing to maintain a clean surface.

Generally, the maximum BOD_5 and TSS content of wastewater recommended for discharge to pressure compensating irrigation lines is 20 g/m^3 and 30 g/m^3 (BOD_5 : TSS), although some manufacturers may allow up to 30/30 g/m^3 (BOD_5/TSS) for effluent irrigation. Treated wastewater quality not meeting the manufacturer's guidelines can lead to premature clogging of the irrigation lines.

E2.2.3 Drip line system installation

Key components generally required for a well-designed and installed PCDI system are summarised in Table 47.

Table 47: Typical PCDI system components

Component	Description	Comments
Drip line	Low pressure drip line with integral and evenly spaced pressure compensated emitters.	• Design and installation of drip line should follow the technical specifications provided by the manufacturer/s.
Dosing equipment	Pumps or siphon.	• Design and installation of dosing equipment should follow the technical specifications provided by the manufacturer. • Refer to Section E1.4 for system control requirements on pump or siphon design.
Treated effluent Dosing tank	A storage or buffer tank to provide flow equalisation. The capacity of the tank can be incorporated in the pump chamber operating capacity.	• Peak flow or emergency storage of a minimum of 24 hours of average daily flow is required.
Disc filter	Usually a 130 µm (120 mesh) filter is recommended following secondary treatment	• This is required to prevent solids clogging the drip lines or emitters.
Filter flush valve	This is to flush filter debris back to the wastewater treatment unit or dosing tank.	• This can be either an actuated valve or a manual valve. • If a manual valve is used, the flushing schedule should be followed as part of the operation and maintenance programme.
Sequencing valves	When multiple land application zones are designed, sequencing valves are used to turn zones on and off.	• Solenoid valves sometimes are applied for this purpose. • It is important to select appropriate valves that are resistant to wastewater application.

Component	Description	Comments
Air-relief valve	The purpose is to: ○ Expel air from the drip lines during pump start-up, thus producing consistent effluent flow dose ○ Prevent soil particles from entering the line via the drippers due to a vacuum following pump shutdown.	• A minimum of two air-relief valves, located at the highest point/s of both the supply and flush manifolds, should be allowed for per land application zone. They are typically placed in a valve box.
Pressure-relief valve	Ensure that the pressure in the drip lines does not exceed a certain limit (e.g. 50-70 psi), and preferable within 10 to 45 psi.	• This may be required on slopes where high pressure may exist.
Check valves	Ensure that wastewater only flows in one direction.	• This is commonly designed when supply or return streams are required to go uphill, preventing wastewater draining back down. • To prevent drainage back to the lowest line and overloading.
Flexible pipe connections	Flexible PVC pipes.	• Allows flexibility in drip line layout.
Supply pipe/manifold	Usually schedule 40 PVC.	• Pipe sizing should be undertaken by a suitably qualified and experienced person and follow the recommendations provided by manufacturer/s.
Flush pipe/manifold	As above.	• As above. The system should be designed to accommodate frequent system flushing.
Flow meter	To provide accurate effluent flow rate measurements. Often a propeller-type meter is used.	• Important tool for system troubleshooting. • Often required to ensure design specifications will meet compliance needs.

E2.2.3.1 Installation

The installation instructions for the PCDI system should be provided by the manufacturer or designer. The PCDI field must be protected and maintained during the lifetime of the on-site wastewater system. For instance:

- Exclude heavy machinery from the proposed PCDI field during construction and avoid creating impervious surfaces on the PCDI field
- Do not use PCDI areas for equipment storage or vehicle parking
- Protect and maintain vegetation on the surface of the PCDI field to enhance evapotranspiration
- Fence off the drip field prior to any construction works
- Exclude utilities, cable wire or drain tiles within the drip field.

When PCDI is installed subsurface, driplines should be installed at a 100 - 150 mm depth into a 250 mm depth of good quality *in situ* or imported topsoil. If surface drip irrigation is selected, the driplines should be covered by a layer of mulch or other approved cover materials with a depth of at least 150 mm. Durable bird-resistant mesh netting should be pinned to the surface to protect the cover layer. Where possible, the manifold trench depth should be the same as the dripline depth. It is advisable to have the dripline pass over an elevated berm between manifold and the dripline, reducing gravity flow back from the laterals.

Common dripline installation methods include:

- **Plowing**: Knifing in the driplines using a vibratory plow
- **Trenching**: Cutting narrow trenches for drip line installation and filling with original materials
- **Fill**: Laying drip lines on ground and covering with fill material
- **Surface placement** in gardens and bush areas.

In many areas, there is insufficient natural soil depth or setback distance between the subsurface dripper irrigation lines and groundwater. In such situations, the ground level should be built up with topsoil (and then scarified).

For a sloping site, the laterals should extend along the contour of the slope (as level as possible). It is important to install at least one air-relief valve at the highest point in each zone. In some designs it may be possible to connect all the high points together and install an air-relief valve on the connecting line. It is also preferable to feed the application field from the bottom of the slope, preventing wastewater from draining to the lowest part of field during rest periods.

Installation of all mechanical and electrical components of the land application system should comply with relevant standards and regulations, including:

- AS/NZS 3000:2018 *Electrical installations*
- AS/NZS 3500.2:2018 *Plumbing and drainage – sanitary plumbing and drainage*
- AS/NZS 3820:2009 *Essential safety requirements for electrical equipment*
- New Zealand Building Regulation 1992 Schedule 1 (The Building Code).

E2.2.4 Maintenance

Maintenance is essential to help keep the system running at its design capacity and increase the life expectancy of the system. The actual maintenance frequency is dependent on the wastewater quality from the wastewater treatment unit. Higher maintenance is needed for activated sludge systems without filtration than packed bed reactors and those with a filtration step upstream of the land application.

Depending on the filtration method applied (e.g. screen, media or disc), various flushing or cleaning procedures and frequencies should be followed based on the designer or manufacturer's recommendations. All filters need to be taken apart, inspected and cleaned as necessary. For disc filters, it is necessary to separate the discs and clean the entire filter with a garden hose. If deposits form on the discs, it can be soaked in hydrochloric acid (in a 10:1 ratio of water to acid, following all safety instructions on the acid container).

Regular flushing of the drip line and manifold is also needed to reduce microbial growth over time (this applies to lines with anti-microbial additives). This can be done by periodically opening the flush line from the drip irrigation field back to the wastewater treatment unit or onto the ground ensuring there is no runoff to surface water. The scouring or flushing velocity setting should follow the designer or manufacturer's recommendations. The use of chlorine or other chemical cleaning agents for removal of slimes and algae is potentially damaging to the soil and is discouraged. Any acid or chlorine injections used to dissolve chemical deposit or slime build-up must follow the manufacturer or designer's recommendations.

Root intrusion can result in clogging of emitters and laterals and require specialist advice. Different PCDI emitter line manufacturers and/or suppliers have their own recommendations for controlling root intrusion in different situations. Root intrusion can be controlled by installing PCDI lines impregnated with herbicide (such as trifluralin or other patented products), or by installing an in-line herbicide dispenser. Where drip irrigation lines are in garden areas, any digging should be undertaken with extreme care to avoid cutting the lines.

A simple, but strict, maintenance programme is required for any PCDI system. Regular monitoring and recording the system flow rates and pressure changes is required in determining whether or not the system is operating at the designed performance level.

Drip irrigation systems require regular three to six-month maintenance including:

- Manual flushing of individual lines and the in-line fine filter either to a soakage pit onto the ground or back into the wastewater treatment unit. The flushing velocity and frequency should be tested to ensure it is consistent with the manufacturer's recommendations
- Checking for emitter blockage (symptoms being excessively dry areas and excessively wet areas which are recorded and investigated)
- Replacement of physically damaged lines, i.e. broken or blocked (where blockages cannot be flushed out).

E2.3 Low pressure effluent distribution irrigation systems

E2.3.1 Overview

LPED subsurface irrigation uses a perforated dose line nested within the draincoil distribution pipe. The distribution lines are laid within shallow narrow trenches backfilled with drainage media. LPED systems work by flooding inverted nested laterals within a drain coil line from widely spaced orifices (squirt holes) in the dose line. These systems enable more effective lineal distribution than LPP of treated wastewater along the full length of the distribution trench during each dosing operation (Section E2.4) (avoiding the spot loading effect associated with LPP). LPED is the preferred subsurface irrigation system over LPP irrigation.

E2.3.2 LPED design and operation

The design of the LPED system should be by a suitably qualified and experienced person.

The drainage media-filled LPED trench design is a much smaller version of a conventional trench. Based on the recommended areal loading rates, the effective basal loading rate of the LPED trench is two to three times that of a conventional trench. Design requirements for achieving even distribution throughout LPED systems are detailed below. Appendix M provides a worked example.

A) Trench structure

LPED trenches

LPED trenches are only suitable in sites with Category 2 to 5 soils where there is a good topsoil layer of at least 250 mm depth.

LPED trenches comprise a series of shallow and narrow (200 mm deep, 200 mm wide) trenches excavated within the topsoil and shallow subsoil layer, with a pressure-dosed small diameter (25 to 30 mm) perforated plastic pressure pipe lateral nested within a 100 mm to 150 mm draincoil or slotted pressure pipe which is surrounded by pea gravel distribution media (Figure 21). Distribution media of 10 mm to 15 mm size can be used in place of pea gravel.

The LPED trench base and leading edge must be laser-levelled and then level-excavated along the contour to ensure there is no breakout from low points.

Trench laterals

The perforated laterals are laid at a depth of 100 to 200 mm within the excavated trenches. The draincoil should be slipped over the distribution laterals and then the lines, laser levelled. Once the lines are laid, concrete blocks or clay dams should be located at each end of the perforated pipes to prevent wastewater flowing from the shallow trench into the main header trench and at the upstand end of the distribution line. For maintenance, the upstand end of the distribution line should include a screw cap to allow flushing of the line. Each distribution lateral supplied by a pump dosed manifold should have:

- A non-return valve to prevent lines draining back to the main header pipe and overloading the lower-most trench
- An orifice plate sized to ensure equal wastewater loading to each lateral.

Alternatively, the laterals can be dosed via automatic sequencing valves.

When the lines are installed, they must be test-dosed (refer to Section F), before they are backfilled. The trench media (i.e. aggregate) is installed to a minimum depth of 200 mm. The completed trenches can be covered with drainage fabric (filter cloth) near ground level. The trench is then further covered by sufficient mounded topsoil, to allow for settlement and to further divert surface stormwater flows and to sustain plant growth.

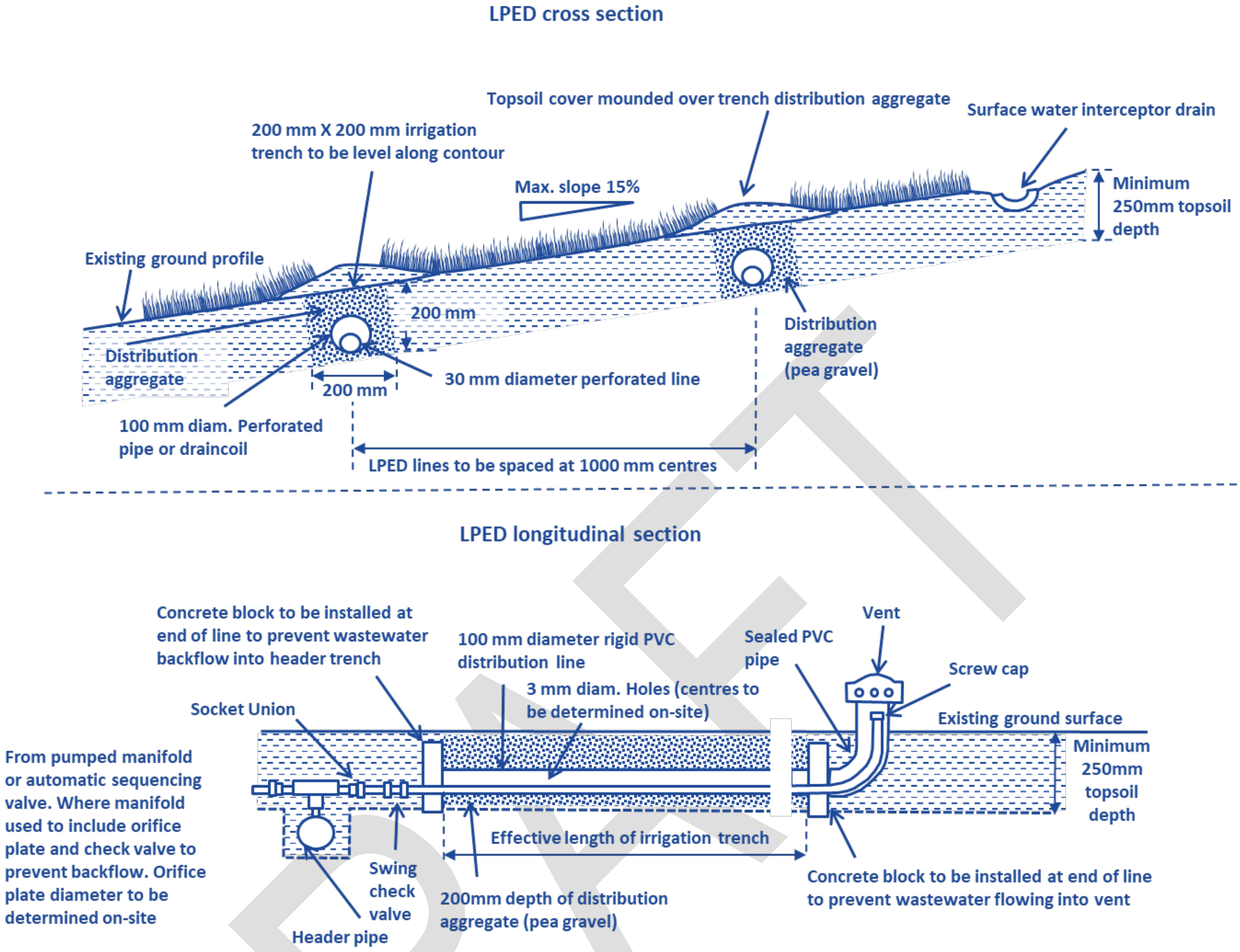


Figure 21: LPED subsurface irrigation system – typical details

B) Effective soakage area

The LPED design concept is to wet the topsoil between trenches and maximise evapotranspiration assistance from plant growth. This relies on the assumption that infiltrated wastewater will move laterally through the topsoil over the entire width, whilst maximising evapotranspiration from plants. This requires a good depth of well-drained quality topsoil or effluent will remain in the trench and break out onto the ground surface.

For design purposes, the effective area between laterals is specified as 1 m, as the area of 1 m downslope of each lateral is considered a realistic and effective area for design purposes. However, a cautious approach is needed with additional safety precautions in the design of all LPED (and LPP) systems. Actual spacing will vary to suit the land contours and any additional land area between laterals beyond the maximum 1 m effective design area can provide a factor of safety but is excluded from the design infiltration area calculation.

C) LPED pipe sizing

The designer can accurately determine:

- The required pipe length to achieve the appropriate design areal loading rate
- The head loss throughout the system
- The required pump pressure
- The number of squirt holes (orifices)
- The space between the squirt holes depending on the respective level of each lateral
- The diameter of each squirt hole.

Engineering formulas for determining all the above design criteria for LPED systems (also including the dynamic head and the required squirt height) are provided in Appendix M.

D) Squirt holes

Correct squirt hole sizing is essential for achieving required pressure differential and even distribution along the lines. The spacing, number and diameter of the squirt holes should be designed to ensure that there is no more than a 10% difference in flow between the first and last squirt hole in each line.

Generally, a 3 mm hole is recommended, with the pressure then set during system commissioning to achieve the 1.5 m squirt height out of each squirt hole on all laterals. A 1.5 m squirt height is necessary to ensure the required scouring velocity is achieved through the squirt hole. A 5 mm hole is generally considered too large, unless the pump capacity is increased to provide sufficient pressure to achieve the same squirt height. A large diameter main supply line can suffer from a falling static head, therefore line diameters of greater than 50 mm should be avoided and for short steep runs, diameters of 40 mm or 32 mm should be sufficient.

Appropriately spaced squirt holes are also required to ensure even distribution between laterals. The supply and lateral lines must all be fully charged by the incoming dose. The number of squirt holes must be adjusted within the engineering calculations to ensure that even distribution along the lines is achieved. This may include wider spaced squirt holes on the lower head lateral.

An LPED system may not be sensitive to minor construction variations. For example, 1 or 2 more-or-less squirt holes in a system of 70 holes may not significantly affect system performance. Detailed calculations tailored for each site are required to ensure that the even distribution will be achieved (an example is provided in Appendix M). The squirt height out of each orifice needs to be rechecked in commissioning tests at the time of construction for actual differences in lateral elevations to ensure the initial system design is achieved in practice.

E) Dose loading and dosing control mechanisms

Pumped- or siphon dosing is essential to ensure uniform distribution of effluent along the length of each trench lateral. Dose loading ensures that wastewater is distributed along the full length of each trench each day, with the periodic loading followed by an extended rest period maintaining aerobic conditions in the trench and receiving soil.

In siphon-dosed systems, for a typical household wastewater flow, a minimum fall of 2.5 m between the outlet of the septic tank and the highest lateral line in the LPED irrigation system is needed (sufficient squirt height). No more than 10% pressure differential along each lateral during each dose is essential for even distribution. The main supply and lateral pipe diameters must be sized to contain the full dose flow to avoid water backing up the main line and tipping the siphon. A siphon should be set with sufficient flow rate that the siphon does not stall.

Normally, the system is designed to dose load the field three to four times per day at the design loading rate. Automatic sequencing valve dosing is an alternative control method that involves a single dose load per day to be flood loaded into each irrigation trench. The trench is then left to drain for 24 hours to enable in-soil treatment prior to the next dose the following day. The dose volume should be controlled to ensure that the applied effluent in an individual trench on each loading cycle does not flood the media (aggregate) to a depth of more than 50 mm to 75 mm.

F) Alternative dosing control methods

There various dosing methods used in both LPP and LPED system designs that aim to achieve even loading along each lateral as follows:

<u>Separate LPED cell method (also known as the Feeder Line Method)</u>

The separate LPED cell system comprises a series of laterals with isolated seepage cells along each lateral of at least 1 m length excavated along the contour and separated end-to-end by at least 100 mm of soil. The rows of cells are maintained at least 1.5 m apart and the effective design infiltration area is 1 m on the downslope side. The short length of cells allows them to be excavated with a level base on sloping bush-covered sites. This avoids significant vegetation removal which is otherwise required with conventional LPP on bush-covered sites to achieve even loading along each lateral.

Treated effluent is dose loaded via a lateral running along and downslope from the line of cells. Laterals can be buried or placed on the ground surface in bush-covered areas. Each cell is loaded individually via a 3 mm diameter feeder line staked to ensure the highest point of the feeder is elevated above the cell and lateral. The top of each feeder line for each cell on the same lateral must be maintained at the same elevation to ensure even loading of each cell. The laterals do not need to be installed level as the feeder lines compensate for elevation variations along the length of the lateral. Each dose load does not need to fill up the volume of each lateral line with each dose and the laterals do not drain following each dosing cycle. This eliminates the risk of wastewater draining from the highest lateral to the lateral at the lowest elevation on the slope and overloading the lowest row of cells.

Elevated main line method

This method involves the installation of manifolds at the lower end of the main line which then terminates above the laterals. The discharge point located at the bottom of the main line feeds the highest lateral and the highest discharge point feeds into the lowest lateral. It is claimed that this ensures that the first plug of effluent during an initial dosing cycle tends to be more evenly distributed between the laterals, avoiding any increase in load to the bottom lateral. Also, at the end of a dosing cycle, the falling head of effluent within the main line should distribute reasonably evenly between the laterals rather than favouring the bottom lateral. All laterals then feed off the main line located higher than the highest lateral and effluent cannot backflow and non-return valves are not required.

The head pressure required in each lateral is achieved by determining the required spacing and number of squirt holes along each lateral rather than use of orifice plates. The main line is generally in the order of 50 mm diameter.

Orifice plate method

The orifice plate method consists of one central main line with each lateral feeding off it. The lines start with an orifice plate and non-return valve, with the squirt holes then installed at equal distances along the laterals. The orifice plates must be sized appropriately by refining the sizes of the holes in the orifice plate by reconstructing and replacing the plate following accurate checks of lateral levels and squirt height during installation. The design should not overload the bottom lines at the start and finish of each dose cycle. This is achieved by installing non-return valves at the beginning of each line or dosing the lines separately by using an automatic sequencing device.

Automatic sequencing valves method

Automatic sequencing valves are a standard and effective method of distributing wastewater throughout an irrigation system and are a common feature of many land application systems. They provide a single dose per day to flood load to each portion of an LPED system for seepage and 24-hours treatment in the topsoil prior to the next dose. They ensure even distribution of wastewater by providing equivalent doses to each portion of a whole LPED system. The dose volume should be controlled to ensure that the applied effluent in an individual trench on each loading cycle does not flood the trench media to more than 50 mm to 75 mm depth.

The loading of only one system element (e.g. each line or groups of lines) separately throughout the day allows lower overall pump pressures. Automated sequencing valves require a minimum head of 6 m to be effective. They also enable simpler calculations of head loss throughout a system (dose per line or per groups of lines) rather than using iterative hydraulic matrix calculations to determine head loss through all lines at the same time.

The use of automated sequencing valves within LPED systems which function primarily as a distribution for dose loading conventional land application system is detailed further in Section E1.4.2.2.

G) Topsoil depths

The LPED irrigation system is suitable for Category 2 to 5 soils with a good (at least 250 mm) topsoil layer and having a suitable structure and texture, with the required topsoil depth being dependent on the underlying soils. For all category soils, adequate topsoil depth is a minimum of 250 mm. Topsoil depth must be considered when determining the appropriate loading rate (Section E1.2).

H) Slopes

Subsurface LPED systems should only be installed on flat to moderately sloping land to reduce wastewater seepage and breakout. With careful design, they can be installed on land with a maximum ground slope of 8.5° (15%). PCDI is more appropriate for sites which have slopes greater than 8.5° (15%)[9]. LPED trenches must be excavated level (using a laser level) along the land contours to avoid wastewater ponding at the low end of the trench. Alternatively, even loading on sloping bush-covered sites can be achieved using the Separate LPED Cell or the Feeder Line Method (as detailed in F) above).

I) Commissioning

Test dosing with clean water should be done prior to backfilling over the LPED lines to ensure the system is evenly loaded. In the commissioning test, the squirt height out of each squirt hole is checked to ensure that there is less than 10% difference along each lateral. If this is not achieved, the distribution pipe should be removed and the calculations for the orifice sizes and spacings rechecked and the lateral pipe replaced with a new one with the required revised dimensions drilled into it. The siphon, where installed, should also be checked to ensure it is functioning properly with the required flows.

Once the system has been tested and verified by the designer as satisfactory, the draincoil should be slipped over the distribution laterals and the trenches backfilled with drainage media (aggregate). The drainage media can be covered with a thin permeable filter cloth or straw or hay before the topsoil layer to prevent ingress of topsoil. Other designers believe the additional layer is not necessary and the filter cloth can inhibit evapotranspiration or can break down over time, eliminating any benefits.

The ends of the lines should be clearly marked so that the flushing taps can be located. Venting mushrooms at the ends of the lines are also recommended to assist with the aeration of the trenches and provide access for flushing. Where rainfall runoff or groundwater intrusion into the land application area may be an issue, cut-off trenches and diversion drains should be installed. It is important that the whole land application area is fully planted before the system is commissioned.

Recommended "areal" loading rates for design sizing of LPED irrigation are provided in Table 48.

[9] PCDI should also be considered as an alternative in the case of any slopes between 5.7° and 8.5° (10% and 15%), or in areas where there is an elevated water table or limited exposure to sunlight.

Table 48: LPED design sizing summary

Line spacing	Variable but minimum of 1 m (Effective infiltrative area for areal loading is within 1 m of LPED lateral line) [Note 1]	
Emitter squirt hole spacing	Variable (typically 0.5 to 3 m depending on site and overall system design)	
Emitter squirt hole size	3 mm	
Squirt height	1.5 m	
Design areal loading rates	[Note 2]	
Soil category [Note 3 & 4]	Soil Category 2	3.5 - 4 mm/day
	Soil Category 3	3.5 mm/day
	Soil Category 4	3 mm/day
	Soil Category 5	2.5 mm/day
Depth of lines	100 mm to 200 mm (or in established bush areas, pinned to ground surface and covered with mulch or bark)	
Trench dimensions	200 mm wide by 200 mm deep	

Notes:

1) At 1 m spacing between dose lines, the maximum effective area used for design purposes is 1 m^2 per metre length of line (refer to further comments in this section).
2) Loading rates apply to systems on flat to moderate slopes. LPED systems are not an appropriate land application option on slopes greater than 8.5° (15%) due to uncertainty with them achieving even distribution.
3) Soil category and thus the corresponding areal loading rate, is dictated by the underlying soils not the shallow topsoil (as indicated in Section B).
4) LPED trenches are to be installed within 250 mm of good quality topsoil. LPED is not advised in Category 1 and 6 soils where PCDI of secondary effluent is the preferred irrigation method.

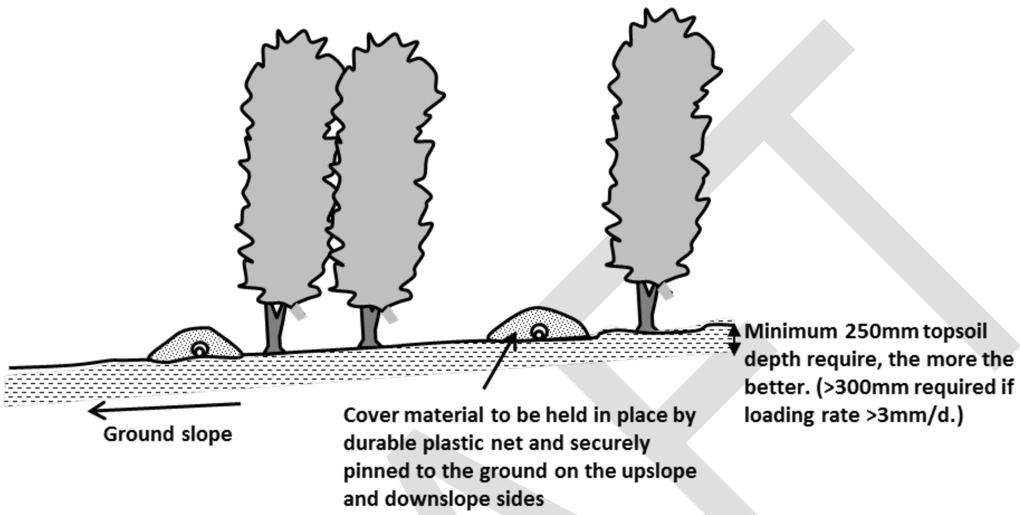
E2.3.3 LPED surface trickle irrigation

This system has application within areas of natural vegetation such as bushed lots on flat land and slopes less than 8.5° (15%) (Figure 22). Parts B, C, D, E and F of Section E2.3.2 above also apply to the design of surface LPED systems, excluding details of the trench excavation.

LPED trickle irrigation lines may be laid on the ground surface where root systems are close to the surface and where shallow trenches cannot be installed. The land application area must then be fenced, or otherwise appropriately controlled, to prevent access. Once the lines are laid, pinned and supported, a full clean water pump test should confirm even distribution and adjusted as needed. Once fully tested, the covering material (bush litter, bark or compost) can be placed over the lines and held in place by durable plastic net pinned securely to the ground up and downslope. This is important in keeping foraging birds or animals from disturbing the cover material. On steeper slopes, it also prevents erosion of the cover material.

Installation and maintenance of level, surface-located LPED trickle irrigation lines within natural vegetation and bush areas is difficult to install and PCDI should be considered as a more practical alternative.

Frequent operation and maintenance inspections are necessary during the initial months of operation to ensure that distribution effectiveness is being maintained. Once the system is established, the routine monitoring and inspection programme can be implemented.



LPED (Low Pressure Effluent Distribution) trickle irrigation lines placed on the ground surface along contour through existing trees, shrubs, bush plantings, and after testing for uniform distribution of trickle irrigation, covered in bark-chip, compost or equivalent.

LPED dose lines comprise a 30mmØ perforated pumped distribution line 'nested' within a 100mm slotted draincoil line. When laid on the ground as for trickle irrigation, the lines are covered with appropriate material as indicated above. The distribution system should be pump tested with clean water prior to covering and the 100 mm line pinned in place to ensure even distribution along full length.

Figure 22: LPED surface trickle irrigation system – typical details

E2.4 Low pressure pipe subsurface irrigation systems

LPP subsurface irrigation is similar in design sizing, layout and operation to LPED (Section E2.3), except that LPP only comprises pressure-dosing lines which are laid directly into drainage aggregate (in contrast to lines being nestled within the draincoil for an LPED system).

LPP consists of a series of shallow and narrow (200 to 300 mm deep, 150 to 200 mm wide) aggregate-filled trenches laid within the topsoil and shallow subsoil layer and pressure-dosed by small diameter (25 to 30 mm) perforated plastic pipe laterals. LPP should ideally be used on slopes of less than 8.5° (15%). With trench spacing at around 1 m to 1.5 m, the concept is to wet the topsoil between trenches and maximise evapotranspiration from grass growth on an "areal" basis.

Pumped dosing is essential to ensure uniform spread of effluent into the design area. This needs to be tested during construction using clean water before any backfilling.

E2.4.1 Design sizing

Design sizing of LPP systems has generally been based on subsurface irrigation of primary treated effluent (usually from septic tanks). Table 49 presents the recommended areal loading rates for design sizing of LPP.

Table 49: LPP design sizing summary

Line spacing	Variable but minimum of 1 m (Effective infiltrative area for areal loading is within 1 m of LPED lateral line) [Note 1]	
Emitter squirt hole spacing	Variable	
Emitter squirt hole size	3 mm	
Squirt height	1.5 m	
Dose volumes	Approximately 200 to 300 L/dose	
Design areal loading rates	[Note 2]	
Soil category [Note 3 & 4]	Soil Category 2	3.5 - 4 mm/day
	Soil Category 3	3.5 mm/day
	Soil Category 4	3 mm/day
	Soil Category 5	2.5 mm/day
Depth of lines	100 mm to 200 mm (or in bush areas, pinned to ground surface and covered with mulch or bark)	
Trench dimensions	200 m wide by 200 m deep	

Notes:

1) At 1 m spacing between dose lines, the maximum effective area used for design purposes is 1 m^2 per metre length of line.
2) Loading rates apply to systems on flat to moderate slopes. LPP systems are not an appropriate land application option on slopes greater than 8.5° (15%).
3) Soil category and the corresponding areal loading rate is dictated by the underlying soils not the shallow topsoil (Section B).
4) LPP trenches must be installed within 250 mm of good quality topsoil. LPP is not suited to Category 1 and 6 soils.

The system layout was previously based on 1.5 m spacing between trench centrelines, with the “areal” loading rate applied either to the total area enclosing the trench system (total trench length x 1.5 m), or more conservatively, to a 1 m strip along each trench. The effectiveness of the area between LPP lines for evapotranspiration can be limited (Section E2.1). As the effective soakage area is more likely to be within 1 m or less of the distribution line/trench, the design areal loading rate should be based on a maximum effective area of 1 m per linear metre of line. Where land area is limited, and sites constraints allow, the trench spacing may be reduced to 1 m. LPED design and operation requirements (refer Parts B, C, D, E and F of Section E2.3.2 above) also apply to LPP systems, excluding specifications for a draincoil around the distribution laterals.

Design of the distribution system is discussed in Section E1.4, together with the methods and consequent benefits of ensuring uniform distribution to each trench. A full-scale, clean-water pump test should be undertaken during commissioning (Part (I) of Section E2.3.2) after the lateral pipework has been laid, and before backfilling.

E3.0 Conventional land application systems design

E3.1 Trenches

E3.1.1 Conventional trenches

Conventional trenches must be carefully excavated and prepared to provide for shallow soakage via the base and sidewalls. In the case of shallow trenches, only the basal (or bottom) area is considered the effective application area; the effective infiltrative surface area required is based on this area only. Figure 23 shows a typical conventional trench cross-section.

Design loading rates set out in Table 51 apply to sizing of the basal area of the trench. Sidewall soakage occurs when effluent ponds within the trench; it is not included in the design calculation but provides a factor of safety.

In rapidly draining soils (Categories 1 and 2), trickle loading via gravity flow is not appropriate effluent preferentially drains at the entry point to the trench, eventually leading to creeping failure. Wherever possible, effluent should be pump-dosed to provide for even distribution along the trench (via low pressure pipe or LPED). It is preferable to dose load by siphon if pumping is not possible and the trenches are located at a lower elevation than the septic tank.

The system can be classed as a conventional bed for design purposes if the bottom width of a trench exceeds the combined effective sidewall depth by more than 30% (refer to Section E3.2).

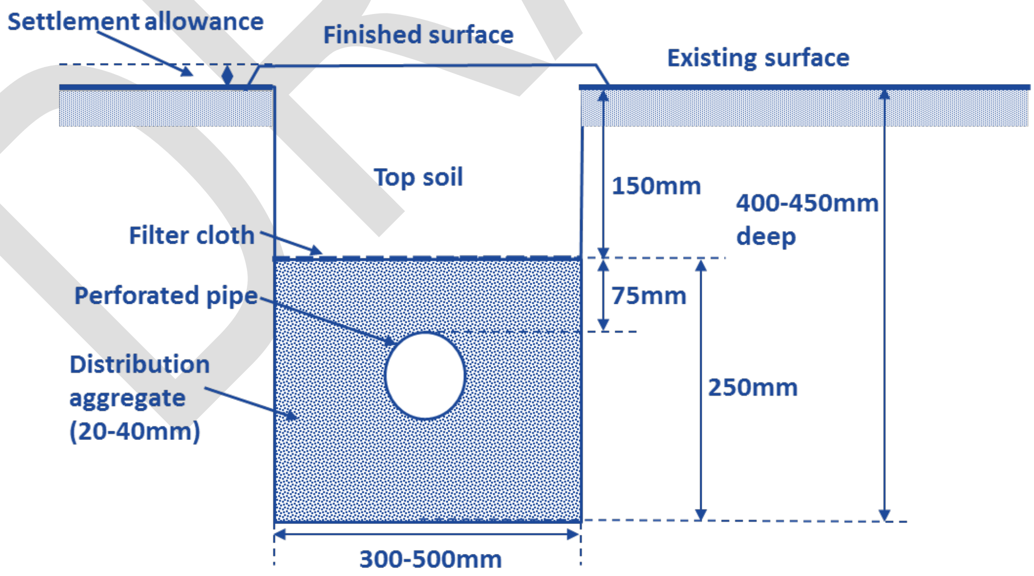


Figure 23: Schematic of a typical conventional trench

E3.1.2 Shallow trench systems

When a site contains at least 600 mm, but less than 1200 mm, of usable soil, shallow trench systems, using the KISS principle (Section E1.1), may be used instead of the conventional 450 mm deep trench system (Figure 23). Depths of 200 to 300 mm provide greater opportunity for sidewall contact. This sidewall contact is enhanced by decreased widths (200 to 300 mm) thereby allowing design loading of primary treated (septic tank) effluent for such trenches installed in soil Category 2 to 4 at up to 150% of the DLR values in Table 51. The resulting increase in loading rate above the normal primary treated effluent values when applied to the narrow trenches will compensate to some extent for the overall increase in trench lengths resulting from the decreased width.

E3.1.3 Discharge control trench system

E3.1.3.1 Overview

Figure 24 shows a typical discharge control trench. Rapidly draining Category 1 soils (gravels and sands) provide little treatment and can result in groundwater contamination. To provide additional wastewater treatment in these situations, a discharge control trench (AS/NZS 1547:2012, Section L6.2) may be required. This is essentially an in-trench intermittent sand filter designed to reduce BOD_5, TSS and faecal coliforms (with negligible reduction in nutrients). Secondary wastewater treatment units, such as AS-AWTS or PBR-AWTS, provide limited reduction in faecal coliforms, unless the resultant effluent is disinfected.

Discharge control trenches are therefore required for primary or secondary treated wastewater where microbial contamination of groundwater is a risk. If nutrients are of concern, it will be necessary to use additional nutrient reduction measures in the wastewater treatment process and possibly, a different land application method.

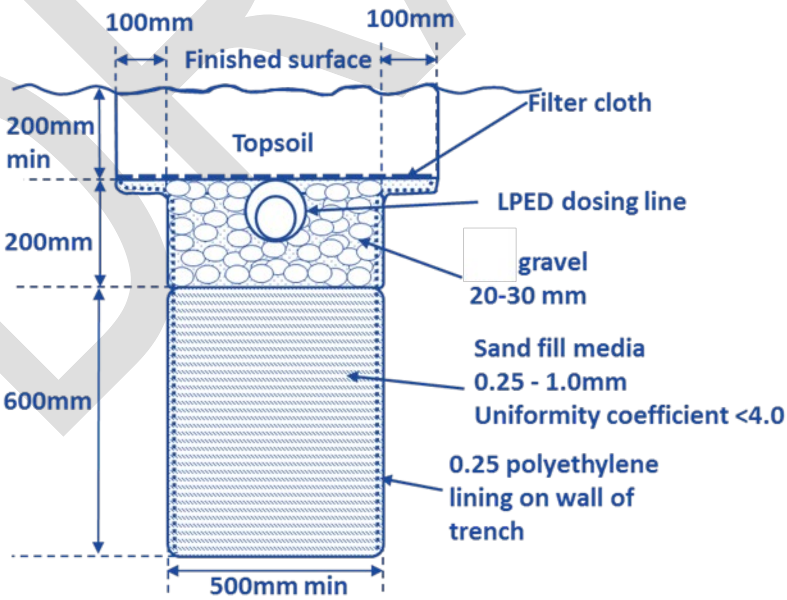


Figure 24: Schematic of a typical discharge control trench

Adapted from: AS/NZS 1547:2012

E3.1.3.2 Discharge control bed system

Where site conditions preclude a discharge control trench system, a discharge control bed may be used. The bed details should be as shown for trenches in Figure 24, with the LPED dosing lines occurring at 600 mm centres.

E3.1.3.3 Minimum wastewater treatment level and distribution

The minimum wastewater treatment, required in association with a discharge control trench, is a septic tank with an effluent outlet filter and pump or siphon dose discharge to ensure distribution of effluent along the entire length of each trench.

Wastewater effluent should be dose loaded to LPED lines located in distribution media laid over the sand in the discharge control trench or bed. For discharge control bed systems, the LPED lines placed at 600 mm centres across the width of the bed may be designed for dose loading all at once (via manifold), or consecutively in sequence (via automatic sequencing valve).

E3.1.3.4 Design loading rate

Design loading rates for discharge control trenches and discharge control beds are provided in Table 50. As noted above, trenches are designed for basal loading only. A discharge control trench has maximum dimensions of 1 m depth and a width of 500 mm. The depth of the trench should ensure that the base of the trench is at least 1500 mm above the highest seasonal groundwater level for wastewater that has only had primary treatment and 1200 mm above that level for wastewater that has been secondary treated (Section D1.2).

Construction details for a discharge control bed should be based on the trenches shown in Figure 24, but modified in accordance with the requirements for distribution as set out under Section E3.1.3.2.

Table 50: Recommended design loading rates for discharge control trenches and beds

Wastewater treatment standard	Effluent quality BOD_5 : SS (mg/L)	Maximum basal loading rate (mm/day)
Primary	>70 : >50	30
Secondary	Better than 20:30	50

E3.1.4 Deep trench systems

E3.1.4.1 Overview

Deep trenches are generally narrow (150-300 mm) and deep (1000-1200 mm) utilising sidewall soakage only for secondary treated effluent. Deep trench systems may be appropriate for use in Category 2 soils where there is at least 1200 mm groundwater clearance from the base of the trench, and no other environmental constraints exist. The acceptable maximum design loading rates to deep trench sidewall area are provided in Table 51.

The design infiltrative surface comprises the total sidewall area of both sides of the trench below the topsoil cover. The basal area is excluded from the design area calculation. Details are provided in Figure 25.

E3.1.4.2 Minimum wastewater treatment level and distribution

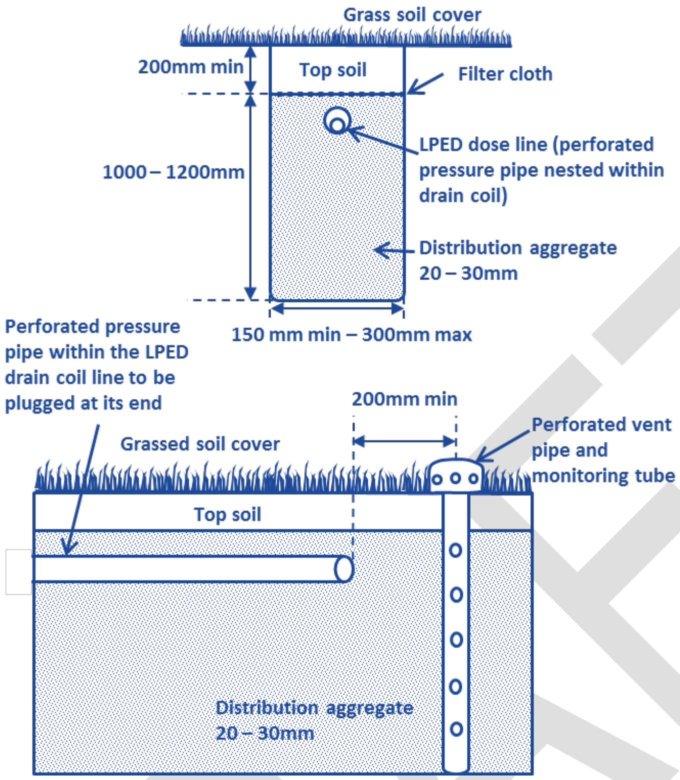


Figure 25: Typical deep trench

The minimum level of wastewater treatment for discharge to deep trenches in Category 2 soils is secondary quality 20:30 g/m^3 (BOD_5 : TSS). It may be appropriate to reduce the groundwater setback distance where wastewater is treated to advanced secondary levels or better.

The secondary treated effluent should be dose loaded via LPED dose lines to ensure even loading of the entire trench length. The dose volume should comprise the full daily flow applied in a single dose from a holding tank or pump sump to maximise contact with sidewalls.

For a typical design (Section E1.3.4), the sidewall contact area varies according to trench width and voids within the trench aggregate. The narrower the trench, the higher the depth of contact with the sidewalls. For the design example in Table 39, a 150 mm wide trench will flood to a depth of 540 mm (54% depth at 50% voids) and a 300 mm wide trench to depth of 270 mm (27% of depth).

Dividing the trench into two to enable alternating daily dosing of each half via an automatic sequencing valve can be used to fill trenches to full sidewall depth at each dose. However, a high-level overflow connection between the twin trenches may be needed to ensure that either trench, if overfilled, does not “break out” to the ground surface.

E3.1.4.3 Design loading rate

Table 51 sets out recommended design loading rates for trenches including conventional, discharge control, shallow and deep trenches, and covering both primary and secondary treated effluent maximum design loading rate values.

Secondary treated wastewater is highly treated in terms of TSS, BOD_5 and ammonia with reduced levels of faecal coliforms. Due to its low organic content, secondary treated effluent also has a relatively low oxygen demand which maintains aerobic conditions in the soils. Therefore, a higher loading rate is allowed for secondary treated effluent, compared to primary treated effluent.

In loading with secondary effluent at the higher design loading rates, designers should consider specific constraints associated with:

- Impact of high rainfall events and durations which may flood trenches and create potential runoff to stormwater and/or surface water features
- Contributions to cumulative effects due to higher density development associated with smaller land application areas and thus potentially, smaller lot sizes.

Risk management measures could include:

- Reducing the DLR in sizing the trench system
- Increasing the reserve area.

Table 51: Recommended design loading rates for trenches

Soil category [Note 1]	Soil texture	Soil structure	Indicative permeability (K_{sat}) (m/d)	Primary effluent mm/day [Note 2]	Secondary effluent mm/day [Note 3]
1 [Note 4]	Gravel and sand	Structureless	>3.0	20 [Note 5]	25 [Note 5]
2 [Note 4]	Sandy loam [Note 6]	Weakly structured	>3.0	20 [Note 5]	25 [Note 5]
		Massive	1.4 – 3.0	15	30
3	Loam	High/moderate structure	1.5 – 3.0	15	30
		Weakly structured or massive	0.5 – 1.5	10	30
4	Clay loam [Note 7]	High/moderate structured	0.5 – 1.5	10	30
		Weakly structured	0.12 – 0.5	6	20
		Massive	0.06 – 0.12	4	10

Soil category [Note 1]	Soil texture	Soil structure	Indicative permeability (K_{sat}) (m/d)	Primary effluent mm/day [Note 2]	Secondary effluent mm/day [Note 3]
5 [Note 8]	Light clay	Strongly structured	0.12 – 0.5	5 [Note 9]	12 [Note 9]
		Moderately structured	0.06 – 0.12	Not advised	10 [Note 9]
		Weakly structured or massive	<0.06	Not advised	8 [Note 9 & 10]
6 [Note 8]	Medium to heavy clay, including swelling and hardpan	Strongly structured	0.06 – 0.5	Not advised	Not advised
		Moderately structured	<0.06	Not advised	Not advised
		Weakly structured or massive	<0.06	Not advised	Not advised

Notes:

1) Refer to Section B for soil category definition.
2) Design loading rates in mm/day equate to L/m²/day.
3) This column represents secondary effluent loading rates developed for the Auckland region based on recommended loading rates specified within AS/NZS 1547:2012.
4) For Category 1 and 2 soils, LPED dose loading is required to ensure even loading of the design area.
5) Conventional trenches or beds are not advisable for Category 1 soils, as well as weakly structured Category 2 soils, when indicative permeability is greater than 3 m/d. The land application systems in these soils require design by a suitably qualified and experienced person, using special distribution techniques (e.g. discharge control trenches).
6) Wind-blown sands are likely to exhibit slow draining characteristics similar to Categories 4 and 5. Caution should be applied in selecting design values for such sands.
7) Trenches should only be considered in Category 4 soils where more appropriate shallow land application options such as drip irrigation or LPED subsurface irrigation cannot be used.
8) For Category 5 and 6 soils, conventional trench systems are not appropriate. Alternative designs based on evapotranspiration or drip irrigation are recommended.
9) Special design requirements and distribution techniques or soil modification may be necessary to allow use of these soils for wastewater land application. For any system designed for these soils, the effluent loading rate should be based upon soil permeability testing results.
10) If K_{sat} < 0.06 m/d, a full water balance for the land application should be used for sizing trenches (refer to AS/NZS 1547:2012 Appendix Q for indicative methodology of water balance calculation).

E3.2 Bed systems

E3.2.1 Conventional bed systems

Conventional bed systems are filled with aggregate and covered with a layer of topsoil. Effluent is dose loaded to cover full infiltration through the aggregate into the surrounding soil. Conventional bed systems are a second-best alternative to trenches and should only be used where the topography and site area is too restrictive for trench installation. Beds should never be installed where room exists for trenches and should only be applied in relatively good draining Category 2 to 3 soils. Discharge control beds should be used for Category 1 soils, except where there are specific environmental concerns regarding bacteria and viruses.

Beds have a limited sidewall area compared to trenches and their design loading rate is reduced as the low ratio of sidewall to bottom area reduces their operational factor of safety. Table 52 sets out bed loading rates for conventional beds. Where the bottom width of a trench exceeds the combined effective sidewall depth by more than 30%, the system can be classed as a conventional bed for design purposes. Design modifications and loading rates for discharge control beds are discussed in Section E3.1.

Table 52: Recommended design loading rates for beds

Soil category [Note 1]	Soil texture	Soil structure	Indicative permeability (K_{sat}) (m/d)	Primary effluent mm/day [Note 2]	Secondary effluent mm/day [Note 3]
1 [Note 4]	Gravels and sand	Structureless	>3	16 [Note 4]	20 [Note 4]
2 [Note 4 & 5]	Sandy loam	Weakly structured	>3	16 [Note 4]	20 [Note 4]
		Massive	1.4 – 3	12	24
3	Loam	High/moderate structure	1.5 – 3	12	24
		Weakly structured or massive	0.5 – 1.5	8	24
4 [Note 6]	Clay loam	High/moderate structured	0.5 – 1.5	Not advised	15
		Weakly structured	0.12 – 0.5	Not advised	Not advised
		Massive	0.06 – 0.12	Not advised	Not advised
5 [Note 6]	Light clay	Strongly structured	0.12 – 0.5	Not advised	Not advised
		Moderately structured	0.06 – 0.12	Not advised	Not advised
		Weakly structured or massive	<0.06	Not advised	Not advised

Soil category [Note 1]	Soil texture	Soil structure	Indicative permeability (K_{sat}) (m/d)	Primary effluent mm/day [Note 2]	Secondary effluent mm/day [Note 3]
6 [Note 6]	Medium to heavy clay including swelling clay and hardpan	Strongly structured	0.06 – 0.5	Not advised	Not advised
		Moderately structured	<0.06	Not advised	Not advised
		Weakly structured or massive	<0.06	Not advised	Not advised

Notes:

1) Refer to Section B for soil category definition.
2) Design loading rates in mm/day equate to $L/m^2/day$.
3) This column represents secondary effluent loading rates developed for the Auckland region based on recommended design loading rates specified within AS/NZS 1547:2012.
4) Conventional beds are not advisable for Category 1 soils, as well as weakly structured Category 2 soils, when indicative permeability is greater than 3 m/d. The land application systems in these soils require design by a suitably qualified and experienced person, using special distribution techniques (e.g. discharge control beds). LPED methods are required to ensure even loading of the design area.
5) Wind-blown sands are likely to exhibit slow draining characteristics similar to Categories 4 and 5. Caution should be applied in selecting design values for such sands.
6) For Category 4, 5 and 6 soils, conventional bed systems are not appropriate. Alternative designs based on evapotranspiration or drip irrigation are recommended.

E3.2.1.1 Construction recommendations

- The recommended minimum bed width is 1 m and the maximum width is 4 m
- Spacing between adjacent beds should be a minimum of 1 m (the recommended normal spacing is 1.5 m)
- The recommended effluent distribution method is dose loading within slotted pipe via a pump or siphon to a distribution box
- Distribution/dose lines to be no greater than 2 m spacing (multiple distribution lines are required for bed widths greater than 2 m).

A typical conventional bed cross-section is shown in Figure 26. The area between and around the outer edges of the beds should be suitably planted to maximise evapotranspiration and assist in managing sideways infiltration of moisture from the edges of the bed into the surrounding soil (see Section E1.5).

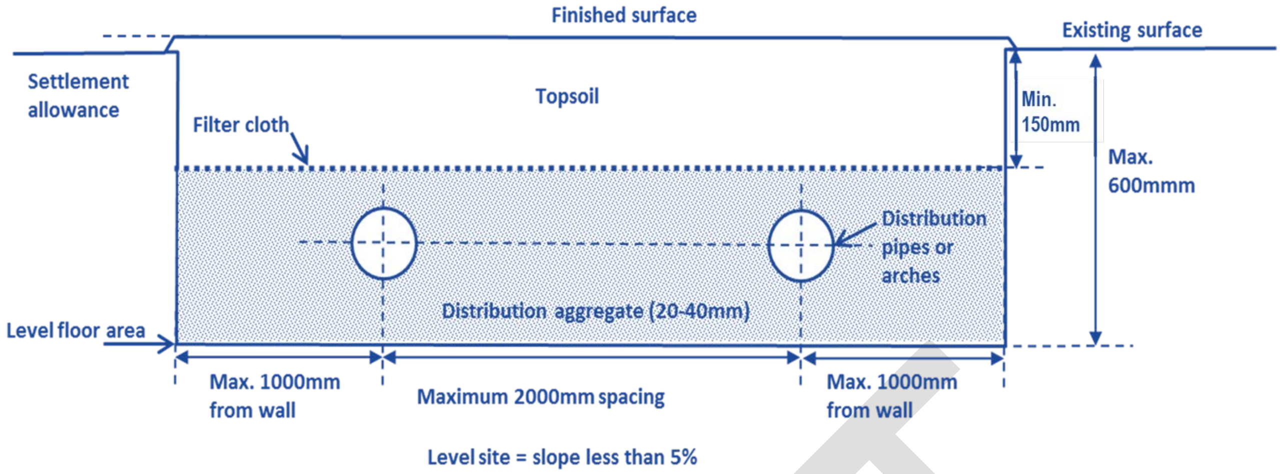


Figure 26: Schematic of typical conventional bed

Adapted from: AS/NZS 1547:2012

E3.2.2 Evapotranspiration seepage beds

In evapotranspiration seepage (ETS) beds, effluent is dispersed into beds planted with shallow-rooted, high evapotranspiration assist plantings. The plants absorb water and nutrients through the roots and release water through the leaves into the atmosphere through transpiration, and sun and wind induced evaporation. Effluent not taken up by plants will be absorbed into the soil.

E3.2.2.1 Function and application

The concept of ETS systems was originally introduced into New Zealand in the 1970s, in response to research undertaken in Canada by Bernhart (Gunn, 2004 and Bernhart, 1973), on the use of evapotranspiration in advanced bed systems. Throughout the 1980s, as an alternative to trench land application, ETS systems became increasingly popular on sites with poor soakage. However more recently, many of these advantages have been replicated and superseded by pressure-compensating drip irrigation (PCDI) systems (Gunn, 2004).

ETS systems are appropriate for use in Category 3 to 5 soils to utilise both subsoil soakage and assist plant evapotranspiration to achieve a more effective land application than that achieved by conventional beds. The applied wastewater infiltrates through the natural soil (via seepage) at a rate determined by the soil structure and texture (soil type). The sand layer overlying the distribution media draws liquid via upward capillary action to feed both water and nutrients to stimulate plant growth and evapotranspiration. During periods of wet weather, surface flows are diverted around the edges of the beds (Figure 27). Rainfall that infiltrates into the surrounding topsoil, and into the bed itself, sits around and above the effluent input. During winter (with low evapotranspiration rates), the effluent water table in the bed rises to take up storage within the media, and sidewall infiltration enables effluent to enter topsoil within the soils between the beds.

Conventional beds are designed for basal seepage only, but the benefits of maximising evapotranspiration in managing effluent moisture levels in the surrounding topsoil is now recognised as important for all bed systems. Good planting of ETS beds and maintenance of vegetation is crucial to achieve the hydraulic absorption required, particularly in Category 4 and 5 soils, where conventional bed land application methods are otherwise unsuitable.

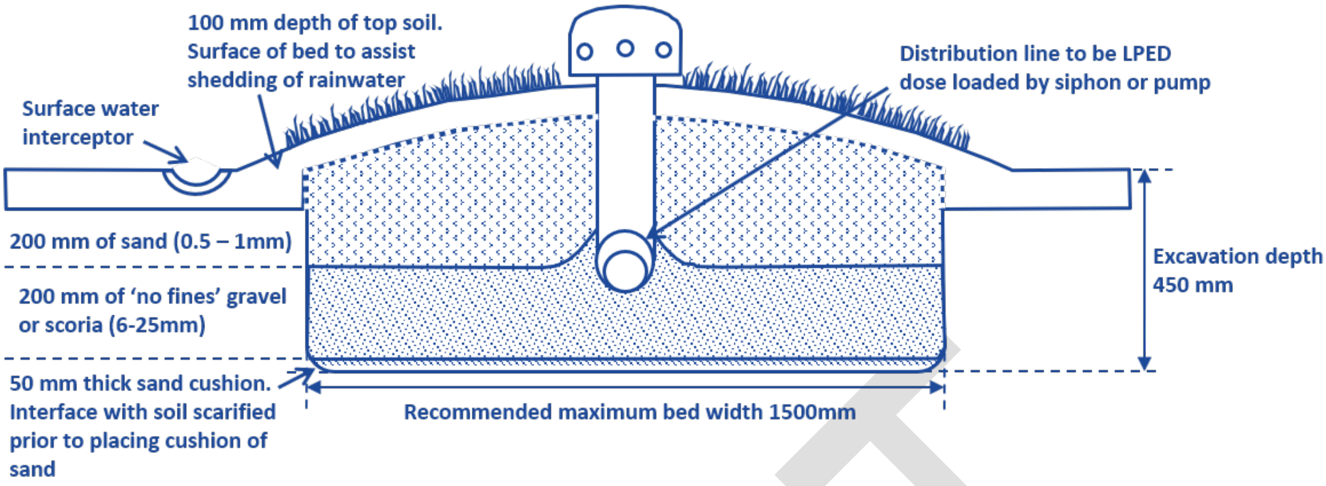


Figure 27: Schematic of typical evapotranspiration seepage bed

Source: Auckland Council Technical Publication 58, 2004

E3.2.2.2 Water balance

Research found that planting could boost pan evaporation rates by two to three times that of bare soil rates. In windy locations, the "clothesline[10]" effect accentuates this evapotranspiration mechanism significantly. The ETS bed loading rate of 5 mm/day to 15 mm/day (Table 53) incorporates an allowance for subsoil seepage together with the effects of pan evaporation plus a multiplier to allow for seasonal transpiration.

The ETS bed will fill with applied effluent during winter while sidewall seepage into the topsoil on the downslope side of the ETS system distributes flow into the space between individual beds. This expands the available evapotranspiration area under the lower winter evapotranspiration rates and, although the soil becomes wet and possibly spongy, planting between the beds will accommodate the moisture from the effluent input in proportion to its availability.

E3.2.2.3 Design considerations

The following items are important considerations in the design and installation of ETS systems (Figure 27):

- The ETS system enables beds to be used in Category 4 to 5 soils where conventional bed systems are unsuited
- Sufficient topsoil depths are required on site (a minimum of 150 mm) to handle controlled sidewall seepage under winter conditions
- Pre-treatment should be a minimum of 4500 L septic tank system (for a standard household) and effluent outlet filter
- Effluent should be dose loaded (by pump or siphon) to ensure even loading of the design basal area at all times
- Maximum bed length should be 20 m to ensure even distribution over the entire infiltration surface
- Minimum media depth should be 200 mm of sand overlying 200 mm of gravel or scoria and 50 mm cushion sand

[10] The effect of wind action over vegetation cover

- Surface water cut-off drains should be provided to intercept and divert stormwater away from the land application area
- Groundwater cut-off drains should be installed where a high seasonal groundwater table affects the land application area
- A minimum of two beds or contour trenches should be installed (each half the design area)
- Distribution lines to be vented at each end
- A 100% reserve area for future extensions should be available (where performance of the initial system does not, due to unforeseen circumstances, match design expectations)
- The bed should be mounded to shed rainwater and planted with grass
- Selected evapotranspiration plantings (such as those listed Table 41 and Table 42 of Section E1.5) can be utilised on the downslope edge of beds or trenches to control seepage or can be planted on the beds.

It is also recommended that where the bed width is 1500 mm or more, two parallel distribution pipes should be used to ensure even loading across the width of each bed.

E3.2.2.4 Sizing and loading

Design area to be sized based on soil type and basal area as follows:

Table 53: Evapotranspiration seepage bed design loading rates

Soil category	Soil structure	Indicative permeability (K_{sat}) (m/d)	ETS beds loading rate (mm/day)
1	Structureless	>3	Not advised
2 [Note 1]	Weakly structured	>3	Not advised
	Massive	1.4 – 3	Not advised
3	High/moderate structure	1.5 – 3	15
	Weakly structured or massive	0.5 – 1.5	12
4	High/moderate structured	0.5 – 1.5	12
	Weakly structured	0.12 – 0.5	8
	Massive	0.06 – 0.12	5
5	Strongly structured	0.12 – 0.5	8
	Moderately structured	0.06 – 0.12	5
	Weakly structured or massive	<0.06	5 [Note 2]

Soil category	Soil structure	Indicative permeability (K_{sat}) (m/d)	ETS beds loading rate (mm/day)
6	Strongly structured	0.06 – 0.5	Not advised
	Moderately structured	<0.06	Not advised
	Weakly structured or massive	<0.06	Not advised

Notes:

1) ETS systems are not normally applicable for Category 2 soils, but where used, are to be loaded at the recommended rate for conventional beds (Section B).
2) If K_{sat} < 0.06 m/d, a full water balance for the land application should be used for sizing trenches or beds (refer to AS/NZS 1547:2012 Appendix Q for indicative methodology of water balance calculation).

Generally, a basal loading method should be applied in sizing the ETS beds. An areal loading check may be undertaken to take into consideration the total available area including the beds, the natural soil space between each bed, and a narrow border of not more than 500 mm width around the outer edges of the bed system.

For ETS, on Category 5 tight clay soils under winter conditions, wastewater in the land application area can seep into the downslope topsoil increasing the total area available for evapotranspiration, and thereby compensating for the lower winter evapotranspiration rates. When an “areal” loading check is being carried out, it is recommended that the areal loading rate over the total area enclosing the ETS bed system is no more than 3 mm/day for primary effluent and no more than 5 mm/day for secondary effluent.

E3.2.2.5 Bed construction details and maintenance requirements

The standard width for ETS beds is recommended at 1500 mm. However, beds can be 1800 mm to 3000 mm wide, provided they are suitably crowned to shed rainfall. Contour ETS beds of 450 mm to 750 mm width can be used on sloping sites (Figure 28). It is recommended that standard beds and contour beds are spaced at least 2 m edge to edge.

It is recommended that where an ETS system is being considered, a comparison is made with PCDI systems. There may well be economic benefits associated with the provision of secondary treatment and PCDI, particularly as the “areal” loading rate check will designate a site area requirement for the ETS beds and 100% reserve area that takes up more lot area than that required for PCDI systems.

Sand size of 0.5 to 1 mm is recommended for ETS beds. It is important that sand size is not too fine, as fine sand reduces void storage space even though this may assist the capillary action which encourages evapotranspiration. On the other hand, if sand is too coarse, then capillary action is likely to be inhibited.

Grass cover over the beds should be regularly maintained to avoid grass overgrowth and vegetation collapse onto the bed surfaces. Likewise, plantings between or downslope of ETS beds should be checked regularly to ensure optimum growth conditions for maximising evapotranspiration.

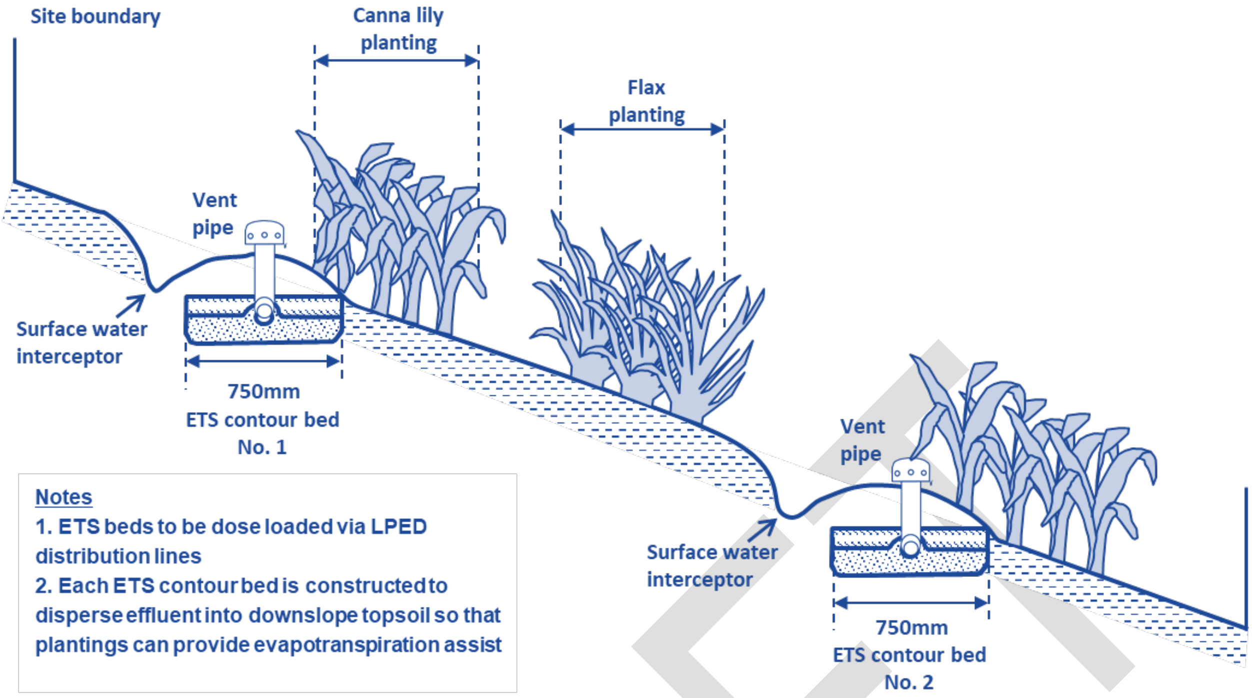


Figure 28: Evapotranspiration seepage contour beds

Adapted from: Auckland Council Technical Publication 58, 2004

E3.3 Mound land application systems

E3.3.1 Overview

Mound land application systems have been used in the past for conditions where shallow soils overly a hardpan or rock, or where water quality protection is required for a high water table in permeable soils and conventional disposal trenches are unsuitable. The mound provides for distribution of effluent onto a layer of sand of at least 600 mm depth to provide treatment before entering the natural soil and then diffusing into the surrounding soil above the hardpan or water table. The sand-fill media provides additional treatment of the primary treated wastewater in a similar manner to an intermittent sand filter.

Effluent must be dose loaded via pumping into the mound distribution system to ensure even distribution across the entire infiltration surface. This also maximises wastewater treatment potential within the sand media to avoid short-circuiting through only a section of the media with resultant ineffectual treatment. Treatment should be via a minimum 4,500 L septic tank with an effluent outlet filter or better.

E3.3.2 Wisconsin Mound systems

The Wisconsin Mound on-site land application system (Figure 29) is utilised on relatively flat sites up to 1.7° (3%) to a slope site of less than 8.5° (15%), and must have at least 600 mm of unsaturated, undisturbed topsoil and subsoil.

The mound is constructed directly onto the natural ground surface that is ploughed or cultivated prior to mound construction. Wastewater treatment takes place within the sand fill of the mound, enabling the unit to be placed on rapidly draining or moderately draining subsoils. Mounds can also be utilised on filled areas.

Location of mounds on steeper slopes increases the risk of wastewater breakout from the downslope edge requiring design of a toe, or toe extension, to assist with assimilation of applied wastewater. Level sites allow wastewater to spread over the infiltration surface under the entire mound area but can result in wastewater mounding in Category 3 soils. Mounds should always be located on the upper portion of slopes, not at the slope base.

On sloping sites, the mounds should be designed and constructed to be as long and narrow as possible and to extend along the contour to ensure that toe-loading limits are reduced and to allow applied effluent to move away from the toe area within the natural soil without breaking out of the toe. The effective basal area taken for disposal in the sloped system is decreased over that for flat land (Figure 30). When determining the required mound basal area, the design should take into account the sand-fill loading rate, the underlying natural soil loading rate and for sloping sites, the linear loading rate along the downslope edge of the toe.

The advantages of Wisconsin Mounds are:

- They increase the vertical setback distance between the effluent infiltration surface (the top of the sand fill) and the water table or hardpan
- They provide additional wastewater treatment
- They provide treatment and slow effluent flow over Category 1 soils.

The disadvantages of Wisconsin Mounds are:

- They can be expensive to construct
- They require a relatively large land area dedicated to wastewater application only, although the entire area is less than that which may be required for PCDI
- They are only suitable for gently sloping sites of less than 8.5° (15%).

E3.3.2.1 Media requirements

The sand-fill media acts as a sand filter, which treats primary or secondary treated wastewater. All aggregate used for construction of the sand-fill and distribution bed must be free of clay and silt and the grain size must be appropriate to avoid clogging (if too fine) and rapid infiltration (if too coarse). The sand-fill grain size and infiltration capacity will determine the distribution bed basal area.

Background regarding suitable grain size distribution for use as sand-fill media in mounds is presented in Appendix O with recommended design in Table 54.

Table 54: Mound media specification and loading rate sizing criteria

Parameter	Design specification
Distribution bed media	Aggregate grading: 20 – 60 mm non-crushed Loading rate: Not to exceed 30 mm/day for primary effluent, 40 mm/day for secondary effluent [Note 1]
Sand media	Grading: D_{10} 0.3 – 0.5 mm UC = 1 – 4 [Notes 2 & 3] Loading rate: • 30 mm/d for primary effluent [Note 4] • 40 mm/d for secondary effluent
Mound basal area	Loading rate: • Soil Category 1 and weakly structured 2 24 mm/day • Soil Category massive structured 2 and 3 16 mm/day
Mound toe length	Maximum linear loading rate [Note 5] 50 L/day per linear metre of length along downslope edge (Length B)

Notes:

1) Distribution media loading rate and the sand fill loading rate is the same.
2) D_{10} refers to the effective grain size that is the 10% by weight for a wet sieve analysis.
3) UC is uniformity coefficient defined by the D_{60}/D_{10}.
4) The application of primary treated effluent into the aggregate distribution bed can result in bio-slimes which can form a clogging mat on the sand-fill infiltration surface if the loading rate is too high. Use of finer sand-fill media than specified above risks clogging the filter and will require a significantly lower application rate.
5) Refer to Figure 29 and Section E3.3.2.2 for illustration of mound toe length B (i.e. L-2K).

Mounds are appropriate for Category 1 to 3 soils but are not appropriate for Category 4 to 6 soils. For Category 1 to 3 soils, secondary treatment and PCDI systems are better suited to shallow topsoil and high water table conditions for which mounds would have been previously used.

E3.3.2.2 Design considerations

The mound must be designed for the sand-fill loading rate, basal-soil loading rate and where the site is sloping, the linear-loading rate of the toe area. The basal area sizing is calculated on the area beneath and downslope from the distribution bed. Wastewater is to be dose loaded into the distribution bed and distributed within the bed by LPED or similar, to ensure even loading at a loading rate not exceeding 30 mm/day for primary treated effluent.

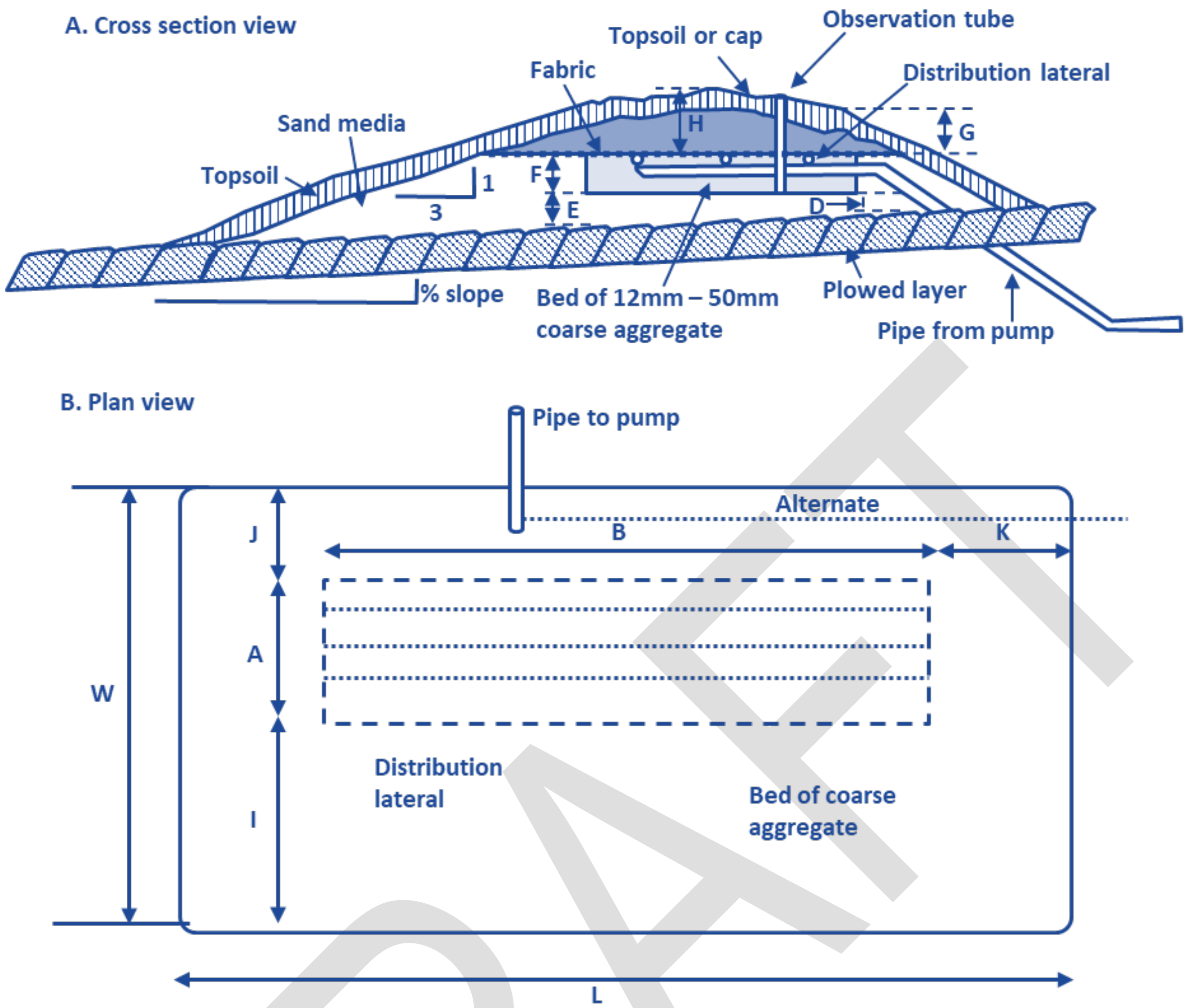
Figure 29 and Figure 30 show the design layouts for a Wisconsin Mound on a flat site (3% or less), and sloping site (between 3% and 15%) respectively. The designer should size the basal area to ensure there is sufficient area to absorb all the applied wastewater before it reaches the edge(s) of the mound or breakout will result. This will require determining the soil category and assigning the basal loading rate. In the case of level sites, the entire basal area [basal length (B) x basal width (W)] is used to calculate the mound basal area in which case, I and J will be equal. In all cases, the maximum side slope is 1 in 3 from the base of the distribution bed. This will set the actual areal footprint of the mound.

For a sloping site (Figure 30)., only the mound area downslope of the distribution bed is used to calculate the design (basal) infiltration area [B x (A + I)]. Where experience shows the basal area loading rate is inadequate to prevent downslope seepage occurring from time to time, then a toe extension should be installed. Alternatively, to minimise the toe leak potential, the toe-linear loading rate should be decreased resulting in longer mounds. The downslope width I is determined by ground slope and the requirement for a maximum mound face angle of 1 to 3. (Refer to Appendix N for an example calculation). The toe length is [L – (2 x K)](equals B, the distribution bed length).

For a level site, since I equals J, the design (basal) infiltration area is [B x (A + 2I)] that is [B x W]. Some design guidelines designate the design basal area as [(B + 2K) x W] that is [L x W]. This includes the perimeter area at both ends of the mound length. However, if the basal area for the level site is designed on [B x W] then the perimeter area at each end of the resulting mound [2K x W] provides a factor of safety in design sizing.

The designer should always include a work sheet when submitting designs for a Wisconsin Mound to enable a simple check of the design for correctness. A worked example for a Wisconsin Mound on a sloping site is provided in Appendix N.

A 6 m setback is required when the mound is located upslope from buildings and on slow draining soils.



Basal area sizing: Flat site, enclosed by (B x W)

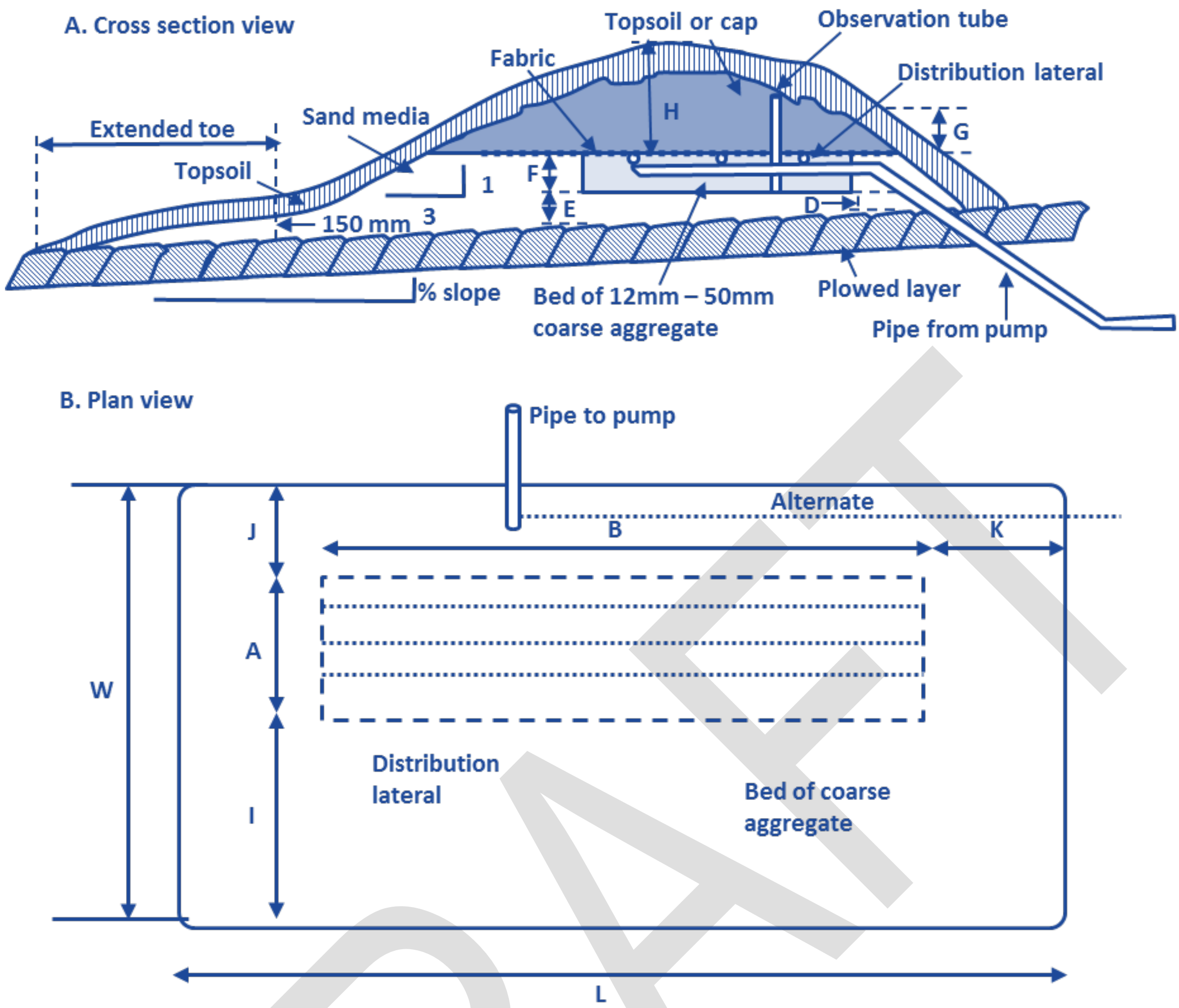
Typical dimensions

Distribution bed:
- A = 1200 to 2000mm
- F = 225mm
- G = 150mm
- H = 300mm

Mound:
- D = 600mm;
- E = 600mm on flat ground and >600mm on sloping ground
- J = 3m on flat ground at 1 in 3 side slope
- I = J on flat ground
- K is determined by height of finished mound and 1 in 3 side slope

Figure 29: Wisconsin Mound details for a flat site (less than 3%)[11]
(Source: Auckland Council Technical Publication 58)

[11] Where land is flat i.e. I=J then the plan view would show the distribution bed placed centrally within the disposal area.



Basal area sizing: Sloping site, enclosed by B x (A + I)

Typical dimensions

Distribution bed:
A = 1200 to 2000mm
F = 225mm
G = 150mm
H = 300mm

Mound:
D = 600mm;
E = 600mm on flat ground and >600mm on sloping ground
J and I are determined by ground slope and 1 in 3 mound face slope, and then adjusted by slope correction factors for sloping ground
K is determined by height of finished mound and 1 in 3 side slope

Figure 30: Wisconsin Mound details for a sloping site (between 3 and 15%)

(Source: Auckland Council Technical Publication 58, 2004)

E3.3.2.3 At-grade fill system

Where there is at least 900 mm between undisturbed topsoil and subsoil overlying a hardpan or rock layer or elevated groundwater, the sand-fill normally present in a Wisconsin Mound can be omitted and the distribution media bed laid directly on the topsoil.

All other details are as for the mound design – including the ploughed topsoil and pressure distribution into perforated pipe. A minimum of 300 mm of soil-fill is placed over the distribution media bed and tapered some

1500 mm beyond the edge of the bed. Grass is planted as ground cover (Converse, Tyler, & Peterson, 1998). Design sizing is based on length times the width of the media bed (i.e. the effective width) at the following loading rates:

- Category 1 soil 24 mm/day
- Category 2 and 3 soils 16 mm/day
- Category 4 to 6 soils Not recommended.

The mound should be long and narrow, and for a sloping site should ensure that the toe loading rate is kept low by reducing the effective width and increasing the system length. Design toe loading rate depends on depth of useable subsoil above a constraining layer. 50 L/day per lineal metre is satisfactory with soil depth up to 1 m. Toe loading rate should be reduced for shallower soil depths. Effective width on flat ground is the width of the aggregate bed. For sloping ground, it is the distance between the top distribution pipe and the downslope edge of the aggregate bed.

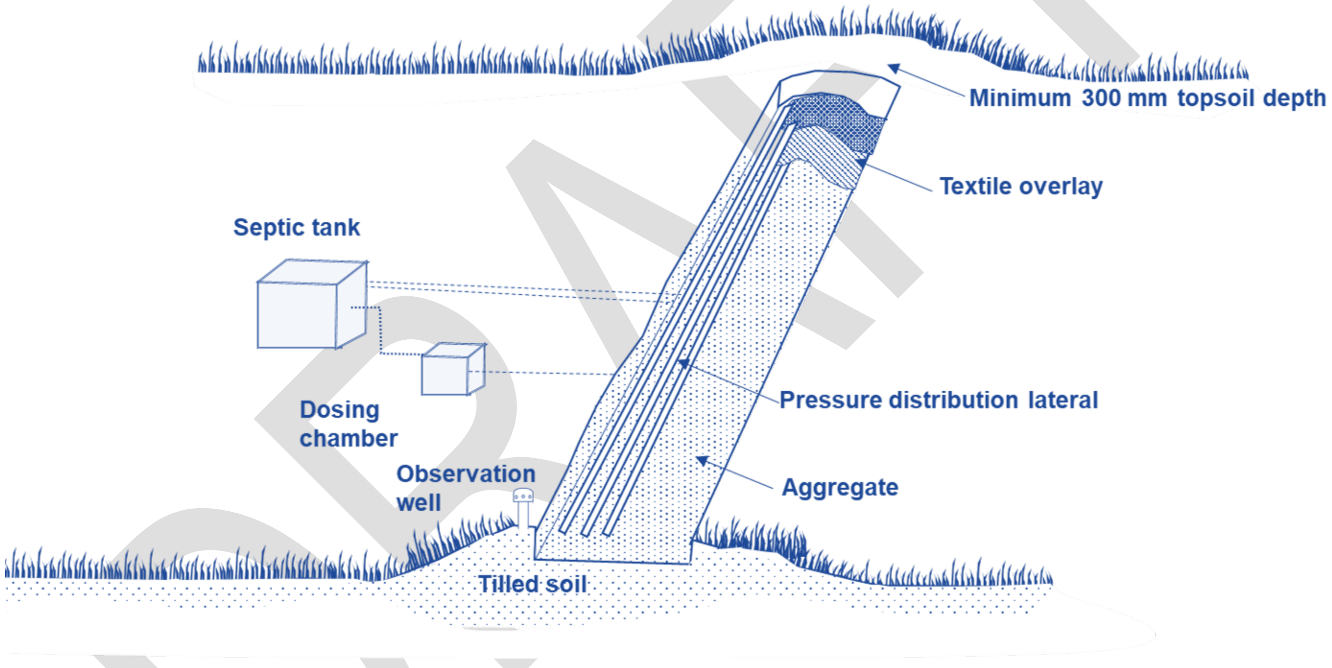


Figure 31: Schematic of Wisconsin mound at-grade design

E3.3.2.4 Mound construction

Key construction components for mound systems include site preparation, placement of fill, construction of the aggregate distribution, grading and seeding the topsoil, etc. It is extremely important that the construction methodology does not affect the integrity of the mound system and the underlying receiving soils. Any heavy construction equipment should not be allowed within the fill area or immediately downslope of the system. Placement of fill material should not occur when the soil moisture is too high.

The natural ground surface onto which the mound fill is to be laid should be cultivated carefully to a depth of 180 to 200 mm by plough or tined cultivator (not rotary hoe). Sand media fill of 0.3 to 0.5 mm size (uniformity coefficient 1 to 4) should be carefully spread over the design surface and built up to full 600 to 700 mm depth with manual or light machine compaction. The preferred distribution aggregate (granular media) size is 20 to 60 mm, with the initial layer of 150 mm laid before the pressure distribution laterals are placed. The distribution system should then be pump tested with clean water to confirm distribution effectiveness, following which the aggregate is completed to the full 225 mm depth before covering with fabric or permeable non-woven geotextile to prevent infiltration of soil into aggregates. The entire mound should be covered with additional sand/loam fill and topsoil and seeded to grass.

Appropriate cut-off drains and diversion ditches should be constructed upslope to divert groundwater or surface water from interfering with the system.

F System construction, commissioning, operation and maintenance

Table of Contents

Tables

F1.0 On-site wastewater system installation

Correct installation and operation management (operation and maintenance) is vital to ensuring that the designed on-site wastewater system meets its ultimate performance objectives. This chapter outlines the key steps recommended as 'best good practice' for on-site wastewater system installation, commissioning, operation and maintenance. In all instances, safe design processes should be in place. Key performance requirements are presented in Table 55.

Table 55: Key performance requirements for construction, commissioning, and maintenance of on-site wastewater systems

Performance category	Performance requirements	Relevant sections
Site preparation/site work	• Ensure site stability. • No adverse impact on other site features, nearby structures and receiving environment.	F1.1/1.2 F1.3
Construction/installation	• Comply with AS/NZS 1546.1, AS/NZS 1546.2, and AS/NZS 1546.3 and AS/NZS 1547 and manufacturers' specifications. • Follow construction/installation instructions. • Prepare management plan. • Obtain construction certifications. • Prepare as-built plans and drawings. • Obtain producer's statements.	F1.3 F3.3
Commissioning	• Prepare commissioning plan. • Follow commissioning procedures, including pre-commissioning check, cold commissioning and hot commissioning. • Prepare an updated system management plan.	F2.0
Operation/maintenance	• Establish a signed maintenance contract. • Follow the operation instructions and maintenance schedules stipulated in the management plan. • Follow monitoring programme as required by the management plan. • Obtain and document maintenance and monitoring records.	F3.0

F1.1 Site protection

Site soils must be protected during construction of dwellings, driveways and other property facilities to avoid impacting their ability to assimilate wastewater. In addition, poor on-site wastewater system construction can significantly reduce soil porosity and potentially cause the land application system to fail hydraulically. Avoid compacting, moving or disturbing soils to avoid negative impacts on their ability to assimilate wastewater.

The proposed treatment and land application area should be clearly identified and defined with safety fencing before construction begins. This ensures all parties, including the construction manager and on-site wastewater system installer, are aware of the need to protect that area, and to keep heavy machinery and material stockpiles off. All requirements should be written into the contract to ensure all protective measures are met. Site access points, traffic areas, stockpile areas and equipment storage need to be specified on the drawings provided to the contractor.

F1.2 Site preparation

The soil moisture should be assessed as defined in Appendix B1.5 before any site preparation activities such as clearing and surface preparation for filling commence. In non-granular soils, compaction will occur if the soil is near its plastic limit. This can be tested by removing a sample of the soil and rolling it in the palm of the hand. If the soil fails to form a 'rope', it is sufficiently dry to proceed.

Clearing should be limited to mowing and raking to minimise soil disturbance. If trees must be removed, they should be cut at the base of the trunk and removed without heavy machinery; stumps should be ground out if necessary. Grubbing should be avoided. If areas on the site are to be filled, the surface should be mould boarded, or chisel-ploughed, parallel to the contour (usually to a depth of 150 to 250 mm) when the soil is sufficiently dry, to ensure maximum vertical permeability. The organic layer should not be removed, but if it is, it should be stockpiled and replaced. It is not appropriate to scarify the surface with the teeth of an excavator or rotary hoe.

Excavation activities can significantly reduce soil porosity and permeability as traffic and vibration can compact and smear the soil's infiltrative surface. Only lightweight excavators without front-end loaders and blades are appropriate. Any disturbance to the exposed infiltration surface should be avoided, including keeping equipment off the infiltration land application area.

Any smeared soil surfaces should be scarified and gently raked before any media such as aggregate is installed. If gravel or other drainage aggregate is used, an excavator bucket should be used to place the aggregate in the trench/bed rather than dumping it directly from the truck. If damage occurs, removing as much as 100 mm of the compacted layer might be necessary to regain the natural soil porosity and permeability. This can be costly, reduce the separation distance to the restrictive horizon, and could place the infiltration surface in an unacceptable soil horizon.

Before excavation begins, soil within the proposed infiltration surface elevation should be below its plastic limit. The infiltration surface should be covered on the same day any excavation is undertaken to avoid loss of permeability from wind-blown silt or raindrop impact. An alternative is to use lightweight gravelless systems, which reduce the damage and speed up the construction process.

The area around the site should be graded as the installation nears completion. Any up-slope surface and/or subsurface water cut-off drainage should be installed to divert surface run-off or groundwater away from the land application area. The backfill over the infiltration surface should be mounded slightly to allow for settling; this will also reduce the potential for ponding. Finally, the area should be seeded or planted and mulched.

F1.3 Critical aspects of on-site wastewater system installation

On-site wastewater systems should be installed so as not to affect any structural elements of buildings. All components should comply with setbacks from boundaries, buildings, surface water and groundwater (refer to Section B5.

The following factors should be considered by the on-site wastewater system installer during the installation of a wastewater treatment unit and land application system.

Manufacturers and designers should provide clear site preparation and installation instructions, including:

- Land excavation required for each part of the on-site wastewater system
- Preparation of the bottom and sides of any excavation
- Methods for safe handling and lifting of components
- Any necessary precautions needed where tanks could be subject to high groundwater or flotation, such as the requirement to fill all tanks with water immediately following installation to prevent flotation
- Fitting of all pipes and attachments, e.g. inlets, outlets partitions, outlet filters, etc.
- Backfilling around tanks, including type of backfill material and method
- Commissioning procedures
- Planting requirements and timeframes.

F1.3.1 Treatment units

Manufacturers and designers should provide clear treatment unit installation instructions, including:

- Specifications for installing all unit components, according to the approved design plans (including separation distances)
- Directives for excavation which must be in accordance with safe practice procedures
- All tanks must be watertight and constructed to the standards in AS/NZS 1546.1
- All joints (pipe to pipe and pipe to tank) must be watertight, glued and socketed
- All access lids to tanks must include risers with plastered watertight connections and watertight lids
- All lids must be able to be fastened to prevent unauthorised access
- There must be no vehicle access across the completed on-site wastewater system (however there should be provision for emergency access to the wastewater treatment plant for maintenance purposes)
- All stormwater must be diverted around the treatment plant
- All electrical connections must be safe, operate correctly and comply with current codes (AS/NZS 3000)
- All pump chambers must have 24 hours of emergency storage and high-level alarms.

F1.3.1.1 Primary treatment unit installation

The performance requirements and criteria for septic tanks are set out in AS/NZS 1546.1:2008, "*On-Site Domestic Wastewater Treatment Units - Part 1: Septic Tanks*".

The availability of pre-cast panel modular septic tanks for *in-situ* assembly raises the question of their structural integrity and water tightness following installation. Potential problems can include distortion, breakage, and the failure of the seal between panels and resultant water infiltration or exfiltration and associated public health and environmental risks. Septic tank integrity is extremely important, particularly in New Zealand where soils are prone to shrinkage and swelling in response to variations in seasonal moisture content. It is important the *in-situ* installation is undertaken by the manufacturer, or agents who are fully trained and accredited by the manufacturer, and that appropriate warranty provisions are incorporated in the sale and installation agreement.

AS/NZS1546.1:2008 requires that maintenance access is provided to septic tanks; lids (and risers where necessary) should be located just above the ground surface level and designed to prevent unauthorised access. This should include measures to ensure that children cannot open lids.

Tanks should be located on the property to provide access by pump-out equipment. Vents should be designed so that there is no opportunity to desludge through the vent pipe. In addition, the access riser to the effluent outlet filter should be marked with signage saying, 'NO ACCESS FOR DESLUDGING'.

Traditional septic tanks should be pumped out at a minimum of three-yearly intervals or prior to the sludge and scum level reaching 50% of the tank volume. Larger septic tanks (which also include an effluent outlet filter) have better solids retention, stabilisation and consolidation. This is because of their larger settling volume, combined with effluent outlet filter, which reduces the frequency of preventative pump-outs. Scum and sludge monitoring will enable determination of the need for pump-out.

Chemical additives may have a role as a temporary measure in controlling odour in situations where septic tanks are overloaded or poorly maintained. Normal tank operation utilises bacteria from within the waste (USEPA, 2002); chemical additives can interfere with bacterial metabolism and interrupt the treatment process. The use of septic tank additives (inorganic or organic chemicals, or biological agent such as yeast, bacteria or enzymes) is therefore not recommended. The exception to this may be the addition of a “starter” from an existing septic tank that is used to introduce a mature microbial population into the wastewater treatment unit.

F1.3.1.2 Secondary treatment unit installation requirements

All secondary treatment units should be installed by registered drainlayers, or by a suitably trained and experienced installer. Installation should be undertaken in accordance with the specifications provided by the manufacturer and the general practices covered within this chapter.

Within three months of commissioning, the supplier and/or installer should inspect the unit to verify that it has been properly installed and they should collect a sample of the final effluent in a sterilised sample vessel (minimum 1 L). The sample should be taken to a registered laboratory for analysis of biochemical oxygen demand (BOD_5) and total suspended solid (TSS) concentrations.

If the first sample is not within the BOD_5 and TSS limits specified in Section D, then weekly sampling should continue. Any recent modifications made to the on-site wastewater system operation should be recorded until the average sample results verify that the system performance is within the specified BOD_5 and TSS limits or until an exemption to those standards is approved by the regulatory authority. The weekly sampling should then be continued until the discharge quality meets the manufacturer's design specifications for at least three consecutive samples.

Sampling for faecal coliforms (or *Enterococci* spp. or *E. coli* levels - depending on the receiving environment) and nutrient levels (total nitrogen, ammonia, nitrate and total phosphorus) may be required if the system is intended to reduce pathogens or nutrients. These sampling results should also be continued until the discharge quality meets the manufacturer's system design specifications for at least three consecutive samples.

F1.3.2 Land application area

Manufacturers/designers should provide clear land application system installation instructions, including:

- Installation of all land application system components to be in accordance with the approved design plans, including separation distances
- Avoidance of the use of heavy machinery and minimising damage to the soil by using lightweight machinery
- Ensuring excavation is only to be undertaken when soils are sufficiently dry to prevent smearing and sealing of infiltrative surfaces
- Ensuring that no surface water flow can access the land application area
- Fencing or planting the land application area's perimeter to prevent vehicle access
- Planting the land application area to maximise evapotranspiration nutrient uptake
- Specification that the terminal ends of all irrigation lines are marked, and ports are flushed.

F1.3.3 Plans and certification

Post-installation plans and certification is critical to the ongoing operation and maintenance of a well performing on-site wastewater system. Having plans and certification in place can save a lot of time and cost in the long term.

Accurate as-built plans, prepared by the installer, should include:

- The location and capacities of all land application system components (including the primary and reserve land application areas)
- Critical components of the land application system e.g. flush points, separation distances, air relief valves and non-return valves
- The location of electrical cables installed as part of the on-site wastewater system
- The location of sewer pipes discharging to the treatment unit
- The location of all rising mains to land application areas

- The location of alarm controls and panels, recirculating valves, splitter valves, monitoring ports and shutoff valves
- Identification of separation distances from buildings, property boundaries and surface water.

The installer should provide certification confirming correct on-site wastewater system installation. Certification needs to:

- Confirm that all components have been installed according to the approved design plan
- Confirm that water conservation devices specified in the design have been installed to the correct specifications
- Specify any variations from the design plan (Note that further building consent approvals may be required).

A summary of those certifications, or producer statements, which are required along the various implementation stages of on-site wastewater system design, installation, and operation is provided in Appendix F.

An on-site wastewater system management plan is best prepared by the system designer or engineer, prior to commissioning and should be regarded as an evolving document with further information on optimum operation of the system added to it over time as experience improves. The plan should then be updated following commissioning and installation inspection.

Manufacturers are required to provide independent assurance that their products meet the requirements of this guideline document.

F2.0 Commissioning and testing

All components of the on-site wastewater system should be installed in accordance with the specifications provided by manufacturers. During installation, either the manufacturer or the designer should provide appropriate construction inspection. Once the on-site wastewater system is confirmed to be properly constructed, relevant construction certificates should be completed and filed appropriately with other relevant reports and certificates.

Commissioning of the on-site wastewater system, including all mechanical and electrical components, should be carried out in accordance with the manufacturer's start-up procedures.

F2.1 Commissioning plan

The manufacturer or designer should develop a commissioning plan (either as a stand-alone document or as a section within the final design report) and the documentation, which is required for each commissioning step, incorporating details of any consents or permits. The commissioning plan should include a risk management evaluation plan which sets out contingency measures to be implemented in the event of any on-site wastewater system failures during commissioning and testing. The plan should provide a detailed commissioning and testing programme and include at least the following information:

- Pre-commissioning testing programme
- Commissioning and testing methodologies proposed
- Details of dates, flows during those dates and all forward planning and events required to allow the commissioning to progress smoothly
- Commissioning testing plans
- Static and dynamic electrical testing, including temporary generator operation capability and electrical protection devices if necessary
- All check sheets (example on-site wastewater system check-sheets are provided in Appendix J)
- Other relevant documents.

F2.2 Commissioning and testing steps

Commissioning and testing is the responsibility of the designer. Records should be kept to demonstrate successful commissioning. Testing includes:

1. **Pre-commissioning tests:** Demonstrate and document that the system is safe to use and ready for cold commission.
2. **Cold commissioning tests**: Undertaken with clean water under manual control. May include the contained use of chemicals to test the ranges and accuracy of instruments and equipment.
3. **Hot commissioning tests:** Undertaken with wastewater.

F2.2.1 Pre-commissioning

The pre-commissioning step demonstrates and documents, without running the on-site wastewater system, that each part of the system is safe to use, meets the design requirements and is ready for cold commissioning.

F2.2.2 Cold commissioning

Treatment process cold commissioning is undertaken with clean water under manual control wherever appropriate. Cold commissioning may also include the contained use of chemicals to test the ranges and accuracy of instruments and equipment. Commissioning should be conducted as set out in the cold commissioning schedules for each specific piece of equipment being used and to the manufacturer's requirements.

Cold commissioning is considered complete when the tests demonstrate that the whole facility can receive and treat wastewater to the requirements set out in the design report. This should be in the absence of:

- Any adverse environmental or health and safety effects
- Unintended spillages or discharges from the process
- Blockages
- Other malfunctions that could result in delays or damage to the on-site wastewater system
- Exceedance of any consent conditions that have been signed off by the designer or manufacturer with no objection.

F2.2.3 Hot commissioning

Hot commissioning may commence once cold commissioning has been completed. A list of key commissioning procedures for various components of an on-site wastewater system is provided in Table 56.

Table 56: Recommended key commissioning procedures for on-site wastewater systems

Commissioning components	Key procedures
Pre-commissioning	
Treatment units	• Check that all works are complete. • Drawings are checked and signed off by the designer or manufacturer as being complete and as-built. • Check that all safety measures are in place and that all systems, pipework overflows and bypasses are fully functional and have been cleaned and checked. • Site pressure test all pipelines, vessels, cylinders and containers. • Undertake hydrostatic tank or pipe testing, if it has not been undertaken by providers. • Check motor rotation. • Confirmation that point-to-point continuity exists. • Loop testing and function testing including logic, sequencing and controls. • Blower discharge pipe air leak testing and valve stroking. • Check electrical protective device ratings and settings.
Distribution and land application system	Check that: • Pumps, siphons, and all mechanical equipment are installed as specified by the manufacturer. • The emergency storage volume above alarm level is appropriate. • The distribution pipework is clean. • The land application area is located as specified in the design. • All components of the land application system have been constructed as specified in the design. • All control and flush valves can correctly open and close when instructed by the control system. • All items in the filter/control chambers and main pump chamber are firmly mounted with struts according to the specifications to avoid movement upon on-site wastewater system start-up and shut down. • Inverts of beds or trenches are truly level. • The soils exposed in the vicinity of the application field are the same as those found in the site and soil evaluation, without signs of compaction during construction. • The planting programme is complete and that installed plants are as specified and are healthy and well established.
Cold-commissioning	
Treatment units	• All inspections and (dry or cold) functional tests demonstrate that each item of the on-site wastewater system operates within the design range. • Confirmation that each component of the on-site wastewater system operates safely and is acceptable to be used in the hot commissioning step. • Clean water aeration tests. • Instrument calibrations.

Commissioning components	Key procedures
	• Each piece of mechanical and electrical equipment should be tested and checked for tolerance and accuracy, confirmation of control linkages to other associated controlled equipment (and all feedback loops) and the fail-safe settings demonstrated.
Distribution and land application systems	• Cold commissioning of land application systems should be carried out after all components have been installed but prior to covering the effluent distribution system with aggregates and topsoil. • Check that all distribution equipment such as pumps, siphons, filters, etc. are operating as specified by the design. • Initially, the on-site wastewater system should be run with all land application field zone valves closed and the main line flushing to the dosing chamber or wastewater treatment unit, until all construction debris has been removed. Each zone should be flushed for at least 10 minutes or until the flush water is clear, whichever is longer. • Start dosing cycles with clean water according to the dosing chamber design (i.e. pump or siphon). • Record the dosing volume and dosing time of each dosing cycle, ensure that the dosing volume falls within the designed range. • Each irrigation zone should be run for at least 20 minutes and thoroughly checked for leaks. • Check that all air-release valves function appropriately. • Ensure that all level switches, alarms, and other control functions of the dosing chamber operate appropriately as specified. • Ensure that the automatic sequencing valves rotate consistently with each dosing cycle. • If an automatic backwash filter does not automatically backwash during the cold commissioning run, a manual backwash cycle should be induced and returned to automatic operation. • Check that uniform distribution is achieved along the length of each distribution line (i.e. uniform flow or height from each squirt hole or emitter). • During the pressure-reducing or pressure-sustaining tests, the pressure should be adjusted and set to ensure that the pressure within any portion of the land application system does not exceed the manufacturer's specifications under any circumstance. • If a chemical injector system is installed, it should be demonstrated to work to specification by manual operation.
Hot-commissioning	
Treatment units	• Undertake all appropriate inspections and functional tests to demonstrate that each item of plant or equipment can be relied upon, including an alarm list and list of set-points. • All controllers of the treatment plant need to be tuned during hot commissioning. • Demonstrate that the wastewater treatment unit can operate safely and as specified and designed under prevailing wastewater influent operating conditions, meet the consent requirements or meet the design requirements.
Distribution and land application systems	• The land application system will be covered appropriately after the completion of cold commissioning. • Check that all components of the distribution and land application system operate appropriately during the hot-commissioning period of the treatment units.

F3.0 Operation and maintenance

Homeowners need to understand the impact of their water use and behaviours on their on-site wastewater system. Concentrated use of high water consumption appliances over a short time period can affect system performance and may need to be moderated.

Some chemicals and solids can lead to system failure (Appendix G) and should be avoided or minimised. These include:

- Laundry detergents (particularly bleaches, phosphates, chlorine, sodium and whiteners)
- Bathroom cleaning fluids (chlorine/bleaches)
- Solids such as wet wipes and any sanitary materials that can cause blockage and maintenance issues
- Antibiotics and anti-bacterial detergents (e.g. triclosan)
- Use of in-sink grinders which increase the total organic load to the system
- FOGs.

F3.1 Importance of regular maintenance

Routine maintenance is vital for optimising the performance of wastewater treatment units and land application systems. This will extend their effective life and minimise potential for adverse effects on the receiving environment. Ignoring on-site wastewater system maintenance requirements may result in problems and ultimately failure. It can also lead to further environmental and health risks including:

- Foul odours, e.g. from the discharge of hydrogen sulphide gas from anaerobic wastewater
- Anaerobic and clogged soil conditions resulting in effluent breakout
- Sewage contamination of groundwater and surface water
- Increased levels of pathogens in the effluent
- Increased risk of human contact with treated/partially treated sewage (with associated pathogens)
- Increased potential for attraction of pests including flies and rodents
- Increased impact on amenity values, such as odour nuisances and decreased property values.

Regular maintenance can reduce potential costs incurred by system failure. All onsite wastewater system owners have a duty under S17 of the RMA (1991) to '*..avoid, remedy or mitigate any adverse effects on the environment arising from an activity….*'

Table 57 provides an overview of the maintenance required for different parts of the on-site wastewater system. More detail is provided in Appendix G.

Table 57: Maintenance overview for on-site wastewater systems

System	Maintenance overview
Primary treatment units	• Regular septic tank pump-outs are required to prevent sludge and scum build-up. • All tanks need to be pumped out before sludge and scum levels occupy half the tank volume. • Annual sludge depth checks are recommended; monthly where there is a high proportion of blackwater in the wastewater flow, such as public toilet facilities and/or food premises. • Regular checks of the septic tank outlet filter are required with excess slime growth hosed back into the septic tank. Under no circumstances should the filter unit be hosed completely clean.
Secondary treatment units	• Site owners must follow the supplier's instructions for required elementary inspections and contact the supplier whenever anything untoward is identified. • Inspections by experienced contractors should be done at least twice a year. • If routine sampling shows an on-site wastewater system is not consistently achieving the required discharge quality standards, more frequent inspections should be undertaken until the on-site wastewater system stabilises.
Specialised treatment system components	• These include chlorination systems, wastewater reuse treatment systems, composting systems and other land-based treatment systems. • Each has specific operational and maintenance requirements.
UV systems	It is critical that sufficient UV radiation is transmitted for effective die-off of micro-organisms. Core maintenance requirements for any UV system (USEPA, 1999) include: • Cleaning Quartz sleeves or Teflon tubes by mechanical wipers attached to the tubes, ultrasonic means, or by chemicals • Manual chemical cleaning • Annual replacement of UV tubes • Replacement of quartz sleeves after five years, unless otherwise advised by the supplier • Ventilation of ballast (control) box to protect against excessive heating • Replacement of ballast (control) box after 10 years.
Land application systems	The owner should make regular inspections of the land application field every 2 – 4 weeks. Checks and procedures include: • Check for even wastewater distribution within and downslope of the land application field • Flush irrigation lines to avoid solids or slime build-up • Control root intrusion • Check for even plant growth across the field and ensure that flush valves and lines remain accessible for maintenance purposes • Regularly remove weed growth • Check vent pipes and distribution boxes are in place and maintained • Ensure children, stock and vehicles are excluded from the land application field.

F3.2 Maintenance contracts

All secondary system owners should enter into a maintenance contract with an appropriately trained and experienced professional maintenance contractor. Inspection frequency depends on:

- System type and component quality
- Specific details in the design and quality of the installation
- Plant performance and whether the required discharge quality standards are routinely met
- The number of people using the on-site wastewater system, occupancy/usage fluctuations and water conservation practices
- Flow volumes, BOD_5 and FOGs in the raw wastewater
- The owner/operator's knowledge of the on-site wastewater system and the level of routine maintenance inspections/system maintenance they can, and actually do, undertake
- Precautions taken to minimise the BOD_5 and toxic/chemical loads.

Maintenance inspections should be done at least twice a year; more frequently for unstable systems and less frequently for those used intermittently, i.e. for short consecutive holiday periods, making annual inspections more appropriate, but this being at the risk of the system owner.

A signed maintenance contract commencing within six months of commissioning is recommended. Actual dates of maintenance inspections can be confirmed at the as-built stage, post-commissioning.

The system owner is responsible for maintenance to ensure it continues to perform as intended and without adverse effects beyond the site boundary. Maintenance should be undertaken in accordance with the installer's management plan (refer to Section F3.3).

F3.3 Management plans

The designer/installer/supplier should provide a management plan prior to commissioning so that the owner has a clear understanding of maintenance requirements from day one. The scope and content of a management plan is shown in Table 58. The final management plan should be updated and completed following commissioning and installation and provided at the as-built plan stage.

Examples of on-site wastewater treatment unit and land application system maintenance summary checklists are provided in Appendix J.

Table 58: Management plans

Content	Description
Contact details	• Designer, supplier, installer, recommended maintenance contractor/s, including 24-hour emergency contacts.
Design discharge volume	• The scope the system is designed for, including peak occupancy/usage and corresponding design discharge volume. Summarise within the Loading Certificate.
The process flow diagram	• Include process components, hydraulic profile, electrical controls and alarm circuitry, timer settings, mechanical controls, flow splitting, proportioning equipment, any special equipment and configurations that need to be set manually or electronically.
The process description	• Physical and biological processes, flow controls, dosing volumes/cycles and loading rates.
A copy of the approved design site plan	• And/or the as-built plans (all plans should be dated).
The wastewater treatment unit maintenance requirements	• Key components, inspection procedures, key maintenance requirements, maintenance frequencies; person responsible (otherwise the purchaser should receive data sheets specifying design start-up and long-term operating parameters).
The land application system maintenance requirements	• Operation and maintenance requirements; inspection procedures and frequencies; who is responsible for undertaking maintenance.
Preventative maintenance worksheets	• Checklists of key operational and maintenance requirements covered above.
Monitoring and reporting requirements	• Frequency and procedures for monitoring and reporting records.
A contingency plan/troubleshooting guide	• Include an action plan for mechanical or biological emergencies or other key failures. • Record all irregular incidents response actions taken to be recorded in the site log.
Educational material of routine precautions	• Details of water-producing activities, devices which can impact the system, water conservation, caution discharging strong chemicals/cleaning agents. • Further details of key matters a householder should be aware of are covered in Appendix G.
Copies of relevant regulatory documentation	• Building consent, discharge consent, land use consent, consent including any monitoring conditions.

F3.4 Monitoring

On-site wastewater system monitoring is the most important tool for verifying performance, assessing the validity of the original assessment of environmental effects and as a means of justifying design assumptions.

In addition to regular contracted monitoring services by a professional operator (as covered in Section F3.2), the most important form of monitoring by the user/owner is regular inspection of the wastewater treatment unit and land application system for any signs of on-site wastewater system malfunction. These system checks should be done routinely in accordance with the management plan (and with attention to problem-solving). Additional system monitoring procedures may be required as a condition of consent. Table 59 provides recommended requirements for system monitoring.

Table 59: Recommended on-site wastewater system monitoring

Monitoring parameters	Monitoring frequency	Notes
Flow rate	Monthly	• Flow meters are recommended in all systems to verify the design specifications and inform the owner/operator of the likelihood of overstressing the wastewater treatment unit and land application system.
Effluent quality		
BOD_5 TSS Faecal coliform or *E. coli* pH Nutrients (TN, TP, NH_4-N, DRP, NO_3-N, etc.)	Fortnightly, monthly, quarterly or six-monthly	• Frequency is determined based on complexity of the on-site wastewater systems and perceived risks of failure. • Nutrients monitoring will be necessary when nutrient reduction is required in the design.
Free available chlorine (FAC) Turbidity or UV transmittance	Weekly	• Frequent FAC residual monitoring is required when treated wastewater (or greywater) reuse system is in place for indoor toilet flushing or other purposes with potential public health risks. Levels of free available chlorine should be 0.5-1.0 g/m^3. • Frequent turbidity measurement is required when a UV disinfection system is in place to ensure optimum UV performance.
Receiving environment monitoring (groundwater or surface water)		
BOD_5; Nutrients (TN, TP, NH_4-N, DRP, NO_3-N, etc.) TSS; Pathogen indicators (Faecal coliform or *E. coli*) Ecological parameters (in-stream ecology and/or terrestrial ecology)	As specified in consent	• The frequency and parameters are determined based on the sensitivity of the receiving environment and the perceived risks associated with the on-site wastewater system.

F3.5 Remedial procedures for failure

Table 60 outlines a five-step procedure for responding to system failure. Further information on solutions for various types of possible on-site wastewater system problems and options for avoiding and addressing such problems is provided in Appendix H and Appendix I.

Table 60: Procedure for investigating and remediating on-site wastewater systems' failure

Identify failure	Possible symptoms, e.g. foul odours and/or wastewater breakout, rank or poorly growing vegetation, poor drainage off-site land or water contamination, and surface water discolouration/eutrophication.
Collect important information	• Site constraints, soil type, groundwater depth • Design wastewater flow volume capacity • Treatment unit design • Land application system design and limitations • Reticulation pipe work layout • On-site wastewater system age • Use/occupancy numbers, extent/frequency of occupancy • Daily flow records/estimates • Recent changes in circumstances • Maintenance record
Investigate problems	• Problems identified from on-site inspection • Problems identified from surrounding environment inspection • Current land application area loading rate versus design loading rate • Wastewater treatment unit performance and discharge quality • Flow records of actual water usage/wastewater discharge volumes
Complete investigation to determine cause	• On-site wastewater system components testing and monitoring • Potential for stormwater/groundwater infiltration • Treated wastewater sampling and analysis • Wastewater breakout/seepage sampling and analysis • Soil bore logs within and downslope of land application area • Occupancy records • Maintenance records • Changes in wastewater character • Increases in organic load and/or FOG concentrations • Condition of receiving soils and vegetation • Condition of downslope soils and water quality
Identify solutions and initiate corrective action	**Get help** • Engage experienced wastewater design engineer/practioner • Engage supplier/maintenance contractor • Arrange one-off/ongoing septic tank pump-outs and off-site land application **Fix system** • Upgrade/service wastewater treatment unit • Repair damaged components • Install outlet filter to septic tank if not in place • Increase capacity • Extend/replace land application system • Improve condition of plantings and maintenance of healthy vegetation • Commence/renew maintenance contract **Reduce flows** • Install flow reduction valves on all water outlets/taps • Improve water conservation • Eliminate baths, decrease shower duration • Decrease washing machine usage • Eliminate stormwater infiltration • Install surface/subsurface water cut-off drains • Reduce organic waste in discharge and avoid toxic discharges

G Risk management

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G1.0 Overview

G1.1 Risk management

The risk management process involves identifying hazards, determining their risk, and mitigating or eliminating them.

Hazards, as they relate to on-site wastewater systems, can be broadly grouped into three types:

Public health	• Contamination of potable water supplies, public exposure to seepage, or to contaminated land during construction.
Environment	• Poorly treated wastewater can have detrimental effects on soils, surface water, groundwater, air (odour) and noise.
System:	• Systems that do not treat wastewater to a sufficiently high standard, are undersized, are not maintained, or where equipment failure causes overflow.

G1.2 Designing for risk prevention

Good design incorporates risk-elimination or mitigation measures aimed at preventing future malfunction and system failure.

A number of risk-elimination or mitigation measures are already built into the performance and design criteria for on-site wastewater systems through the processes and procedures recommended in Sections B through F. For example, the recommended separation distances for land application systems are established to mitigate risks on various site features. This section expands on these in-built, risk-reduction measures and assists stakeholders in identifying additional and site-specific risks that will need to be addressed.

Climate change brings uncertainty regarding future climatic conditions, potential changes to groundwater levels, increased intensity and duration of rainfall events, or potential drought conditions. New Zealand Land Treatment Collective Technical Review 35, "*Daily impact of climate change on land application of waste*" (2018) provides more detail.

Table 61 presents the elements of on-site wastewater system design and identifies those risk-reduction measures inherent in good design.

Table 61: Examples design elements and risk reduction measures

Elements of design, installation and management	Risk-reduction measures
Site and soil investigation	• Selection of appropriate design soil horizon. • Identifying environmental features to be protected. • Setting appropriate separation distances.
Design (on-site wastewater system selection and sizing)	• Ensuring designer is a suitably qualified and experienced person. • Determining appropriate level of wastewater treatment. • Matching on-site wastewater system selection to site and soil constraints. • Including on-site wastewater system certification and warranty. • Providing conservative factors of safety in the design (such as design flows). • Provision and sizing of a reserve area for extension or duplication of the selected on-site wastewater system. • Designing for climate change.
Installation	• Ensuring builder and drainlayer are suitably qualified and experienced persons. • Provision of detailed installation and commissioning instructions. • Comprehensive inspection during installation. • Requiring commissioning sign-off by installer/designer.
Operation and maintenance (O&M) and performance monitoring	• Provision of specific O&M guidelines/instructions to the home owner/occupier. • Setting up an O&M contract for regular servicing and monitoring inspections performed by a suitably qualified and experienced person. • Providing a loading certificate for information of owner/occupier.

G2.0 Risk management process

Risk management is a design-led approach involving the steps in Figure 32. The process requires continual review and evaluation, from initial planning through to operation of the on-site wastewater system.

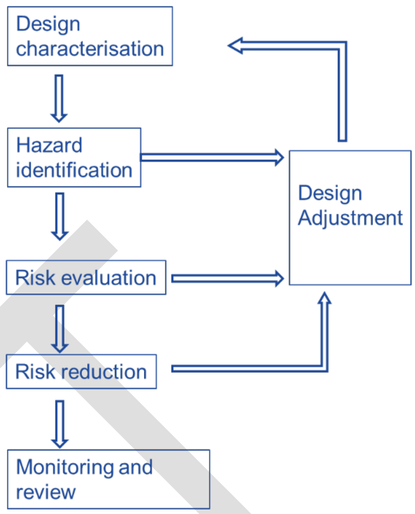

Figure 32: Hazard identification and risk management process

G2.1 Design characterisation

Table 62 provides guidance on elements to consider for design and risk assessment.

Table 62: Examples of questions used to characterise design elements

Feature	Questions
Receiving environment	• What is the topography of the site? • What site and soil conditions are present at the site? • What is the natural drainage prior to development? • What is the extent and location of the groundwater and surface waters? • What environmental or cultural sensitivities are present at the site? • Is there potential for cumulative effects? • Is there a risk of coastal inundation?
Public exposure	• Is there recreational use of nearby waterways? • What is the potential for humans to be exposed to wastewater from the development? • Is there food collection (shellfish, watercress, etc.) within the receiving environment? • Is drinking water sourced from areas (such as groundwater and surface water) that might be impacted by the wastewater discharge?
Wastewater service to be provided	• What is the maximum expected occupancy? • What are the expected maximum usage patterns (permanent/intermittent residence)? • What are the expected maximum average and peak flows? • What is the expected raw influent quality?

Feature	Questions
Wastewater treatment unit	• What treated effluent standard is required? • What are the design components of the wastewater treatment unit? • What is the expected effluent quality from the designed wastewater treatment unit? • What are the operation and maintenance requirements of the wastewater treatment unit? • What performance monitoring requirements are needed, and how regularly are they needed?
Land application system	• What land application systems have been considered? • What type of land application system has been chosen? • What distribution system has been chosen? • What are the operation and maintenance requirements? • What are the performance monitoring requirements?
Regulatory and administrative process	• What are the resource and building consenting requirements and what are the timelines for approvals? • What is required in terms of professional expertise: trained and experienced technical specialists, installers and maintenance contractors? • What provision is made for ensuring a maintenance contract is in place and the owner has ready access to it?

G2.2 Hazard identification

Hazard identification should be undertaken at each stage of design, construction and operation. Table 63 sets out some of the questions that should be asked to identify hazards. The impacts of the identified hazards may have environmental, public health or administrative effects, or a combination of these; the consequences of which can be used to prioritise risk.

Table 63: Examples of questions used to understand hazards associated with the design

Feature	Questions
Site and soil investigation	• What constraints are apparent from the soil texture and structure, slope, groundwater, surface water, clearances, etc.? • How will the development impact soil, subsoil and vegetation? • What might the effects on groundwater and surface water be? • Are there possible cumulative effects (both internal and external to the property)? • Could climate change impact the design?
Design	• What are the risks associated with the selected on-site wastewater system? • Is there a performance certification for the on-site wastewater system? • What risks are imposed by under design? • What risks are imposed by over design? • What is the expected energy use of the on-site wastewater system? What might happen if there is a loss of power?

Feature	Questions
Installation	• Are there risks associated with where the on-site wastewater system is sited? • What is the known integrity of existing and proposed pipe network? • What is the quality of the workmanship (both existing and proposed)? • What inspection process is being used to validate all the above questions?
Commissioning	• How will commissioning be done? • Is the distribution system effective? • What is the proposed inspection process? • How will overall commissioning be evaluated?
Operation	• What is the variability in the influent and effluent quality and quantity? • What happens in power outages or when blockages occur? • Does the on-site wastewater system have an alarm response? What maintenance is required? • What happens when an on-site wastewater system malfunctions? What are the indicators of failure? • What happens if an on-site wastewater system overflows (including both treatment unit and land application)? • What happens if effluent surfaces in the land application area?
Maintenance and monitoring	• What are the implications of infrequent/inadequate inspections? • What are the implications of poor/no monitoring? • What are the implications of non-renewal of maintenance contracts?
Usage	• What happens when the on-site wastewater system is underloaded? • What happens when the on-site wastewater system is overloaded? • What happens when influent contains substances which can impact the function of the microbiota in the on-site wastewater system (such as household chemicals, medications etc.)?
Regulatory/ administrative	• What on-site wastewater system documentation is going to be maintained (e.g. assessments, installation methodology)?

G2.3 Risk evaluation

Risks are prioritised by their likelihood and consequence as well as timeframe, spatial extent of the impact and whether it is cumulative. Risk evaluation comprises three elements:

- Potential effects of key risk areas on the on-site wastewater system’s long-term performance
- Potential effects on intermittent and/or cumulative adverse impacts
- Is the level of risk: low, moderate or high?

Figure 33 can be used as a guide in determining the level of risk based on an assessment of likelihood and consequence. Examples of risks are provided in Table 64.

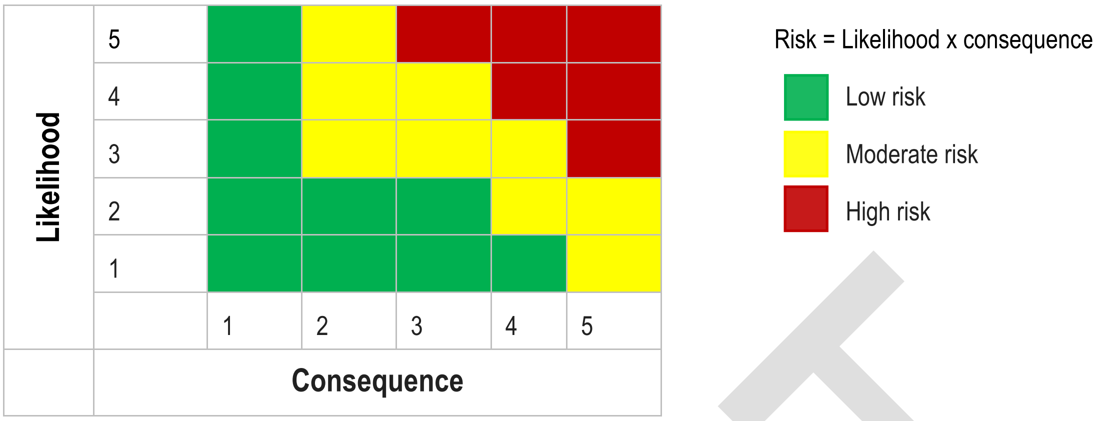

Figure 33: Template of risk level

Table 64: Examples of risk, as a function of a hazard's likelihood and consequence

Hazard	Likelihood	Consequence	Assigned risk
Land application area located on Category 5 soils adjacent to potable water bore used by local school.	#5: Highly likely since soils have been identified as poor.	#5: Public health consequences are high with potential for multiple illnesses amongst children.	High
Primary treatment unit is at a holiday home, used intermittently by multiple occupiers. The on-site wastewater system overloads and land application area becomes inundated and flows to a recreational beach.	#3: On-site wastewater system is poorly designed for intended use and likely to fail intermittently.	#4: Users of the beach may be exposed to partially treated wastewater from the on-site wastewater system.	Moderate
Secondary treatment unit on large private property is not maintained regularly and has no alarm system. On-site wastewater system operates sub-optimally and effluent quality is poor prior to discharge to land.	#2: Likelihood increases over time as maintenance is deferred.	#2: Neither public health nor environmental consequences occur.	Low

G2.4 Risk reduction

Once a risk has been identified and prioritised, it needs to be removed or reduced, with the highest risk prioritised first. The ability to reduce or eliminate risks is influenced by factors such as available technology, budget, regulatory framework, timeframes and technical resources. All risks and risk-reduction measures should be documented in the design report.

Risk-reduction measures need to cover:

- Protection of public health and receiving environment
- Responding to site and soil constraints
- Incorporating factors of safety into design
- Responding to climate change
- Preparation of installation and commissioning requirements
- Setting out operation and maintenance requirements
- Maintaining long-term monitoring.

Table 65 provides examples of risk-reduction measures based on hazard identification and risk evaluation. These examples are not exhaustive, and each individual design situation will have its own risk profile.

G2.5 Monitoring and review

Hazard identification and risks may change over time so it's important to monitor and review the process at each stage of the design, construction and operation of the on-site wastewater system. Risk monitoring and review should also occur whenever maintenance or repair activities are undertaken. As part of the review process, the risk reduction measures should be:

- Monitored to ensure they are implemented
- Reviewed to ensure they achieve the desired outcome
- Documented.

The design report should include:

- A narrative characterising the on-site wastewater system elements
- A summarised risk management response schedule.

An example of a risk management response template is provided in Appendix K.

Table 65: Risk reduction measures

Risk Identification		Risk evaluation	Risk reduction measures
Design feature	**Risk element**	**Potential risk scenarios**	
Site and soil investigation	• Constraints (climate, soil, slope, ground water, surface water, clearances) • Impacts on soil, subsoil, vegetation • Groundwater and surface-water effects • Off-property cumulative effects • Stakeholder consultation (if required)	• High rainfall • Shallow and/or poor soils • Steep slopes • Shallow groundwater • Surface water features • Flooding potential • Nutrient build-up in soils • Nutrient and bacterial transport to groundwater • Nutrient and bacterial transport to surface water	• Surface water diversion measures • Reduce DLR or DIR values • Import good quality topsoil • Adjust clearance distances • Provision and designation of reserve areas • Plant vegetation to assist evapotranspiration • Nutrient reduction treatment stages • Disinfection treatment • Subsurface and/or surface drainage controls • Extend or replace land application system to reserve area.
Design	• System selection • Performance certification • Under-design • Over-design • Energy use	• Structural and materials' integrity of the treatment unit • Assessment of occupancy levels/requirements • Presence of treatment unit performance monitoring/ certification information • Availability/reliability of power supplies	• Compliance with treatment unit standards • Loading certificate to define capabilities of on-site wastewater system • Flow balancing within treatment unit and land application storage capacities • Set level of treatment appropriate to land application system • Selection of DLR or DIR values • Alternative/backup energy sources
Installation	• System siting • Integrity of pipe network • Workmanship • Inspection process	• Lack of or reduced exposure to sunlight • Quality of plumbing materials • Experience of tradespeople • Frequency and thoroughness of inspections	• Avoid shading by excessive vegetation/trees • Specification and check of materials • Qualifications and experience of contractors • Designer on-site inspections

Risk Identification		Risk evaluation	Risk reduction measures
Design feature	**Risk element**	**Potential risk scenarios**	
Commissioning	• Distribution effectiveness • Inspection process	• Inadequate/uneven distribution • Distribution checks omitted • Effluent seepage to surface soils	• Dose loading of land application systems • Check of even distribution throughout dosing lines • Commissioning signoff by installer/contractor and designer
Operation	• Influent variability • Power outages • Potential blockages • Alarm responses • System malfunctions • Overflows from treatment and land application systems • Effluent surfacing throughout land application system	• Discharge of solids to land application area • Addition of new water using appliances (e.g. food waste disposal units) • Occupier checks of on-site wastewater system performance • Lack of response to, or disabling of, alarms • Occupier switching off on-site wastewater system to save power • Power outages • Access to land application areas • Presence of children in household • Presence of pets in household	• Provide effluent outlet filter on all primary treatment units and septic tanks • Loading certificate to define capabilities of on-site wastewater system and consequences of misuse • Provision of emergency response contacts • Remote monitoring provisions • Provision for reporting performance issues (ready access to contact details) • Fencing/planting of land application areas • Sign-posting land application areas • Extension of land application system into reserve area • Implementation of remedial works
Maintenance and monitoring	• Inadequate inspections • Lack of monitoring • Non-renewal of maintenance contracts	• Owner/occupier's neglect of O&M requirements • Failure of land application system	• Provision of maintenance contracts • Provision of operation and maintenance procedures specific to installed on-site wastewater system • WOF inspection procedures (owner capability versus specialist capability) • Provision of remediation guidelines • Extend or replace land application system into reserve area

Risk Identification		Risk evaluation	Risk reduction measures
Design feature	Risk element	Potential risk scenarios	
Usage	• Underloading • Overloading • Household chemicals • Medications	• Vacation absences by owner/occupier • Poor treatment performance • Compromise effectiveness of soil treatment in land application area	• Provide loading certificate to advise on on-site wastewater system capabilities and consequences of misuse • Make provision for "idle" mode in mechanical treatment units • Check internal flow balancing capability from storage in treatment unit and land application system • Seek advice where owner/occupier illness involves prescription drug use • Provide O&M guidelines specific to installed system
Regulatory/ administrative	• Capacity of owner/occupier to manage use and oversight of the on-site wastewater system during its life period • System documentation (e.g. assessments, installation methodology) • Resource and building consenting requirements	• Owner transferring from urban to rural environment • Owner knowledge of on-site wastewater servicing capabilities • Documentation supplied is not complete or insufficient for the on-site wastewater system • Resource and building consent assessment and applications insufficient or incorrect resulting in delays to processing • Stakeholder consultation not undertaken (e.g. mana whenua)	• Provide owner/occupier education materials • Loading certificate to define capabilities of on-site wastewater system and consequences of misuse • Provision of O&M manual outlining procedures for use and care of on-site wastewater system • Ensuring regulatory call-up regarding extension/renewal of maintenance contract • Regulator to check supplied documentation to ensure it is fit for purpose • Engage technical specialists for resource consent and or building consent assessment and application • If stakeholder consultation is required for consent, this is undertaken early in Stage 1 site investigations

Appendices

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Appendix A1.0 On-site wastewater consenting process

This Appendix provides general guidance only. Interested parties should obtain their own professional advice and refer to the Auckland Unitary Plan and other relevant legislative materials for specific advice and information.

Auckland Council, as Auckland's unitary authority, is responsible for ensuring that all significant building and associated works are safe, durable, sustainable, pose no danger to the health and wellbeing of people under the Building Act (1992), and that their environmental effects are well managed as per the Resource Management Act,1991 (RMA).

There are three types of consents associated with on-site wastewater systems:

- Wastewater discharge consent
- Land use consent
- Building consent.

Land use consent and wastewater discharge consents are governed by the RMA, while building consents are governed by the Building Act (1992). Users should note that regardless of wastewater discharge consent requirements, a building consent is required for all private drainage works such as on-site wastewater system installations or upgrades. Developments that may have an effect on the environment, such as installation of an on-site wastewater system may also require resource consent.

During building consent review, Auckland Council will require validation of design considerations (such as verification of treatment performance, occupancy, design flows, water reduction fixtures and setbacks) and evidence of compliance. Where designs appear to be undersized, inadequate for the site constraints, not a permitted activity, or misrepresentative of intended use, a discharge consent will also be required.

Appendix A1.1 Wastewater discharge consent

Wastewater discharge consents are required for on-site wastewater systems that cannot comply with Auckland Unitary Plan permitted activity criteria. For all such systems, a building consent will also be required along with the wastewater discharge consent.

To apply for a wastewater discharge consent, the applicant will be required to provide sufficient information to confirm that the development can be adequately serviced and that the proposed discharge will not lead to adverse effects on the environment. For wastewater discharge consents, as a minimum, applicants are required to provide (per Appendix C1.0) the following:

- All information as required by Auckland Council's general resource consent application process. (Refer to Auckland Council's 'Applying for Resource Consent' webpage for more information.)
- Any pre-application meeting minutes or other relevant past correspondence with Auckland Council (if any)
- Any relevant past consent documents

- An on-site wastewater system design report as per the design report checklist
- A completed copy of design report template checklist
- A completed copy of the activity status worksheet to confirm consenting requirements
- All relevant plans in accordance with the Plan's requirement checklist
- All relevant attachments as per the attachment list.

Note: guidance regarding the assessment of environmental effects for the proposed on-site wastewater system is addressed on the Design Report Template (Appendix C1.0).

Appendix A1.2 Land use consent

Depending on the extent and location of the proposed on-site wastewater system, a land use consent may also be required for construction of the proposed system. Where wastewater discharge and land use consents are required, both consents should be submitted together as one application. Information required to obtain the relevant land use consent depends on the applicable Auckland Unitary Plan rules.

Refer to the Auckland Council webpages for more information on the resource consent application and process.

Appendix A1.3 Building consent

A building consent is required for the installation or upgrade of all on-site wastewater systems. Only information required to support the on-site wastewater system aspect of the building consent is within the scope of this section. Building consent applicants are required to provide sufficient information to demonstrate that the requirements of the building code can be met. As a minimum, applicants are required to provide the following:

- Supporting information for the whole development as per the application forms
- Pre-application meeting minutes or other relevant past correspondences with Auckland Council
- Relevant previous consent documents
- On-site wastewater system design report as per the design report template (Appendix C1.0)
- A completed copy of design report template checklist
- A completed copy of the activity status worksheet to confirm the consenting requirements
- All relevant plans including those outlined in the Plan requirements checklist (Appendix C1.0)
- All relevant attachments as per the attachment list (Appendix C1.0)
- All other supporting information for the remaining development outside of the scope of the on-site wastewater system.

Appendix B1.0 Soil description and assessment

Appendix B1.1 Soil logging and records

The soil evaluation plan developed after the site walk over should ensure required information is collected at specific locations, particularly within the preferred land application and reserve areas.

The soil log must be accompanied by photos of the soil samples and supporting information including:

- Drilling date and time
- Sampling method (auger, drilling etc)
- Sample location, ideally GPS location
- Sample depths
- Assessment method
- Soil properties – including:
  - Texture
  - Structure
  - Consistency
  - Moisture
  - Colour
  - Colour patterns (size and abundance of mottles)
  - Abundance of roots
- Depth to groundwater table
- Depth to any slowly permeable or impermeable layers (hardpans, bedrock or other features identified that would affect the downward percolation of water).

Field assessment and description of soils should follow the guidance given in this appendix. If further detail is required refer to the Soils Description handbook (Milne et al.), the NZ Geotechnical Society guideline for the field description of soil and rock (2005) and numerous publications or websites (e.g. www.nzsoils.org.nz or www.landcareresearch.co.nz).

Appendix B1.2 Soil texture

In a full laboratory assessment, soil texture is determined by the relative proportion of sand, silt and clay in your soil. Sand, silt and clay are the individual grains in soil that are distinguished by their size. Sand grains are between 2 mm and 0.06 mm, silt between 0.06 and 0.002 mm, and clay is smaller than 0.002 mm (2 µm). In the field this can be approximated by assessing the behaviour of the soil using the following method.

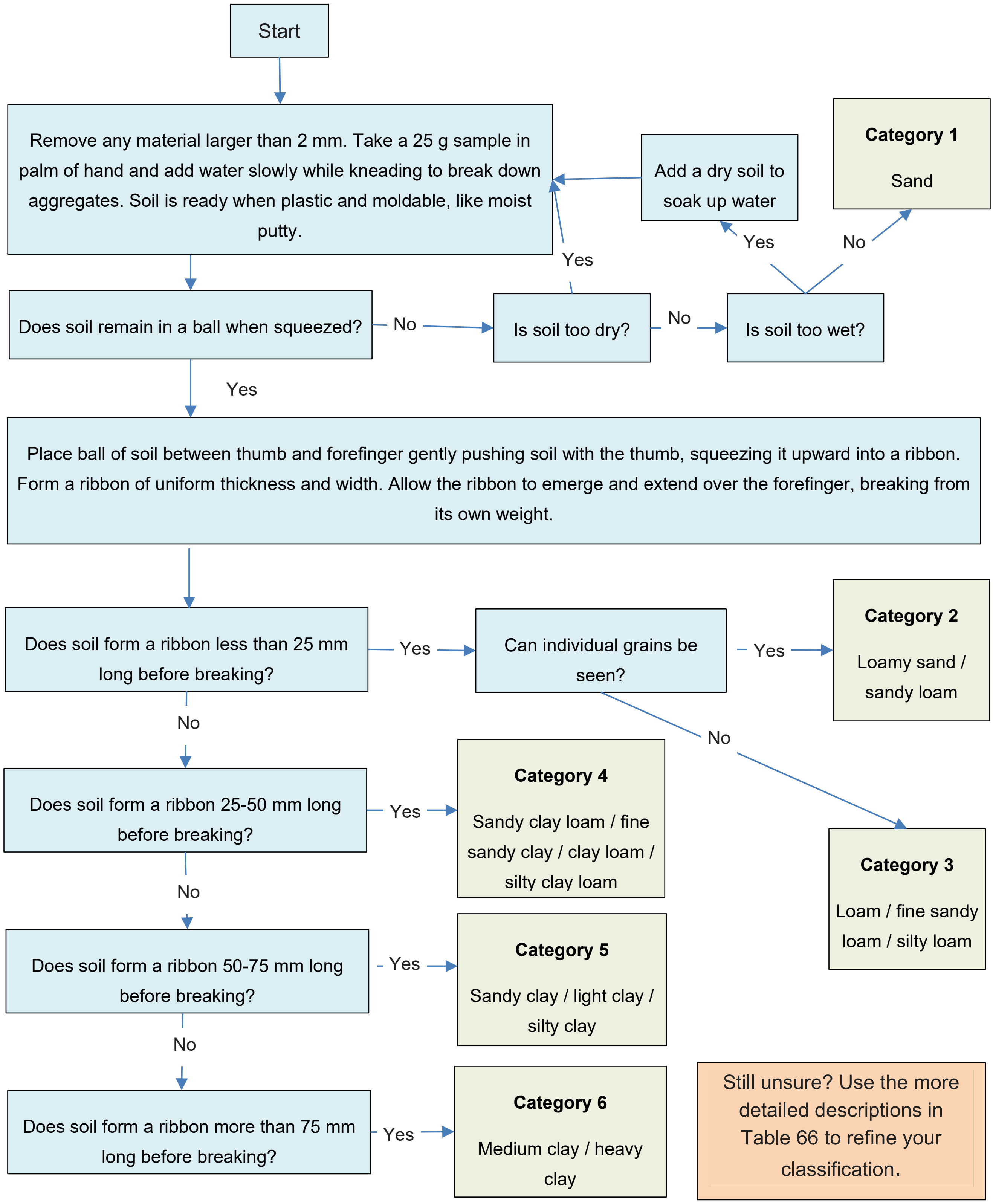


Figure 34: Soil category flow chart

Modified to be consistent with the descriptions in AS/NZS 1547:2012 from original by Thien (1979).

The results of the field assessment flow chart can be double-checked if in doubt using the more detailed assessments shown in Table 66.

Table 66: Field assessment of soil textures[1]

Soil category	Classification	Feel test		Typical clay content
1	Gravels and sands	• Ball test:	Does not form a ball	< 5%
		•	Texture: Gritty. Individual sand and gravel grains are visible (> 1 mm in diameter) and comprise >35% of the total volume	
		• Ribbon test:	Does not form a ribbon	
		• Staining:	Does not discolour the fingers	
2	Loamy sand	• Ball test:	May be rolled into a fragile ball	5 – 10%
		• Texture:	Gritty. Individual sand grains are visible and can be felt	
		• Ribbon test:	Forms a very short ribbon < 5 mm long that breaks easily	
		• Staining:	Discolours the fingers	
	Sandy loam	• Ball test:	Can be rolled into a fragile ball	10 – 20%
		• Texture:	Gritty. Individual sand grains are visible and can be felt	
		• Ribbon test:	Forms a short ribbon < 25 mm long	
		• Staining:	Discolours the fingers	
3	Fine sandy loam	• Ball test:	Can be rolled into a fragile ball	10 – 20%
		• Texture:	Slightly gritty. Individual sand grains are not visible but can be felt	
		• Ribbon test:	Forms a short ribbon < 25 mm long	
		• Staining:	Discolours the fingers	
	Loam	• Ball test:	Forms a fragile ball that feels "spongy"	10 – 25%
		• Texture:	No obvious grittiness or smoothness May feel greasy if organic matter is present	
		• Ribbon test:	Forms a short ribbon < 25 mm long	
		• Staining:	Discolours the fingers	
	Silt loam	• Ball test:	Forms a ball	10 – 25%
		• Texture:	Soil feels smooth or silky May feel greasy if organic matter is present	
		• Ribbon test:	Forms a short ribbon < 25 mm long. Dries rapidly	
		• Staining:	Discolours the fingers	

[1] Sources: AS/NZS 1547:2012, USDA (1993) and TP58

Soil category	Classification	Feel test		Typical clay content
4	Sandy clay loam	• Ball test:	Forms a ball	20 – 30%
		• Texture:	Gritty. Sand grains are visible and can be felt	
		• Ribbon test:	Forms a ribbon 25-40 mm long	
		• Staining:	Discolours the fingers	
	Fine sandy clay	• Ball test:	Forms a ball	20 – 30%
		• Texture:	Slightly gritty. Sand grains are not visible but can be felt	
		• Ribbon Test:	Forms a ribbon 40-50 mm long	
		• Staining:	Discolours the fingers	
	Clay loam	• Ball test:	Forms a ball that feels "spongy"	25 – 35%
		• Texture:	No obvious grittiness or smoothness	
		• Ribbon test:	Smooth to manipulate; forms a ribbon 40-50 mm long	
		• Staining:	Discolours the fingers	
	Silty clay loam	• Ball test:	Forms a ball (does not feel "spongy" as for clay loam)	25 – 35%
		• Texture:	Very smooth or silky	
		• Ribbon test:	Smooth to manipulate; forms a ribbon 40-50 mm long. Dries rapidly	
		• Staining:	Discolours the fingers	
5	Sandy clay	• Ball test:	Forms a plastic ball	35 – 45%
		• Texture:	Gritty; individual sand grains are visible and can be felt	
		• Ribbon test:	Forms a ribbon 50-75 mm long	
		• Staining:	Discolours the fingers	
	Light clay	• Ball test:	Forms a plastic ball that can be rolled into a rod	35 – 40%
		• Texture:	Smooth	
		• Ribbon test:	Slight resistance to ribboning Forms a ribbon 50-75 mm long	
		• Staining:	Discolours the fingers	
	Silty clay	• Ball test:	Forms a plastic ball	40 – 50%
		• Texture:	Very smooth and silky	
		• Ribbon Test:	Slight resistance to ribboning Forms a ribbon 50-75 mm long, but fragments and dries rapidly	
		• Staining:	Discolours the fingers	

Soil category	Classification	Feel test		Typical clay content
6	Medium clay	• Ball test:	Forms a plastic ball. Can be moulded into rods without fracture	40 – 55%
		• Consistency:	Smooth, handles like plasticine	
		• Ribbon test:	Some resistance to ribboning Forms a ribbon > 75 mm long	
		• Staining:	Discolours the fingers	
	Heavy clay (includes swelling clay, hard pan, grey clay)	• Ball test:	Forms a plastic ball. Can be moulded into rods without fracture	≥ 50%
		• Consistency:	Smooth, handles like stiff plasticine	
		• Ribbon test:	Firm resistance to ribboning Forms a ribbon > 75 mm long	
		• Staining:	Discolours the fingers	

Appendix B1.3 Soil structure

Soil structure should initially be assessed by examining the walls of the test pit (where used) or cores from the bore sample. Peds can then be assessed by carefully teasing peds apart from one another by hand and allowing them to separate naturally into shapes which can then be assessed. These results for each soil horizon should be recorded in the bore log. Soil structure affects the ability of water to move through the soil and is a major consideration for assigning a suitable hydraulic loading rate. For soil structure record:

Ped shape	• Shape influences the movement of water, e.g. platy peds restrict the vertical movement of water.
Ped size	• Smaller peds create more inter-pedal fractures, which provide more flow paths for percolating water. Larger peds will have reduced flow paths.
Degree of structure	• The degree of structure defines the distinctness of peds. A soil with a “strong” degree of structure has clearly defined fractures or voids between the peds, allowing water to pass through more easily. A “weak” degree of ped structure is less distinct and offers more resistance to water flow.

Table 67: Soil structure shape

Term	Description for visual assessment
Blocky	• Square shapes. Irregular blocks about 1.5 to 5.0 cm in diameter. • Blocky structure in clay soils during dry weather shrinkage can provide high vertical transmission rates, but when wet and swollen, will resist passage of water.
Columnar	• Vertical columns of soil, similar to prismatic, that have rounded tops; typically found in soil of arid climates.
Granular	• Spherical structures. • Granular soils tend to be without structure, with peds typically being less than 0.5 cm in diameter.
Platy	• Flat plate-like structures. • Thin flat plates of soil that generally lie horizontally. Can be found in compacted soil. • Platy structures are resistant to vertical water movement but facilitate horizontal movement.
Prismatic	• Vertical elongated units. • The individual units are bounded by flat to rounded vertical faces. • The faces are typically casts or moulds of adjoining units. • Vertices are angular or sub-rounded; the tops of the prisms are somewhat indistinct and normally flat.

Source: Natural Resources Conservation Services, United States Department of Agriculture

Table 68: Degree of soil structure

Degree of Structure	Appearance	
	Undisturbed soil (i.e. *in situ*, as viewed within test pit face)	**Disturbed soil (i.e. removed from profile)**
Massive (structureless)	Coherent soils which have no visible structure. Any partings present, both vertically and horizontally, are spaced at greater than 100 mm.	Pieces do not break along planes of weakness but break according to stress loads, e.g. the soil has no visible structure, appearing to be cemented as one mass, and is hard to break apart.
Single-grained (structureless)	Loose, non-cohesive soils, individual particles show no tendency to cling together. Single grain is characteristic of sands with very little organic matter content, e.g. dune sands or sandy soils.	As for undisturbed appearance.
Weakly structured	Weak structure is where the soil aggregates are indistinct, i.e. the peds are poorly formed and barely visible.	The soil material breaks down into a mixture of few aggregates and un-aggregated material. When disturbed approx. 30% of the soil volume consists of peds smaller than 100 mm.
Moderately structured	Moderate structure is where the soil aggregates are moderately durable and evident but not distinct.	The soil material breaks down into a mixture of many distinct entire aggregates, some broken aggregates and some un-aggregated material. When disturbed, approx. 30% – 60% consists of peds smaller than 100 mm.

Degree of Structure	Appearance	
	Undisturbed soil (i.e. *in situ*, as viewed within test pit face)	Disturbed soil (i.e. removed from profile)
Strongly structured	Strong structure is where soil aggregates are well-formed, distinct, durable and evident.	This structure type will break down and consist of entire aggregates, which will include few broken ones and little or no non-aggregated material. When disturbed > 60% consists of peds smaller than 100 mm.

Appendix B1.4 Soil consistency

For Category 1 soils (sands and gravels), the material should be described as one of the two following options:

- Loosely packed: Can be removed from exposures by hand or removed easily by shovel.
- Tightly packed: Requires a pick for removal, either as lumps or as disaggregated material.

For other soils classes (2 to 6), the consistency should be selected from Table 69.

Table 69: Soil consistency – behaviour of soil to applied force

Term	Description for visual assessment
Very soft	Easily exudes between fingers when squeezed
Soft	Easily indented by fingers
Firm	Indented by strong finger pressure and can be indented by thumb pressure
Stiff	Cannot be indented by thumb pressure
Very stiff	Can be indented by thumb nail
Hard	Difficult to indent by thumb nail

Source: NZGS Field Description of Soil and Rock, 2005

Appendix B1.5 Soil moisture

Table 70: Soil moisture

Term	Description for visual assessment	Granular soils	Cohesive soils
Dry	Looks and feels dry	Run freely through hands	Hard, powdery or friable
Moist	Feels cool, darkened in colour	Tend to cohere	Weakened by moisture, but no free water on hands when remoulding
Wet	Soil adheres to both fingers after release of pressure with some stretching on separation of fingers	Tend to cohere	Weakened by moisture, free water forms on hands when handling
Saturated	Feels cool, darkened in colour and free water is present on the sample		

Source: NZGS Field Description of Soil and Rock, 2005

Appendix B1.6 Soil colour

Soil colour is measured by comparison with a standard colour chart e.g. Munsell Soil Colour Charts (Munsell Colour Company, 2000). These charts allocate colours based on hue, value and chroma, i.e.:

- Hue (e.g. red, yellow, green, blue or purple). These are individual tabs in the Munsell Soil Colour Book with names like 5R, 2.5Y etc.
- Value: The measure of darkness or lightness, from 0 (absolute black) to 10 (absolute white)
- Chroma: The measure of strength of colour or level of brightness, or its departure from a dull colour. These range from 0 for neutral greys and increasing to 20, although soils are unlikely to have a value above 10.

The colours can be reported using these codes, or using the descriptive name given on the chart. For example, a soil with a colour hue of 5YR, a value of 5, and a chroma of 6 could be written as either of the following:

- 5YR 5/6
- Yellowish red.

For reporting on logs, both should be provided because the coded version is more accurate, and the descriptive version is easier to use. In this case the colour would be written on the log as 5YR 5/6 (yellowish red).

For reproduction quality and copyright reasons the Munsell colour charts are not provided in this guidance. They are available for purchase online. The methodology for determining soil colour using colour charts is provided with the charts.

Appendix B1.7 Soil colour patterns (abundance of mottles)

Separate colours should be recorded for each of the following aspects where the soil is patterned.

Table 71: Soil colour patterns

Term	Description for visual assessment
Matrix	The fine-earth ground mass that in mottled soil materials surrounds the mottles. It need not have the dominant colour.
Mottles	Discrete areas of fine earth material surrounded by a matrix of contrasting colour. Typically, height is similar to width.
Banding	Discrete bands of fine earth material separated by bands of a contrasting colour. Significantly longer in one plane.
Solids	Soil components larger than 2 mm.
Surface features	Coatings, commonly on fractures or grain surfaces.

Appendix B1.8 Root presence

Table 72: Root presence

Roots encountered/abundance (in 100 x100 mm area)		
None	Roots not encountered in test	Include a description of how the roots are growing – such as horizontally, along ped faces, throughout soil horizon, etc.
Few	1-10	
Many	25-200	
Abundant	>200	

Appendix B1.9 Example bore log template

Subsurface investigation bore log

Sheet ____ of ____

Site address:			
Project name/reference:			
Consultancy:	Client details:	Bore ID:	Sample ID:
		Log date:	Relative Level: mRL
Excavation/drilling contractor *(if any)*:		GPS Coordinate:	
	Excavation type:	Consent No:	

Depth	Texture	Structure	Colour Matrix	Consistence	Moisture	Roots	GD06 Soil Category

Note: See page below for bore log terminology guidance.

Drainage properties: Good Average Poor
If poor, please outlined mitigation measure(s):

Fill material encountered: Y/N *If yes, please describe depth and extent of fill*

Standing water encountered: Y/N *If yes, depth:____________m*	**Estimated depth to seasonally high water table** *(based on soil colour):__________m*
Handpans, dense clay layer or Other Restrictive layers Encountered: Y/N *If yes, depth:____________m*	**Bedrock encountered: Y/N** *If yes, depth:____________m*

Overall GD06 soil category:

1 2 3 4 5 6

Comments:

Please insert:

- *photo of bore core or test pit*
- *map of sub-surface soil investigation locations including test bore/pit ID*

Appendix C1.0 Design report

User instructions:

1) Address all the outlined bullet points in the on-site wastewater system design report checklist and tick each item off (☑) when they have been addressed or where justification has been provided for their omission. **Appendix C1.1**
2) Fully complete the note boxes in the report template; these will allow quick identification of key information which would decrease assessment time. **Appendix C1.2**
3) Ensure your plans comply with the checklist provided **Appendix C1.3**
4) **Attach the complete copies** to the back of the design report and submit as part of the supporting information for the consent application.

Appendix C1.1 Design report checklist

This checklist identifies the minimum information required in the on-site wastewater system design report. This information provides Auckland Council officers with the necessary background to assess a consent application.

Designer information

- ☐ Consultant/designer name and qualifications
- ☐ Consultant firm name, address and contact details
- ☐ Consultant/designer declaration

Summary of proposed development

- ☐ Site physical address and legal description
- ☐ Map view showing development site location
- ☐ Total, gross and net site area
- ☐ Nature of the on-site wastewater system (new or upgrade of existing)
- ☐ Any neighbouring on-site wastewater systems and known performance
- ☐ Any relevant previous consent/s and their consent number/s
- ☐ Site water and power supply source/s
- ☐ GIS NZTM reference of discharge location
- ☐ Legal rights to discharge at the proposed location/s of discharge, such as easements or ownership documents
- ☐ Nature of the facility to be serviced (residential/commercial/public facility) and intended use, e.g. restaurant, holiday accommodation etc.

- ☐ Intended number of occupants
- ☐ Number of bedrooms (residential developments only).

Site and soil evaluation

- ☐ Name and contact details of consultant/party who undertook the site and soil evaluation
- ☐ Assessment method including documents reviewed and actions taken
- ☐ Slope stability assessment method and findings
- ☐ Slope angle and aspect
- ☐ Climate factors (including rainfall patterns, intensity, evapotranspiration potential)
- ☐ Flooding potential
- ☐ Vegetation cover
- ☐ Location and setback distances of all identified constraints including all site features listed in Section B
- ☐ Any historical site use that may impact the position or capacity of the proposed on-site wastewater system
- ☐ Additional comments such as justification of omission of any information outlined above
- ☐ Investigation method and techniques, including but not limited to, excavation method, depth, number of test pits/bore holes (historical soakage tests are NOT accepted)
- ☐ Full soil descriptions from each soil investigation or borehole, including, but not limited to, soil structure, texture and colour, permeability, drainage and any other factors that may affect the long-term acceptance rate
- ☐ Photos of soil horizons and profiles from bore/test pits
- ☐ Analysis of findings including, but not limited to, potential for short circuiting, seepage or salinisation, including the shortest depth based on soil colour mottling and/or winter groundwater levels
- ☐ Groundwater table depths and seasonal variation
- ☐ Rationale of soil categorisation selection as per GD06 Section B.

Design flow calculation

- ☐ Total design flow calculation including justification of selected design flow rate include design considerations such as:
  - Number of bedrooms
  - Staff/visitor occupancy pattern
  - Nature of commercial/public facility
  - Seasonal variation in occupancy/user numbers
  - Intention and types of proposed water reduction fixture
  - Intention and types of proposed water production fixture

- Intention and method of wastewater reuse.

☐ Calculation method for wastewater buffer storage capacity, with water balance indicating time frame for reduction of stored volume.

Design overview

☐ Summary of proposed on-site wastewater system design

☐ System operation flow diagram to illustrate how the wastewater will flow from the facilities to final land application including stages of treatment and any recycled flows.

Treatment system

☐ Clearly outline the proposed treatment level

☐ Description of proposed treatment system and design capacity include description of proposed treatment system packages including product name, make and any OSET NTP testing details

☐ Intention and method of any mitigation measures such as, but not limited to: grease traps, septic tank outlet filters, flow meter and warning alarms

☐ Justification of the proposed treatment system including details of any site constraints including limitation and assumptions

☐ Treatment system design/sizing calculations

☐ Evidence to demonstrate that effluent requirements are achieved.

Land application system

☐ Land application and reserve area sizing calculations

☐ Description of proposed loading method including multiple loading zones details, if applicable

☐ Loading rate calculation

☐ Description of the proposed land application method including irrigation and feeder line layout, size, number and location

☐ For pressure compensating drip irrigation (PCDI) systems, provide details of any proposed TNL or DNL (tube non-leakage or dripper non-leakage), air release, automatic flushing and manual flushing valves, as well as any orifice plates

☐ If irrigation lines are intended to be laid at surface level, include method for covering the lines

☐ If conventional land application systems are proposed, specify the layout of trenches or beds or LPED lines on site including details of any flushing ports, dosing line size, feeder line size and orifice plate size

☐ If shallow irrigation is proposed, include details of distribution aggregates including its types

☐ If gravity loading is proposed, specify the location and design of the distribution box

☐ Details of any applicable anti-siphon or non-return measures

- ☐ Evidence to demonstrate that even effluent distribution across the land application field will be achieved
- ☐ Justification of the proposed land application system; include details of any site constraints including limitations and assumptions
- ☐ Description of proposed land application and reserve area vegetation including planting density, species and planting method
- ☐ Description of the reserve area and any additional design requirements needed should the reserve area be used (such as additional planting, cut off drains etc.)
- ☐ Detail and contact of intended system installer including registration number (if known).

Installation and commissioning

- ☐ Specify installation/construction methodology including site protection, preparation methods
- ☐ Specify commission testing methods.

Risk assessment

- ☐ Risk assessment including details of:
  - Hazard identification and analysis
  - Risk reduction mitigation measures
  - Monitoring and review procedures.
- ☐ Design limitations and assumptions
- ☐ Potential effects of design effluent quality and any proposed mitigation for water quality, public health, the receiving environment, nearby drinking water supply, any cultural or natural heritage
- ☐ Potential effects of the following on the proposed wastewater land application area (including reserve) and any proposed mitigation: earthworks and steep slope *(wastewater discharge consent only).*

Conclusion

- ☐ Summary and recommendations

Attachments

An Appendix section providing all design investigation and supplementary information is also required. Attachments required in the subject appendix are as following:

Required for both building and resource consent:

- ☐ Attach a copy of a formal documentation confirming easement and/or covenants of final discharge location *(if different from site of origin)*
- ☐ Certificate of title of all relevant properties
- ☐ Plans, as per plan requirements checklist
- ☐ Site and soil evaluation report

☐ Soil/borehole logs (a bore log template is provided in 0)

☐ Soil permeability test results/data collected *(where applicable)*

☐ Slope stability assessment/geotechnical report *(where appropriate)*

☐ Other soil evaluation data collected *(where applicable)*

☐ Any evidence of stakeholder consultation *(when applicable)*

☐ Assessment of existing system performance level signed by a suitably qualified professional *(where applicable)*

☐ OSET NTP testing performance certificate *(where system has been test-certified)*

☐ Effluent outlet filter performance standard and performance report reference *(when possible)*

☐ Attached proposed treatment plan specification and supporting documentations(s)

☐ All relevant producer statement(s)

☐ Draft system operation and maintenance plan

☐ Draft loading certificate[2]

☐ Draft operation and maintenance plan with final to be provided at as-built stage

☐ Draft maintenance contract with a suitability qualified on-site wastewater professional commencing within six months of system commissioning (Section F)

☐ Proof (either letter or email) of Mana Whenua engagement (where required).

Building consent only:

☐ Product specification

☐ Draft installation methods/instructions

☐ Draft commission and testing methods/instructions.

Resource consent only:

☐ Cultural impact assessment *(if proposal is within cultural heritage area)*

☐ Flooding report *(if proposal is within or within close proximity of flood plan or overland flow path)*

☐ Arborist report *(if proposal is within or within close proximity of protected trees).*

[2] The loading certificate should set out the design criteria and the limitations associated with use of the system and incorporate such matters as:

(i) System capacity (number of persons and daily flow)

(ii) Summary of design criteria

(iii) The location of and use of the ‘reserve area’

(iv) Use of water efficient fittings, fixtures, or appliances

(v) Allowable variation from design flows (peak loading events)

(vi) Consequences of changes in loading (due to varying wastewater characteristics)

(vii) Consequences of overloading the system

(viii) Consequences of underloading the system

(ix) Consequences of lack of operation, maintenance, and monitoring attention, and

(x) Any other relevant considerations related to use of the system.

Appendix C1.2 Report template

1. DESIGNER/SPECIALIST SUMMARY			
Company:		Contact person:	
Designer/ specialist:		Phone:	
Email:		Area of expertise:	
"I hereby certify that to the best of my knowledge the information provided in the following design report and all attachments are true and complete."			
Signed:			

2. DESCRIPTION OF PROPOSAL	
Is the discharge location on the same property as where the wastewater originates from?	☐ Yes ☐ No
What is the status of the on-site wastewater system?	☐ New (proposed) ☐ Replacing an existing system ☐ Change to an existing system ☐ Consent renewal
What are the facilities where wastewater is generated?	☐ Domestic residential dwelling ☐ Commercial ☐ Public facility
What is the proposed number of users/occupants of the facility?	
What is the facility's water supply?	☐ Town supply ☐ Bore/wall ☐ Roof water
Has desktop study been undertaken?	☐ Yes ☐ No

3. DESCRIPTION OF PROPOSAL

Surface investigation methodology:

Subsurface investigation methodology:

Surface constraints identified:

☐ Steep slope (>15°)	☐ Flood plain	☐ Overland flow
☐ Geotechnical hazard	☐ Cultural heritage	☐ Natural heritage
☐ Modified land (including proposed development	☐ Open watercourse	☐ Surface water drainage
☐ Protected vegetation	☐ Building footprint (including proposed development	

Soil categories identified on site (based on most limiting horizon)

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

From ground surface, what is the depth of the water table as per bore log records?

Winter (m)		☐ Measured	or	☐ Estimated
Summer	(m)	☐ Measured	or	☐ Estimated

4. DESIGN FLOW CALCULATION

Area to wastewater ratio:

System 1: ☐ System 2: ☐ System 3: ☐

Proposed daily flow rate of each proposed on-site wastewater system – include justification in the design report if different from GD06:

Building name / numbering	Number of bedrooms (residential only)	Design occupancy	Design flow allowance (L/person/day)	Total design flow rate (L/d)

Total daily design flow (L/d):

If residential, will the house be permanently occupied?

☐ Yes

☐ No, only partial occupation (holiday accommodation)

Proposed water reduction fixtures or measures:

☐ Non-water toilet/portaloos
☐ Water-saving shower head
☐ Water-saving sink
☐ Water-saving dishwasher
☐ Water-saving hand basin
☐ No baths
☐ Dual or low flush toilets
☐ Water-saving washing machine
☐ Greywater reuse (resource consent is required for any proposed wastewater reuse)

Peak wastewater flow buffer is proposed:

☐ Yes

☐ No

Additional water production fixtures proposed:

☐ Garbage grinder/waste disposal unit

☐ Spa bath

5. WASTEWATER TREATMENT SYSTEM

Proposed treatment level:

☐ Primary	☐ Secondary	☐ Advanced secondary

Proposed treatment level:

☐ Septic tank/s	☐ Septic tank/s with outlet filter	☐ Advanced secondary

Septic tank capacity ______ (m^3)

Confirm the proposed secondary / advanced secondary treatment system:

☐ Aerated wastewater treatment	☐ Intermittent sand filter/packed bed reactor
☐ Recirculating textile filter/packed bed reactor	☐ Membrane bioreactor (MBR)
☐ Recirculating sand filter/packed bed reactor	
☐ Other (specify):	

Has the proposed secondary treatment system undergone OSET NTP testing?

☐ Yes

☐ No, If yes, state performance rating

Proposed disinfection systems:

☐ UV Disinfection system	☐ Chlorine	☐ Other (specify)

Proposed 24-hour peak flow emergency storage capacity – *If not provided, include reasoning in design report:* ______ (L)

Additional mitigation or treatment components:

☐ Grease traps	☐ 24-hour emergency storage
☐ Audible and visual harm	☐ Disc filter or treated effluent discharge flow
☐ Water meter	☐ Wastewater meter
☐ Disc filter	☐ Remote telemetry unit (RTU)
☐ Carbon filters	☐ Anti flotation devices
☐ Re-use water meter	☐ End of line vents

6. TREATMENT QUALITY

Expected treated effluent quality discharge into the land application field:

Biochemical oxygen demand (BOD_5): g/m³		Total suspended solids (TSS): g/m³	
Faecal coliforms/E.coli (FC): CFU/100 ml		Total nitrogen (TN): g/m³	

7.LAND APPLICATION AREA

Proposed loading method – include justification for the selected loading method in design report:

- ☐ Gravity
- ☐ Loading demand dose
- ☐ Dosing siphon
- ☐ Timer dose loading by pump
- ☐ Pump

If pump is proposed, provide pump details:

Proposed land application method:

- ☐ PCDI
- ☐ Bed Trench
- ☐ ETS Bed
- ☐ Soakage Trench
- ☐ LPED
- ☐ Soakage Mound
- ☐ LPP

Other (specify):

Wastewater loading rate (fill in if applicable):

Areal loading rate: mm/day		Basal loading rate: mm/day		Sidwall loading rate: mm/day	

Confirm the following (where applicable):

Shallow irrigation

Number of LPED trenches:		Separation distance between trenches: m	

PCDI irrigation

Total area of irrigation field: m²		Dripline emitter spacing: m	

Irrigation line brand:

Drip irrigation line layout:

- ☐ Surface
- ☐ Subsurface

Reserve area	
Reserve land application area: m^2	Reserve area percentage: %
Soakage trench/bed/mound – (if applicable, include soakage sizing calculations in design report)	
Number of beds/trenches/mounds:	
Separation distance between beds/trenches/mounds:	
Soakage width: mm	Soakage length: m
Soakage depth: mm	Reserve area: m^2
Soakage basal area: m^2	
Will additional design requirements be needed if reserve area was to be used for expansion or replacement of land application systems?	
☐ Yes Please - include details of the additional design requirements in the design report:	☐ No
Note: Reserve area percentage is the equivalent percentage of primary (initial) land application area.	

Proposed land application area vegetation:		
☐ Planted	☐ In lawn	☐ Bush
☐ New	☐ Existing	
Other (specify):		
Proposed planting density:		
Proposed planting species:		
Land application field dimensions (width, length etc. of enclosing area including edge buffer widths):		
Surface/subsurface cut off drains/bunds/swales are proposed: Yes ☐		
No ☐		
Multiple loading zones are proposed. If so, include details of how even loading will be achieved in the design report:		
☐ Yes	☐ No	

Appendix C1.3 Plans for on-site wastewater system

The following information is required to illustrate the proposed on-site wastewater system:

General: The following is required on all plans:		
A1	☐	Title box including: • Plan title • The name of the person and/or company that prepared the plans • Address of property/site • Date plans were drawn • Unique plan reference or identification or variation number where relevant.
A2	☐	Legend explaining symbols on plan
A3	☐	Appropriate metric scale, e.g. 1:2000 (1 cm = 20 m) and page size reference (e.g. @ A3)
A4	☐	Wherever relevant the North arrow, preferably pointing upwards
A5	☐	Minimum of A3 size
Site Plan (*location and clear labelling is required for the following):*		
B1	☐	All existing and proposed property boundaries
B2	☐	Total site area (in ha or m². In case of subdivisions, area of each lot is required)
B3	☐	Street numbers of neighbouring properties
B4	☐	Existing and proposed roads, including road names
B5	☐	All existing and proposed impervious area including all associated drainage and proposed area size
B6	☐	All existing and proposed buildings including all associated drainage
B7	☐	Any historical structures that may have affected the proposed wastewater discharge, e.g. buildings, underground storage tanks.
B8	☐	Nearby structures such as fences or swimming pools
B9	☐	Swimming pool backwash filter disposal area *(if relevant)*
B10	☐	Soil test locations (bore hole/test pit/hand augur bore locations)
B11	☐	Any existing or proposed water tanks and overflow discharge points
B12	☐	Soil types found on site
B13	☐	Key horizontal pathways for contaminate migration and potential receiving environment
B14	☐	Site contours at minimum of 1 m intervals
B15	☐	Any existing on-site wastewater systems

B16	☐	All relevant proposed treatment system components such as: • Primary treatment system • Secondary treatment system • Advanced secondary treatment system • Proposed drainage connection between treatment system and building.
B17	☐	All relevant proposed land application system components such as: • Primary land application field including field size • Reserve land application field including field size • Pump chambers and rising main • Emergency storage • Flow meter • Bunds • Distribution box • Cut-off drains • Proposed irrigation line layout • Flush valves and their discharge points • Drain layout from facility to final land application system.
B18	☐	GIS NZTM map reference of primary and reserve land application fields
B19	☐	All relevant site constraints such as: • Embankments • Retaining walls • Underground services such as stormwater, water, fibre or gas • Stormwater systems such as above and underground drains, sub-soil drains, road side drains, soakage, dispersal trenches, kerb outlets, wetlands, raingardens, swales, permeable paving or bio-retention cells • Surface water features such as open water course, streams, lakes or ponds • Culturally significant site such as wahi tapu or archaeological site • Naturally significant site such as special ecological features, indigenous vegetation or other sites with conservation values • Flooding features such as overland flow path, flood prone areas, flood sensitive areas and flood plains. 1 in 20 (5% AEP) and 1 in 100 (1% AEP) year flood plains should be identified • Up and downstream water supply bores or tanks • Swimming pool backwash disposal area • Coastal marine area • Mean high water spring • Depth of groundwater tables including seasonal variation. Potential site constraints located outside the subject site, on neighbouring sites, but within close proximity of the proposed and reserve land application fields also needs to be included.

B20	☐	Available minimum actual measured separation distance to the nearest metre between all site constraints and proposed and reserve land application field. Separation distances from the following are required: • Existing and proposed site boundaries • Existing and proposed buildings • Existing and proposed impermeable areas • Any existing and proposed structures that may impede maintenance access, such as fences • Embankments • Retaining walls • Underground services such as stormwater, water, fibre or gas • Stormwater systems such as above and underground drains, sub-soil drains, road side drains, soakage, dispersal trenches, wetlands, raingardens, swales, permeable paving, bio-retention cells or tree pits • Surface water features such as open water course, streams, lakes or ponds, road side curb drains • Culturally significant site (such as wahi, tapu) or archaeological site • Naturally significant site such as special ecological features, indigenous vegetation or other sites with conservation values • Flooding features such as overland flow path, flood prone areas, flood sensitive areas and flood plains. 1 in 20 (5% AEP) and 1 in 100 (1% AEP) year flood plains should be identified • Up and downstream water supply bores or tanks • Swimming pool backwash disposal area • Coastal marine area • Mean high water spring • Potential site constraints located outside of the subject site, on neighbouring sites, but within close proximity of the proposed and reserve land application fields also needs to be included.
Site plans should be preferably drawn A3 size to enable all features to be clearly and accurately drawn and labelled.		
Earthworks plan (*with location and clear labelling is required for the following):*		
C1	☐	Site contours at minimum of 1 m intervals
C2	☐	Direction of ground slope *(indicate with arrows)*
C3	☐	Area of historical or proposed cut & fill, stockpile, compaction and heavy machinery works
C4	☐	Areas of heavy machine exclusion zones
C5	☐	Area of historical landslips

Planting plan (*with location and clear labelling is required for the following):*		
D1	☐	Existing ground cover
D2	☐	Proposed vegetation removal areas
D3	☐	Proposed land application and reserve area planting including name of proposed plant species in each area
Cross-sections (*cross-sections with clearing labelling of key features is required for the following):*		
E1	☐	Key vertical pathways for contaminate migration and potential receiving environment
E2	☐	Subsurface system components such as cut-off drains or trenches
Enlarged site plans (*with location and clear labelling is required for the following):*		
F1	☐	Adjoining properties where any downstream open channel drains or watercourse, streams or flooding features beyond the boundary is within 20 m of the proposed land application area
F2	☐	Nearby site features where any flooding or open water features are within 50 m of the land application area
F3	☐	Proposed on-site wastewater system where developments within site are closely clustered together
***Note:* Proposed building floor plan illustrating the proposed bedrooms will also be required if not already provided.**		

Appendix D1.0 Example flow allowance reduction calculations

Table 73: Example flow allowance reduction calculations for households

(refer to Table18 Section C)

Flow allowance litres/person/day	Calculation	Assumptions
B. Standard fixtures		Assumes toilet use flow volume based on 5 flushes/day @ 11 L/flush l(L/f) 11 L/f x 5 f/p/d = 55 L/p/d (toilet use only)
C. Household with 11/5.5 or 6/3 litre flush 160 L/p/d	180 L/p/d – 22 L/p/d = 158 L/p/d	Assumes dual flush flow volume of 11 or 5.5 L 1 flush x 11 litres plus 4 flush x 5.5 litres = 33 L/p/d or 22 L less per person per day (toilet use only)
D. Household with 6/3 litre flush and water reduction fixtures 145 L/p/d	180 L/p/d – 37 L/p/d = 143 L/p/d	Assumes dual low flush of 6 L or 3 L 1 flush x 6 L plus 4 flushes x 3 L = 18 L/p/d or 37 L less per person per day
E. Household with full water reduction fixtures 120 L/p/d	145 L/p/d – 26 L/p/d = 119 L/p/d	Assumes dual flow flush AND water reduction valves etc. have an 18% reduction from water saving devices. Therefore 26 L/p/d giving a total % reduction from 180 L/p/d to 120 L/p/d of 35% (made up of 20% for dual flush 6L/3L toilets and 15% for water reduction fixtures)
G. Household with full water reduction fixtures and No bath 115 L/p/d	120 L/p/d – 5 L/p/d = 115 L/p/d	No bath: allow 5 L/p/d
H. Households with full water reduction facilities plus recycle to toilet cisterns 95-100 L/p/d	120 L/p/d – 18 L/p/d = 102 L/p/d	Dual low flush PLUS water reduction valves PLUS recycling of secondary treated and chlorine disinfected effluent for reuse in toilet cisterns reducing the discharge volume to 100 L/p/d (or 95 L/p/d with NO bath). (Made up of 18 L/p/d reduction for toilet cisterns off 120 L/p/d)
I. Households blackwater only (based on 11 litre flush) 66 L/d	11 L/flush x 6 flush/p/d = 66 L/p/d	Toilet use flow volume based on 5 flushes/d @ 11 litres/flush (toilet use only)
J. Households blackwater only (based on 11/5.5 litre flush) 45 L/d	2 flush x 11 l + 4 flush x 5.5 L = 44 L/p/d	Toilet used flow volume based on dual flush @ 11/5.5 L (toilet use only)
K. Households blackwater only (based on 6/3 litre flush) 25 L/d	2 flush x 6 l + 4 flush x 3L = 24 L/p/d	Toilet use flow volume based on dual low flush 6/3 litre (toilet use only)

Appendix E1.0 Composting toilets

A composting toilet is a well-ventilated container that provides an optimum environment for the biological and physical decomposition of unsaturated, but moist human excrement, into an oxidised humus-like product under controlled sanitary aerobic conditions. The process is affected by the ambient air temperature and moisture conditions, which should be managed to optimise microbial activity (USEPA, 1999). The primary objective of composting toilet systems is to contain, immobilise and/or destroy pathogens, and to accomplish this in a manner that is consistent with good sanitation (minimum human contact or contact with disease vectors such as insects). The process should produce an inoffensive and reasonably dry end product that provides low to minimum risk if handled (USEPA, 1999).

Composting toilets have gone through several phases of popularity in New Zealand. While they are often perceived as an environmentally friendly approach, some people have a less favourable view of the need for keeping, turning, and emptying composted human excrement (Gunn, 2004). Where the house owner is committed to correctly operating the composting toilet, such systems can be successful in reducing household wastewater volumes. However, they are never appropriate in rental properties, and they should only be used in commercial or public premises where a permanent maintenance contract is held with a contractor who will undertake frequent inspections and the required system maintenance, and where caution can be assumed in the cleaning chemicals used.

If composting toilets are used in residential dwellings, there will still be a requirement for a greywater treatment and disposal system to be installed on the site.

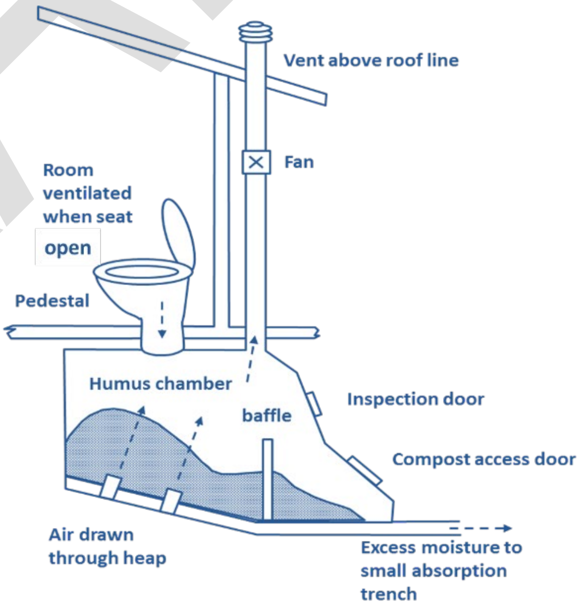


Figure 35: Cross-section illustration of composting toilet

(Adapted from Water New South Wales, 2012))

There is a range of alternative toilet systems other than composting toilets for which detailed guidance is not included within this document. These include:

- **Dewatering toilets:** Treatment is by dehydration and pasteurisation
- **Incinerating toilets:** Treatment is by total combustion
- **Liquid chemical toilets:** Treatment is by a sterilising fluid
- **Dry bucket toilets:** Limited treatment through a dry soakage material
- **Vault toilets:** A watertight storage chamber followed by off-site disposal
- **Pit toilets:** A permanent excavation for human waste.

A summary of the design considerations for several of the above systems (and including the composting toilet in Figure 35) is provided in Section D1.7.3.

Appendix E1.1 Types of composting systems

Human excrement is mostly water, with urine comprising 98% water and faeces more than 70% water, such that the actual amount of solid material is less than 50 kg/person/year. Domestic composting systems require mixing solid human faecal matter, often with a bulking agent (such as sawdust), stabilising the mixture in the presence of air, allowing biodegradation in warm, moist conditions and then removal and disposal of the resulting compost material.

The smaller composting toilet is often walled off from the bathroom itself but located so that it is easily accessible for maintenance. Other larger units can be located under, or outside, the dwelling (Figure 35).

There is a wide variation in the type, features and costs of composting toilet systems available. The most common type for domestic use is the enclosed compost system, which is sealed to control temperature, oxygen input and odour emissions. In vertical reactors, the materials are loaded through the top of the reactor and composted material is removed from the base. Oxygenation can be provided by forcing air up from the bottom through the composting mass. The most common type comprises of a chamber directly adjacent to or below the toilet/s, which is enclosed except for a maintenance hatch, air admittance valve and a removal chute for access with a hand auger.

There are proprietary composting toilets available in the New Zealand market, although they can also be site-built. Normally for individual residential usage, the toilet seat and the composting chamber are a combined enclosed system. However, for larger systems, a centralised composting chamber may be located elsewhere. Usually, for a single composting toilet system, human excrement is continuously loaded to the top. If a multiple chamber system is designed, one chamber can be filled and allowed to mature, while the other chamber is filled. In terms of composting efficiency, some composting toilets are considered active systems, where the composting material is actively manipulated (e.g. aeration, mixing, heating) resulting in a greater composting efficiency while in other systems, human waste is just allowed to decompose slowly in a cool environment without any active process control.

Composting toilets should not be installed in preference to conventional toilets unless the owner is confident that they will be appropriately used and maintained over the long term. Questions that the purchaser should ask when deciding whether to install a composting toilet system include:

Perceived acceptability	• Are you comfortable with the system and with any guests using it? • Does it look all right? Does it smell?
Ease of use	• How easy is it to learn to operate the system?
Ease of maintenance	• How often is routine maintenance required? • How long does maintenance take? • Is it unpleasant or tedious? • What special skills are necessary and are they easy to learn?
Reliability	• How likely are things to go wrong with correct use? • Are there weak points in the system? • Can they be tolerated or easily corrected? Is there after sale service and how much is covered by the warranty?

Robustness against misuse	•	Will things easily go wrong if the system is misused? Is it fragile or easily disturbed?
Robustness of design and construction	•	Is it built to last? Will it weather well?

Appendix E1.2 Design features of composting systems

The main design features of a composting toilet system include the following (USEPA, 1999):

- A dry or micro-flush toilet/s discharging to a composting unit
- A screened air inlet and an exhaust system or vent to remove odours and heat, water vapour, carbon dioxide and other by-products of aerobic decomposition
- A mechanism to provide the necessary ventilation to support the aerobic organisms in the composter
- A means of draining and managing excess liquid and leachate
- Process controls to optimise and facilitate management of the process
- An access mechanism for the removal of composted material (humus).

The composting unit must be designed to separate the solid and liquid fractions and produce a stable humus material with a faecal coliform level of less than 200 MPN (or CFU) per gram of dry weight (USEPA, 1999). The compost unit can be heated using solar power or electricity to provide and maintain optimum temperatures.

Vents make a big difference to odours and fly problems and should discharge at a high point outside the building, well above the highest window. The warm air around the compost rises naturally if the vent is generously sized (for a passive vent). Vents may also be powered with an electric fan. Vents may need to be screened with a metal gauze to exclude flies and other insects. If there is no vent, the compost air will discharge via the toilet itself, generating odours and attracting flies.

The main process variations are continuous or batch composting. Continuous composts are single chambers where excrement is added to the top and the composted product is removed from the bottom. Batch composts are two or more compost units that are filled then left to mature without continuous addition of new potentially contaminated excrement. There are many different methods of alternating between compost units.

The special features of composting toilet systems depend on the system type and can include semi-flush units and urine-separation units. Proprietary systems are sized by the manufacturer to handle the design occupancy, and should be installed, operated and maintained in accordance with the manufacturer's guidelines.

Australian and New Zealand standards governing the minimum materials, design, construction and performance of composting toilet systems is AS/NZS 1546.2:2008 "*On-site domestic wastewater treatment units – Part 2: Waterless composting toilets*".

Appendix E1.3 Conditions required for effective composting

The predominant micro-organisms that break down the solid waste in the compost unit are bacteria and fungi. These micro-organisms require favourable moisture content, temperature and oxygen levels. These are discussed further below (USEPA, 1999).

Moisture content	• Moisture enables micro-organisms to hydrolyse the organic compounds by biochemical processes into simple forms for use as an energy source in metabolic processes. • Moisture should be between 40 to 70% with the optimum level around 60%. • Excess moisture creates low oxygen conditions and can result in foul odours. • If the compost is too dry, the micro-organisms will die off and the composting will slow.
Temperature	• Heat is produced during the biodegradation process and some is retained within the compost. In summer conditions, the compost may need to be mixed more often and additional moisture provided due to elevated temperatures. • In lower winter temperatures, the biodegradation process can be a lot slower and less mixing and additional moisture is required.
Oxygen level (aeration)	• Maintaining an aerobic environment in the composting unit is the most important factor for growth of the micro-organisms. • Sufficient aeration assists to control the moisture content and to minimise the production of ammonia (with its associated in foul odour). • Aeration can be improved by mechanical mixing or by adding woodchips or sawdust to the composting material.
Nitrogen	• The micro-organisms that breakdown solid wastes require a source of nitrogen and carbon. • Nitrogen is critical for biological growth and a shortage of nitrogen slows the composting process severely. • For effective composting, material should normally be blended to have a carbon to nitrogen ratio of 30:1 by weight. • Carbon to nitrogen levels for various forms of organic materials are in the order of the data ranges in Table 74.
Carbon	• The carbon level in human waste alone is usually insufficient for effective composting and the excess nitrogen, indicated by the low carbon: nitrogen ratio (Table 74), can lead to ammonia volatilisation. • The carbon level in the compost material can be increased by the addition of woodchips, sawdust, paper, food scraps or green waste. In compost units where most urine drains to the bottom and out of the solid compost material, nitrogen levels are reduced meaning that there is a reduced need for an additional carbon source (USEPA, 1999). • The compost system supplier/manufacturer should provide advice on the types and volume of additional carbon material that should be added, with this depending on the size and design of the unit and its level of use.
pH	• Optimum pH is between 6.5 to 7.5. While the formation of organic acids may drop the pH, other biochemical compost processes buffer this effect, so pH is not typically a concern to the user.

Table 74: Carbon to nitrogen ratio in organic materials

Organic material	Typical carbon: nitrogen ratio (weight to weight)
Human faecal wastes	6-10:1
Sewage sludge	5-16:1
Vegetable wastes	11-19:1
Grass clippings	9-25 (Average 17):1
Leaves	40-80:1
Refuse (food scraps and mixed paper)	34-80:1
Paper from domestic refuse	130-180:1
Effective compost material	30-40:1

Source: Richard, 1996

In an effective compost system, pathogen viability is reduced by waste products from the aerobic/anoxic bacteria and fungi populations (which are toxic to pathogens) and by their exposure to unfavourable conditions (time and temperature dependent). Literature indicates that most disease-causing bacteria and viruses will not survive for more than two months in wastewater and for more than four months in soils, at 20 to 30^{o} C (Crites, 1998; USEPA, 1999; Richard, 1996 and Silyn Roberts, 2002). This survival time may be somewhat reduced further in effective compost systems, particularly where there is adequate heat.

Appendix E1.4 Benefits of composting toilets

The key advantages of composting toilets are the actual, or perceived, environmental benefits of eliminating excrement from sewage wastewater. This can result in a less contaminated raw wastewater flow, reduced treatment requirements, and a reduction in the total wastewater volume that then needs on-site disposal.

The key advantages and disadvantages of composting toilets are summarised in Table 75.

Table 75: Key advantages and disadvantages of compost systems

Advantages	Disadvantages
• Systems do not require water for flushing, reducing domestic water needs.	• Maintenance of composting toilet systems requires more responsibility from owners and users than conventional wastewater systems.
• Reduced quantity and strength of wastewater to be disposed of on-site, and reduced size of the land application area.	• Removing the final product is an unpleasant job, even if the system is properly installed, operated or maintained.

Advantages	Disadvantages
• Can be well suited to remote sites where conventional on-site systems may not be feasible, due to lack of power and/or water and due to the maintenance requirements of conventional systems.	• Improper maintenance can make cleaning difficult, increase health hazards and cause odour problems. • Poorly installed or maintained systems can lead to unprocessed material and corresponding odours.
• Most have low power consumption.	• May require a power source (to assist with ventilation).
• When self-contained, they reduce the need for transportation of wastes for treatment or disposal (although the final product will need a formal method of disposal).	• Must be used in conjunction with a greywater system. • The greywater system may be undersized and fail if a new house owner decides to replace the compost toilet with a conventional toilet.
• The burying of composted human waste around tree roots and non-edible plants can enhance growth of surrounding vegetation.	• Health risks and aesthetic issues with the handling and disposing of composted excrement.
• They can accept other forms of household waste, in particular kitchen waste, reducing household refuse.	• Too much liquid residual (leachate) in the system can disrupt the composting process. • They need to be regularly drained and properly managed.
• Providing the waste is fully biodegraded and all pathogens are destroyed in the composting process, they can reduce pathogen levels discharged to the environment.	• Smaller units may have limited capacity for accepting peak or shock loads.

Appendix E1.5 Building code requirements of composting toilets

Composting toilets fall into the definition of “privy” under New Zealand Building Code. NZ Building Code Compliance Document indicates that:

> *“privies are acceptable if located at least 3.0 m from any building having a classified use, other than outbuildings or ancillary buildings. Receptacles for excreta are to be constructed to exclude flies and be fitted with a hinged lid.”*

However, the Building Act 2004 (Part 2, Section 67) enables the building consent authority to grant a waiver or modification of the building code, subject to appropriate conditions. Most modern commercial composting toilet systems, when used and operated within these guidelines, can readily achieve the personal hygiene requirements envisaged under Clause G1 of Building Code Acceptable Solution G1/AS1 (Section 5.02), and hence, can be consented for installation and use within a dwelling.

Appendix E1.6 Risks from use and maintenance of composting systems

In a review commissioned by ARC, the major disadvantages associated with composting systems in the Auckland situation were summarised as follows (Silyn Roberts, 2002):

- Composted material is a hazardous waste that must be handled such that it does not pose a health risk. As such, it needs to be buried for at least 12 months before incorporation within gardens where it can be in contact with humans. There is reference in the literature to helminth (worm) eggs surviving in buried compost in excess of three years, so in the case of public garden areas, compost should preferably be applied in areas where close human contact is unlikely and/or where access is restricted
- Composting micro-organisms need a regular food source to ensure continued effective biodegradation, and therefore, unless the systems are located on remote sites where odours are less of a concern, they must not be located on sites subject to irregular or intermittent use
- Unless the correct conditions are maintained (water content, temperature), there is a high risk of unpleasant odours
- The systems require frequent regular manual maintenance but are seldom adequately maintained by owners
- Mature compost is usually also contaminated by fresh waste, through filtration of blackwater or from untreated waste falling onto the outer section of the pile
- Auckland Regional Public Health Service advises against any direct contact with compost systems except by professional contractors or by people trained and experienced in appropriate methodologies
- A solids' disposal management plan for either on or off-site disposal is required to minimise potential for human contact with a contract with a professional waste removal contractor required for any off-site removal and disposal.

Appendix E1.7 Risk mitigation

Composting systems must be installed by professionals, sized to the capacity required and the owner must be provided with clear maintenance instructions on installation. Only people who understand the necessary maintenance requirements should operate them to ensure that the core maintenance needs are undertaken as required, in accordance with the required safety precautions discussed further in this section. Compost systems are not appropriate for everyone, and particularly not for those who are unfamiliar and/or unwilling to undertake the critical maintenance requirements.

Composted humus material from composting toilets needs to be handled much more cautiously than 'ordinary' garden compost. It should be buried for approximately 12 months before further handling or distribution in a garden. It can then be mixed with soil or other materials but shouldn't be used anywhere near food crops or areas where there is ready access by people, especially children (Sinclair, 2004).

Owners must have a contract with an authorised contractor for both maintenance and compost disposal.

The following is a list of precautionary measures required for the minimisation of risks associated with maintenance of composting systems and/or contact with composted material (Silyn Roberts, 2002):

Reduce pathogen content in the waste	• Assume all waste is hazardous and accordingly, treat it with caution • Maintain the compost at 55°C for three days in a static pile or buried for 12 months prior to contact with land surface and have the compost removed by a licensed waste removal contractor • Restrict use of composting toilet systems for public facilities if viable alternatives exist, unless remote from electricity and/or water supplies and professional maintenance procedures are in place • Discourage use of public composting toilets • Organic material should be air-dried to 75% solids to meet vector attraction reduction requirements.
Reduce risk of inhalation	• Wear protective clothing whenever handling the compost unit or its materials. A face mask and ideally, goggles, should also be worn during all maintenance work • Disposal of waste should only be undertaken in areas where public access is restricted • Organic material should be turned frequently to minimise fungal growth.
Eliminate risk of ingestion	• Bury compost for at least 12 months to a minimum depth of 150 mm and in an area where it will not be in contact with any consumable plants or surface waters, prior to its use as a soil additive • Prevent access (particularly the elderly and children) to any areas containing compost • Maintain immunisation of all waste removal contractors and any persons undertaking maintenance on public facilities.
Reduce risk of abrasion	• Wear protective clothing, including thick gloves and appropriate footwear at all times during maintenance and disposal • Wash all protective clothing or handling equipment cautiously and disinfect gloves after use.
Other more general maintenance requirements include:	• Take caution with the cleaning agents used near and/or discharged into the compost toilet unit, in accordance with the system supplier/manufacturer's instructions • Periodic mixing of the compost material, in accordance with the system supplier/manufacturer's instructions, unless a mixing mechanism is provided. This is most important for continuous single chamber systems, where new material may mix randomly with composted material • Regular addition of organic bulking agents as a carbon source to enhance porous conditions for air distribution, in accordance with the system supplier/manufacturer's instructions • In cooler winter conditions, heating of the compost unit may be required to levels specified by the manufacturer • Regular removal of composted end product in accordance with the system supplier/ manufacturer's instructions (likely to be anything from three monthly to two yearly).

Necessary response actions in the event of inadequate maintenance	• Where a home owner is not prepared to undertake the necessary maintenance requirements on a regular basis, as specified by the system supplier/manufacturer and in conjunction with the relevant safety precautions, they shall either decommission and replace the composting toilet or enter into a maintenance contract with a professional system maintenance contractor • The maintenance contract should require that regular maintenance be undertaken at the frequency recommended by the manufacturer • Should the owner choose to completely decommission the compost toilet system, they should arrange for the wastewater from the replacement toilet to be connected into the on-site wastewater system (following approval for any modifications to increase the wastewater system capacity from the relevant local authority) • Until the on-site system has been appropriately upgraded, they should arrange for all waste to be collected and disposed off-site by commercial waste removal contractors.

If complete composting has taken place, the end product should be inoffensive and relatively “safe” to handle, but precautions are always necessary due to uncertainty concerning the potential for poorly composted pockets to be present within the humus material and due to ability of some organisms to survive and/or remain dormant for an extended period following the compost process.

The compost system maintenance contract should require that regular maintenance be undertaken at the frequency recommended by the system manufacturer/ maintenance contractor.

Other general design precautions include:

- Wherever practicable, the main on-site wastewater treatment and land application system should also be sized as if the blackwater (toilet wastewater) is also discharged into the main system, should this become necessary in the future, such as in the event the current or new owners choose to replace the composting unit with a conventional toilet
- Wherever the design wastewater flows are reduced due to the inclusion of a composting toilet (so that the wastewater flow consists predominantly of greywater), the land application area reserve allocation must be increased by an additional 40 to 50%. This is necessary to ensure that the wastewater system can accommodate the full potential wastewater flow volume that could be generated on the site should the composting toilet be decommissioned in future.

Appendix F1.0 Post-construction information requirements

After installation of the on-site wastewater treatment and land application system, the wastewater engineer or consultant will be required to verify its correct installation in accordance with the approved design.

These one-off requirements include As-Built Plans, Operation and Maintenance Plans, Maintenance Contracts and Installation Certification. The following is a list of the information that should be covered in each of these documents.

Appendix F1.1 As-built plans

As-built plans must include the following items:

- The location and capacity of all key treatment system components, including pre-treatment devices, remote septic tanks and disc filters
- The location of:
  - All land application system components including the location of all distribution lines and the size and location of the primary and reserve land application areas
  - All electrical cables and components
  - All sewer pipes discharging to the treatment plant
  - All rising mains to the land application system
  - All system control components, including control units and alarms, meters, recirculating valves, splitter valves/boxes and shutoff valves
- Identification and quantification of all critical separation distances, such as to buildings, property boundaries and surface waters
- The date drawn (i.e. date of system installation), title and site address, north point, scale bar, installers name and contact details
- Sign-off from the engineer/consultant.

Appendix F1.2 Operation and maintenance plans

Operation and maintenance plans are required so that the property owner has a clear understanding of how the system is designed to work and the key maintenance requirements necessary to achieve this.

Operation and maintenance plans should include the following:

The system and process description	• Details of the type and scale of facilities the system is designed to service, details of each of the system components and how the effluent flows through the system.
Wastewater treatment and land application system maintenance	• Details of the key operation and maintenance requirements and inspection procedures and frequencies. • It should also specify who is responsible for undertaking the maintenance tasks at different levels.
Monitoring and reporting requirements	• Details the frequency and procedures for system monitoring and reporting of monitoring records. • The location on the site or within the treatment system that any samples should be taken, and a procedure for correctly undertaking any required sampling.
Troubleshooting guide	• A guide for diagnosing system problems and potential causes and determining appropriate response actions. • For example, what to do in the event of pump failure, power failure, alarm activation or effluent breakout on the land application field.
Routine precautions:	• Precautions that a householder should be aware of, including details of water producing activities, devices which may influence the performance of the system (e.g. garbage grinders, dishwashers), the need for water conservation and the need to minimise the addition of strong chemicals to the wastewater treatment system (refer Appendix G1.3).
Contact details	• Emergency contact details of the system supplier, installation agent, and recommended service agent, including 24-hour emergency contacts.
Additional information	• A copy of the As-Built Plans, Loading Certificate, Installation Certification, Maintenance Contract and system warranty (if applicable).

Appendix F1.3 Maintenance contracts

Maintenance contracts are required to ensure the on-going maintenance of the treatment and land application systems for the lifetime of the system. The maintenance contractor should have a high level of experience with the operation of on-site wastewater treatment systems and should be familiar with the specific design and components of the system to be serviced.

Maintenance servicing for secondary wastewater treatment systems should be undertaken at least on a 6-monthly basis, and more frequently where the system is subject to high or fluctuating wastewater loads (such as increased or seasonal occupancy – refer to Section C) or is where the system is servicing commercial facilities.

Appendix F1.4 Installation certification

Certification verifying the correct installation of the wastewater system should be prepared by the wastewater design consultant/engineer and should be provided to the property owner, and if required, to Auckland Council as soon as practicable after installation.

It may be a regulatory requirement for installation certification to be in the form of a Producer Statement. Producer Statements are issued by registered professional engineers and may be a requirement for gaining final Auckland Council approval.

Installation certification should confirm:

- That the system has been installed in accordance with the approved design or should specify where installation has varied from this design. It is important that Auckland Council and/or the system designer are consulted prior to installation of any component that is not part of the approved design
- The design loading rate and operating range (hydraulic and organic) of the treatment and land application systems
- That any existing components to be re-used have been inspected and are in sound condition
- That any abandoned components have been decommissioned as required
- The date of inspection of the installed system
- The name, contact details and qualifications (including professional memberships) of the certifying person.

Appendix G1.0 Key maintenance requirements

Appendix G1.1 How to avoid problems with on-site wastewater treatment and land application systems

Conventional septic tank systems fail due to a variety of causes. They may be:

Undersized for the current wastewater flow volumes	• This must be addressed with either changes to the household water usage or by upgrading the system.
Inappropriate inputs from the household	• This may include flushing medications (such as antibiotics) into the waste stream, overloading the system with organic material (such as from garbage grinders), use of chemicals (such as bleach).
Lack of wastewater treatment system maintenance	• Primary and secondary systems that are not maintained (with regular inspection and pump outs) can fail. • For instance, build-up of sludge and scum can result in poor separation in the tank which leads to carryover of solids into the land application area, clogging of filters and potentially overflows from the septic system.
Lack of maintenance of the land application area	• Drainage within the land application area must be maintained (e.g. inspections and flushing lines) in order to avoid clogging. • Problems with the land application area can also be a result of hydraulic overloading caused by increased occupancy and/or greater water use.

Malfunctioning on-site wastewater treatment and land application systems can contribute to environmental pollution and can become potential health risks. Ignoring system maintenance requirements will lead to signs of system failure which can then lead to further significant problems such as health risks from pathogens, odours, contamination of groundwater and surface water, attraction of flies and rodents, and decreased property value.

Proper maintenance of septic systems not only lessens environmental pollution and aesthetic value of a property, but also lessens potential costs that could be incurred when a damaged system needs to be repaired or replaced.

Appendix G1.2 Maintenance and enhancement of existing on-site septic systems

All septic tank owners are required to:

Regularly pump out the septic tank	• Check the respective depths of sludge, liquid wastewater and scum in the septic tank at least once per year. • The tank needs to be pumped out once the combined depth of sludge and scum occupies 50% of the tank depth. For a standard household, this should be in the order of once every 3 to 5 years. This may be required more frequently where houses are fully occupied and/or there is no outlet filter and for tanks serving public toilets, and less frequently, up to once every five years or longer, where occupancy is low or intermittent, and/or where an effective outlet filter has been maintained. • Tanks with outlet filters enable faster build-up of organic solids to critical mass where anaerobic digestion in the gas phase commences, thus accelerating consolidation of sludge mass and extending the life of the solids treatment process prior to needing pump out. Pump out frequencies of 8 - 10 years can be achieved. Annual monitoring of sludge levels can confirm the slower rate of sludge accumulation.
Install and maintain an outlet filter	• These are required to be installed on all new septic tank systems and it is strongly recommended that they be retrofitted to old septic tanks. They are often the most effective and cheapest option for improving the performance and life of a wastewater system. • They ensure all solids ≥ 3 mm diameter are retained and biodegraded within the septic tank, and do not access or clog the soakage lines. • Check the biomat (slime layer) build-up on the filter regularly and clean it as required to avoid excessive build-up affecting filter performance. • To clean the filter, remove it from the septic tank and hose down, discharging the rinse water back into the septic tank, or elsewhere into dense vegetation where it will not cause any nuisance, and reinstate the filter into the septic tank.
Avoid flushing the following into the system	• Non-biodegradable chemicals, e.g. drain cleaners or disinfectants. • Any anti-microbial agents (such as antibacterial soaps, chlorine etc.). • Sanitary napkins, other hygienic products, dental floss, kitty litter, etc. • Oil and fat. • Detergents (toxic detergents and other household cleaners should be avoided as they kill the bacteria in the septic tank). • Discharge from garbage disposal units. • Food scraps. • Discarded medicines (such as antibiotics).
Minimise water usage/improve water conservation	• This is particularly important on sites where the area available for wastewater dispersal and the system's capacity is constrained, where any seepage or run-off could access natural water and affect water quality or where land application areas may be accessed by children. • Install water-reduction fixtures on water outlets and/or low flush toilets. This is important on small sites and/or where there is high occupancy in the dwelling where the system land application system capacity is threatened.

	• Do not leave taps running for long periods. • Install push button taps on public facilities. • Fix water leaks. • Do not connect rain gutters or stormwater drains to septic tanks.
Enhance evapotranspiration and discourage access to land application areas	• Plant the land application area densely, maintain plantings and check regularly for even wastewater distribution and even plant growth. Trim vegetation when necessary to encourage optimal evapotranspiration. • Where the land application area is grassed, it should be regularly mowed to optimise growth and prevent the grass from becoming rank. • Do not pave the land application area. • Use dense border planting, low chains, signage and/or fencing to discourage human access and to prevent any vehicle or stock access.

Records should be kept of all maintenance undertaken on the wastewater systems, particularly when contractors are involved. This includes tank pump outs, tank inspections, and access openings. Do not add or alter any part of your system without Auckland Council approval.

Appendix G1.3 'Do and do not' for homeowners

All wastewater (toilets, shower, sinks, laundry) produced on the site is discharged to an on-site wastewater treatment and land application system. The wastewater treatment system is a fragile biological process and therefore requires care by all residents.

You can help maintain an effective wastewater system on your site by ensuring that no toxic chemicals are put down the sinks or toilets and use only environmentally-friendly cleaning products. Toxic chemicals, drugs (e.g. antibiotics) can kill the bacteria in the treatment system. These organisms are required to treat wastewater. If healthy populations are not maintained, the system will fail resulting in poorly treated wastewater discharging into the soil, odours, increased maintenance requirements and eventually, the expense of upgrading the system. You should also minimise your water use as much as possible to protect the system from overloading.

Below is a list of suggestions for ensuring for your wastewater system functions as designed:

DO	DO NOT
• Minimise your water use • Minimise the length of showers • Use showers in preference to baths • Use bio-degradable soaps and cleaners • Check that all your cleaning products are suitable for septic tanks • Minimise use of chemical toilet cleaners • Scrape all plates and dishes to remove as much fat and grease as possible. Clean with paper towels and place in the rubbish • Report/fix all leaking taps as soon as possible • Use phosphate free/low phosphorus-based laundry detergents.	• Pour any toxic/strong chemicals into the drain. This includes paint, oil, grease, paint thinners, pesticides • Flush any products down the toilet, other than standard toilet paper • Discard any drugs down the sink or toilet • Tip chlorine cleaners or disinfectant based products into the system • Use excessive amounts of any cleaners • Use chemical drain cleaning products • Do all your laundry on one day • Install in-sink garbage grinders. If a grinder exists, don't discharge high volumes of scraps, especially carbohydrates or fats/oils down it • Put coffee grounds down the sink.

Appendix G1.4 Use of household chemicals

Effects of household chemicals on land application system receiving soils

Use of many cleaning chemicals in facilities served by on-site land application systems can result in high cleaning agent concentrations being discharged into the receiving soils. Over time, these chemicals and constituents can build up and change the function of the receiving soil both in terms of quality and condition.

Many chemicals can disrupt soil structure and decrease hydraulic conductivity while others can act as bactericides, destroying the essential micro-organisms required to achieve the high level of biodegradation in the treatment and land application systems. This then increases the potential environmental impacts of the contaminants in the receiving environment.

Improved wastewater treatment technologies can only reduce the composition and concentration of some cleaning agents, not the strong acids and strong alkaline agents. Therefore, the use of these chemicals must be avoided or minimised.

Considerations when using household chemicals

Normal use of household cleaners should not impact the septic system. The exceptions are laundry, dishwashers and direct discharge of concentrated chemicals. The following matters need to be considered when using cleaning agents in a domestic situation:

Laundry	• Laundry powders are often extremely high in sodium which will destroy the salt balance in soils. Check the labels and ensure they are appropriate for septic systems. • Greywater consisting of washing machine wash-cycle discharge water can have an alkaline pH of up to 10. Although this will be diluted in a septic tank, it will impact on micro-organism populations and can also lead to detrimental effects on soil structure. • Choose a laundry powder with a zero-phosphate content and low in alkaline salts (in particular, a low sodium level). • Laundry discharge should not contain any chlorine.
Dishwashers	• Wastewater flows from dishwashing machines can have an impact on wastewater treatment systems, not only in terms of wastewater flow volumes and additional organic waste, but more importantly, in terms of the strong cleaning chemicals. • Avoid using dishwashing powders and liquids which contain alkaline chemicals, enzymes and/or chlorine.
Direct discharge	• No chemicals should be poured directly into the wastewater system. In addition, empty containers should not be rinsed into the system. • Highly corrosive cleaners (such as toilet and drain cleaners) that have precautionary labels warning users to minimise direct contact, are an indication that they can adversely affect the wastewater treatment system. • Up to 1 cup of bactericides (such as bleach) can be sufficient to impact on all the micro-organisms/bugs in a septic tank, severely affecting tank performance for some time.

The best solution for optimising the long-term effectiveness of soils within a wastewater land application field is to minimise the use and discharge of strong cleaning chemicals at source.

Substitutes for household cleaning chemicals

Use of the following readily biodegradable substitutes for common potentially harmful household cleaning chemicals will reduce the stress on a septic system, significantly enhance the performance of the whole system and increase the life of the land application field, while reducing the potential effects of the receiving soils. Alternatives include:

- Soft soap cleaners and biodegradable cleaners, if they have low chlorine levels
- Baking soda directly or on a damp sponge/toilet brush and scrub for cleaning
- A solution of 50 mL white vinegar to 1 litre of water used for cleaning
- Borax at a concentration of 25 g in 1 litre of water for disinfection
- Mechanical de-clogging - use a plunger, metal snake, or remove and clean trap.

Appendix G1.5 Maintenance requirements

Key maintenance requirements to be undertaken by system maintenance contractor

Wastewater system owners are required to enter into a maintenance contract with the system supplier or other contractor experienced in wastewater treatment system operation and maintenance.

The minimum system maintenance requirements for the most basic on-site treatment and land application systems include, but are not limited to, the following three-monthly actions:

Cleaning	• Remove and clean (hose down) the effluent outlet filters from the septic tank or primary treatment compartment as well as the disc filter from the treatment system prior to the rising main leading to the drip irrigation lines. • Ensure appropriate protective clothing is worn and the rinse water is discharged back into the tank or alternatively to densely vegetated inaccessible ground where there is no opportunity for runoff.
Measure the sludge depth	• This can be done by removing the septic tank lid/vent and inserting a stick into the tank and noting the change in density of material at the liquid-sludge layer interface within the tank. • If the layer is more than one third total tank depth (this equates to more than 0.7 m from top of a 2 m septic tank), the tank needs to be pumped out.
Check all electrical parts	• In particular, check and test that all visual and audible alarms for pump chamber and aerator blower are working.
Clear the aerator	• Lift the aerator out of the aeration compartment and check for any material that would cause drag. • Clean the aerator by hosing it.
Flush all the land application lines	• If the system consists of pressure-compensating drip irrigation lines, remove the flush valves and flush with fresh water from a hose, then reinstall the valves.
Walk over the land application area and look closely for any signs of failure	• This can include uneven vegetative growth, uneven effluent distribution, any wet patches and/or signs of effluent ponding, or clogging or channelling of the soils. • In the event that any such problems are identified, contact the installer and/or a maintenance contractor to remedy the situation. Also consider measures to reduce water usage.

Appendix G1.6 Problem solving

Table 76 provides a list of suggested actions in the event of problems with an on-site wastewater system.

Table 76: General guidance for problem solving

Problem	Solution
Odour	• Insert activated carbon filters into the septic tank vents. • In the case of an aerobic treatment plant, contact the supplier and ensure that the system is sufficiently aerated.
Septic tank or aerobic treatment plant bacterial breakdown	• Use soft soap solutions or biodegradable cleaners for cleaning. • Use only detergents low in alkaline salts, phosphorous, and chlorine levels. • Avoid heavy use of detergents and the use of disinfectants and other household cleaners as they affect the bacterial action within septic tanks. • Do not discharge any pharmaceutical medication or disinfectants into the wastewater system. • Minimise discharge of food waste and fats and oils into kitchen sink/garbage grinders.
Septic tank overflow/odours	• Immediately engage a drain layer/contractor to investigate any blockages. • Pump out the septic tank. • Decrease water usage until the problem is remedied. • Install high-level alarms, 24-hour storage in new tanks and 12-hour storage in existing tanks as a warning system. • Mitigate initial problems by removing inspection covers annually to check the depth of the scum mat and sludge. The tank should be cleaned out when combined depth of scum and sludge occupy half the tank's volume or at least every three years. (Compost tea leaves and other kitchen wastes that are slow to break down, to avoid your system filling more rapidly.)
Blocked filter	• Cleaning is required. This often only involves a quick hose down of the filter. It should then be undertaken regularly at a frequency recommended by the manufacturer, depending upon the type of filter in place.
Clogged land application system	• Pump out the tank and the land application lines. • Inspect and/or consider reconstruction of the land application system and/or individual lines. • Upgrade the system to improve the treatment system, e.g. by a pressure-compensating drip irrigation system.

Appendix H1.0 Common wastewater system operational faults

The following is a list of problems identified during typical system compliance and maintenance inspections and indicative of system operational or maintenance faults. These faults will affect the immediate and/or longer-term performance of a system and should be addressed immediately by the system owner or identified and remedied by the contractor as part of a routine maintenance inspection.

Appendix H1.1 General problems with treatment system

- System pipe overloaded by weekend or other peak flow events
- Treatment plant flooded or blocked due to heavy rain
- Surface water entering treatment system/pump chamber through lids
- Aerator shaft dislodged
- Split in the airline
- Aerator seized
- Diaphragm in blower failed
- Bearing noisy in aerator
- Grass roots inside aerator riser
- Blockages in sludge return pipe
- Sludge return pipe installed around the wrong way
- Inlet tee absent
- Overflow pipe damaged by ground movement
- Overflow pipe blocked
- Non-return valves fail and need replacement
- Pump intake blocked
- Pre-treatment tank outlet filter blocked causing tank to overflow
- Pump seized if system not used for a while
- Tree/weed roots intrude into sand filter
- Power left off when owner cleans filter, causing plant to flood
- Sand filter infiltration
- Infiltration and inflow of groundwater or stormwater through poorly installed pipework and seals
- Odours from overloading/poor performance.

Appendix H1.2 System electrical problems

- System operating on a single 16-amp circuit breaker, so when the pump comes on it draws excess power, causing circuit breaker to trip
- Air light not working and audible alarm on mute and/or visual alarm light bulb removed
- Faulty pump floats
- Electrical conduct not sealed
- Timer replaced but not reset
- Float switch missing, causing pump to run all the time
- Float switch sparking
- Faulty wiring
- Pump float stuck in lead
- Pump float cable too loose
- Blower tripping on overload
- Diffuser blocked
- Isolating switch damaged
- Air pressure switch replaced
- Power connection via a temporary lead
- Float control wired up incorrectly or caught causing pump to run continuously and burn out
- Pump failed water level rose up, covered the plug in pump chamber and caused the fuse to blow.

Appendix H1.3 Common problems with land application systems

- Uneven loading within land application area
- Blocked distribution boxes, e.g. stand pipes removed and/or lack of regular rotation leading to preferential loading of one part of land application system
- Land application area wet/saturated/ponding water
- Lines blocked, damaged, contain black worms
- Blocked lines cause irrigation pump to burn out
- Pump line pulled out of socket at pump
- Irrigation pump float caught
- Irrigation lines pulled out of pump rising main/manifold
- No/inadequate topsoil
- Irrigation field poorly planted (e.g. low density, poor growth and incorrect species)
- Root intrusion into distribution lines
- Heavy sludge build-up in distribution lines due to lack of outlet filter
- Water meter on irrigation field full of sand so needs to be replaced
- Overflow pipe from water tanks discharges over irrigation field, and flooding it in heavy rain
- Irrigation pump replaced with another pump with the wrong/inadequate head

- Heavy scum build-up in lower most distribution line
- Permanent structures in place within reserve area specified on approved plans.

Appendix H1.4 Common problems with PCDI irrigation lines

- Irrigation lines kinked/creased (restricting flow)
- Irrigation lines used as the header supply pipe for irrigation field
- Irrigation lines not set in place and randomly moved around property by owner
- Bite holes in irrigation lines (due to rats)
- Damaged pump rising main/manifold (caused possibly by lawn mower)
- Leak/ hole in pump rising main/manifold
- Rising main creased (tank flooded) to irrigation field
- Pump rising main/manifold found coiled up below treatment plant
- Pump rising main/manifold joined with PVC pipe with tape around it
- Pump main disconnected by the tank
- Flush valves cannot be located
- Refuse or green waste placed over flush valves
- Faulty air relief valves
- Top missing from TNL/DNL[3] valves
- Flush valve missing
- In-line filter blocked (e.g. solids build-up, inadequate flushing/poor performance) or removed
- In-line filter installed back to front
- In-line filter has a split within the outside casing.

Appendix H1.5 Common problems on LPED irrigation lines

- Stock access leading to damage of LPED lines
- Broken pipe in LPED manifold
- Dosing siphon reset
- Siphon manifold blocked
- Orifice plate blocked
- Surface mounted pumps can lose their prime if not used for a while
- Uneven loading from lines not installed level or along contours
- Odours – especially from shallow/overloaded LPED lines.

[3] TNL valve (Tube Non-Leakage) has now been replaced by the DNL valve (Dripper Non-Leakage)

Appendix I1.0 Potential remedial actions[4]

Appendix I1.1 Background

On-site wastewater systems which are exhibiting poor operational and environmental performance can be:

a) Remediated through maintenance actions

b) Upgraded via on-site remedial works

c) Upgraded by on-site plus off-site (cluster) remedial works

d) Made redundant and replaced by a modified, or conventional, community sewerage scheme.

Appendix I1.2 Schedule of potential remedial actions

The extent of remedial upgrade works should be investigated, keeping in mind specific environmental constraints which have an impact on each site. This will assist in identifying the direct relationship the failure has with the surrounding environment and enable system repairs to be prioritised accordingly. Any solutions with regards to remedial actions can best be attained with the full co-operation of the home owner.

It may well be that in evaluating situations of area-wide poor performance, then proceeding directly to remedial works is the best solution rather than attempting to recover the performance levels intended by the original designs via instituting remedial maintenance measures. In all cases, remedial maintenance may need to be supplemented by various levels of remedial works. The fall-back position is to proceed to (c) and (d) in Appendix I1.1 above.

Whatever approach is adopted would require follow-up through a Programmed Operation, Maintenance and Management Scheme (POMMS) incorporating community-wide WOF (warrant of fitness) inspection and servicing of on-site wastewater systems.

Appendix I1.3 Improving performance of existing on-site wastewater systems

Improvements options are presented for:

a) Primary treatment systems (Table 77)

b) Secondary treatment systems (Table 78)

c) Distribution systems (Table 79)

d) Land application systems (Table 80)

[4] Adapted from Ian Gunn. On-SiteNewZ, October 30, 2012

Acronyms:

ATP	Aerobic treatment plant	MBR	Membrane bio-reactor
AutoSV	Automatic sequencing valve	POMMS	Programmed operation, maintenance and management scheme
AWTS	Aerated wastewater treatment system (activated sludge)	RBC	Rotating biological contactor
EOF	Effluent outlet filter	rtPBR	Recirculating textile packed bed reactor
ETS	Evapotranspiration seepage	sfPBR	Sand filter packed bed reactor
LPED	Low pressure effluent distribution	ST-EOF	Septic tank-effluent outlet filter
LPP	Low pressure pipe	WOF	Warrant of fitness

Table 77: Improving performance of existing on-site wastewater systems – A schedule of potential remedial actions – Primary treatment systems

Item	Type or component of system	Remedial maintenance actions	Remedial upgrade actions
A: Primary treatment systems			
A1	Older custom-built single chamber septic tank systems	• Pump out tank and inspect for damage/leaks • Undertake repairs and re-commission tank • Check size/capacity against inflow/dwelling size and/or design loading • Match future pump out frequency against tank size/capacity • Add system to database for regular WOF inspections • Incorporate system into area-wide POMMS	• Repair damage/leaks • Install effluent outlet filter (EOF) either internally or externally (Note: An external filter has potential to block prematurely given the small chamber it can be expected to be installed into.) • Add a second septic tank as a Stage 2 treatment unit subject to effluent flows exceeding design loading • Add secondary treatment upgrade unit (ATP) (aerobic treatment plant) retrofit or wetland • Replace system with modern septic tank (4,500 L minimum capacity) incorporating an effluent outlet filter (ST-EOF) • Replace system with modern ATP secondary/tertiary treatment plant (AWTS; RBC; sfPBR; rtPBR; MBR)
A2	Older precast septic tank systems	• As for A1 above	• As for A1 above
A3	Double chamber septic tank systems	• As for A1 above	• As for A1 above • Note: effluent outlet filter to be installed at outlet of second chamber – outlet of tank
A4	Modern high capacity septic tank with effluent outlet filter (ST-EOF)	• Check effluent outlet filter • Check size/capacity against inflow/dwelling size and/or design loading • Match future pump out frequency against tank size/capacity • Add system to database for regular WOF inspections • Incorporate system into area-wide POMMS	• Add a second septic tank as a Stage 2 treatment unit • Add secondary treatment upgrade unit (aerobic treatment plant) retrofit or wetland • Replace system with modern ATP secondary/tertiary treatment plant (AWTS; RBC; sfPBR; rtPBR; MBR)

Table 78: Improving performance of existing on-site wastewater systems – A schedule of potential remedial actions – Secondary treatment systems

Item	Type or component of system	Remedial maintenance actions	Remedial upgrade actions
B: Secondary treatment systems			
B1	Aerated wastewater treatment system (activated sludge)	• Check primary treatment chamber for sludge accumulation, and pump out as required • Check secondary sludge chamber for solids accumulation, and pump out as required • Check air lines to aerator • Check aerator capacity against inflow/dwelling size and/or design load • Check aeration compartment capacity against inflow/dwelling size and/or design load • Change aerator timing cycle to better suit flow and population loading • Check return secondary sludge delivery system • Check control system governing aerator operations • Add system to database for regular WOF inspections • Incorporate system into area-wide POMMS • Check pH levels	• Increase system capacity with new high-performance aerator • Replace return sludge transfer system with higher capacity unit • Add final effluent disinfection system if groundwater quality protection required • Add tertiary treatment via wetland • Replace unit with upgraded aerated wastewater treatment system or alternative ATP treatment system • Alkalinity added to stimulate bacteria if pH levels too low

Item	Type or component of system	Remedial maintenance actions	Remedial upgrade actions
B: Secondary treatment systems			
B2	Sand filter packed bed reactor (sfPBR)	• Check condition of sand • Check under-drainage collection system • Check grading of sand • Remove upper sand layer and replace with clean sand • Check sfPBR capacity against inflow/dwelling size and/or design load • Add system to database for regular WOF inspections • Incorporate system into area-wide POMMS	• Increase depth of sand • Remove sand and replace with new - grading to be accurate depending on system being Recirculating Sand Filter (RSF) or Intermittent Sand Filter (ISF) • Note: Coarser sand will allow effluent to flow through an ISF too quickly and result in poor effluent quality leading to irrigation line blockages, odour etc. • Add final effluent disinfection system if groundwater quality protection required • Add tertiary treatment via wetland • Replace unit with upgraded sfPBR or alternative ATP treatment system
B3	Recirculating textile packed bed reactor (rtPBR)	• Check condition of textile sheets • Remove and hose down textile sheets • Check recirculation pumps • Adjust recirculation ratios and/or timing of recirculation pumping • Check for solids build-up in recirculation tank • Check rtPBR capacity against inflow/dwelling size and/or design load • Add system to database for regular WOF inspections • Incorporate system into area-wide POMMS MS	• Add extra textile module • Replace old textile sheets with new • Add final effluent disinfection system if groundwater quality protection required • Add tertiary treatment via wetland • Replace unit with upgraded rtPBR or alternative ATP treatment system

Table 79: Improving performance of existing on-site wastewater systems – A schedule of potential remedial actions – Distribution systems

Item	Type or component of system	Remedial maintenance actions	Remedial upgrade actions
C: Distribution systems			
C1	Trickle (gravity) loading	• Check and adjust distribution box effectiveness • Check for blockages, fats, bio-slime etc. within pipes leading from distribution box to independent soakage trenches • Add system to database for regular WOF inspections • Incorporate system into area-wide POMMS	• Add flood loading (tipping bucket) device • Add dosing chamber siphon to convert to dosed system • Add dosing sump and pump to convert to dosed system
C2	Pressure dose loading	• Check and test all dose lines for distribution effectiveness • Change pump cycle times • Purge dose lines of accumulated solids (Note: Flushing lines with brush will remove bio-slime and associated build-up of foreign matter) • Add system to database for regular WOF inspections • Incorporate system into area-wide POMMS	• Add up-stand pipes at end of dose lines for checking delivery pressures on regular basis and allow for flushing/brushing of laterals • Change pump unit to higher performance system • Convert dosing system to sequential dosing by adding automatic sequencing valve (AutoSV)
C3	Automatic sequencing valve (AutoSV)	• Check sequencing rotations • Adjust spring loaded cam controller • Check the AutoSV is at highest point of system OR adequate non-return-valves are fitted to allow relaxing of spring following dose loading • Add system to database for regular WOF inspections • Incorporate system into area-wide POMMS	• Replace unit if faulty

Table 80: Improving performance of existing on-site wastewater systems – A schedule of potential remedial actions – Land application systems

Item	Type or component of system	Remedial maintenance actions	Remedial upgrade actions
D: Land application systems			
D1	Deep trench or soakage pits	• Check vegetation within and around system enclosing area and down slope • Trim vegetation within and around system enclosing area and down slope • Check effluent water level in system • Install standpipes to facilitate regular checking of effluent water level in system • Pump out standing effluent in trench system • Add system to database for regular WOF inspections • Incorporate system into area-wide POMMS • DO NOT use oxidising chemical treatments (chlorine or peroxide based)	• Install surface water and/or groundwater diversion trenches/swales • Plant evapotranspiration assisting vegetation/ plantings/shrubs • Install greywater diversion system to garden irrigation • Pump out trench system and add EOF to primary treatment tank • Pump out trench system and change treatment level to secondary with an ATP retrofit system • Abandon original trench system and construct new trenches within the undisturbed soil between the original trenches • Abandon original primary treatment and trench system, change treatment level to secondary with an ATP system and construct drip line irrigation within the undisturbed soil between and beyond the original trenches
D2	Shallow trenches	• As for D1 above	• As for D1 above

Item	Type or component of system	Remedial maintenance actions	Remedial upgrade actions
D: Land application systems			
D3	Shallow beds	• Check vegetation within and around system enclosing area and down slope • Trim vegetation within and around system enclosing area and down slope • Check effluent water level in system • Install standpipes to facilitate regular checking of effluent water level in system • Pump out standing effluent in bed system • Add system to database for regular WOF inspections • Incorporate system into area-wide POMMS • DO NOT use oxidising chemical treatments (chlorine or peroxide based)	• Install surface water and/or groundwater diversion trenches/swales • Plant evapotranspiration assisting vegetation/ plantings/shrubs • Install greywater diversion system to garden irrigation • Pump out bed system and add EOF to primary treatment tank • Construct new bed system at alternative location • Pump out bed system and change treatment level to secondary with an ATP retrofit system • Abandon original bed system and relocate to a new replacement bed or alternative land application system • Abandon the original primary treatment and bed system, change treatment level to secondary with an ATP system, and construct drip line irrigation over the surface of and beyond the original bed system
D4	Older borehole systems (NOTE: Older borehole systems should be phased out.)	• Check effluent water level in system • Install standpipes to facilitate regular checking of effluent water level in system • Pump out standing effluent in borehole system • Temporary air sparge system • Add to database for regular WOF inspections • Incorporate unit into area-wide POMMS • Add system to database for regular WOF inspections • Incorporate system into area-wide POMMS • DO NOT use oxidising chemical treatments (chlorine or peroxide based) and DO NOT use explosive charges	• Install surface water and/or groundwater diversion trenches/swales • Plant evapotranspiration assisting vegetation/ plantings/shrubs • Install greywater diversion system to garden irrigation • Add permanent air sparge system • Add additional deep bores in the natural soil between the existing ones • Improve effluent discharge quality by adding an EOF to primary treatment unit. • Pump out borehole system and change treatment level to secondary with an ATP retrofit system • Abandon original borehole system and relocate discharge to a new treatment and alternative land application system

Item	Type or component of system	Remedial maintenance actions	Remedial upgrade actions
D: Land application systems			
D5	ETS beds	• Check vegetation within and around system enclosing area and down slope • Trim vegetation within and around system enclosing area and down slope • Check equal distribution of effluent through all beds • Check effluent water level in system • Install standpipes to facilitate regular checking of effluent water level in system • Pump out standing effluent in bed system • Add system to database for regular WOF inspections • Incorporate system into area-wide POMMS	• Install surface water and/or groundwater diversion trenches/swales • Plant evapotranspiration assisting vegetation/ plantings/shrubs • Install greywater diversion system to garden irrigation • Construct new ETS bed system at alternative location • Pump out bed system and change treatment level to secondary with an ATP retrofit system • Abandon original bed system and relocate to a new replacement bed or alternative land application system • Abandon the primary treatment unit and original bed system, change treatment level to secondary with an ATP system, and construct drip line irrigation over the surface of and around the original bed system • Install pump or dosing siphon to achieve equal distribution through multiple ETS beds • Retrofit LPED lines within existing distribution lines to ensure equal distribution along the entire length of arch ETS beds
D6	Wisconsin Mounds	• Check vegetation within and around system enclosing area and down slope • Trim vegetation within and around system enclosing area and down slope • Check effluent water level in system • Install standpipes to facilitate regular checking of effluent water level in system • Pump out standing effluent in mound system • Add system to database for regular WOF inspections • Incorporate system into area-wide POMMS	• Install surface water and/or groundwater diversion trenches/swales • Plant evapotranspiration assisting vegetation/ plantings/shrubs • Install greywater diversion system to garden irrigation • Construct "toe" extension on down slope edge of mound • Pump out mound system and change treatment level to secondary with an ATP retrofit system • Construct new mound at alternative location (retaining option for ATP retrofit) • Abandon the primary treatment unit and original mound system, change treatment level to secondary with an ATP system, and construct drip line irrigation system at an alternative location

Item	Type or component of system	Remedial maintenance actions	Remedial upgrade actions
D: Land application systems			
D7	LPP (low pressure pipe) irrigation fields	• Check for access to LPP by stock or vehicles • Check vegetation within and around system enclosing area and down slope • Check for "soggy" areas within irrigation field • Trim vegetation within and around system enclosing area and down slope • Check effluent water level in system • Install standpipes to facilitate regular checking of effluent water level in system • Check pumping unit operation and duty • Install up-stand pipes at the end of pressure lines to check distribution pump pressures • Pump out standing effluent in bed system • Add system to database for regular WOF inspections • Incorporate system into area-wide POMMS	• Install surface water and/or groundwater diversion trenches/swales • Overlay LPP with suitable soil, planting and fence from stock/vehicles • Plant evapotranspiration assisting vegetation/ plantings/shrubs • Install greywater diversion system to garden irrigation • Supplement topsoil cover • Replace LPP lines with LPED • Change pump unit to higher performance system • Convert dosing system to sequential dosing by adding automatic sequencing valve (AutoSV) • Abandon original LPP lines system and construct new lines within the undisturbed soil between the original trenches • Provide secondary treatment level via ATP retrofit and dose original LPP lines • Abandon original primary treatment and LPP trench system, change treatment level to secondary with an ATP system and construct drip line irrigation within the undisturbed soil between the original trenches • Abandon the original LPP system, and construct new system at alternative location

Item	Type or component of system	Remedial maintenance actions	Remedial upgrade actions
D: Land application systems			
D8	LPED (low pressure effluent distribution) irrigation fields	• Check for access to LPED by stock or vehicles • Check vegetation within and around system enclosing area and down slope • Check for "soggy" areas within irrigation field • Trim vegetation within and around system enclosing area and down slope • Check effluent water level in system • Install standpipes to facilitate regular checking of effluent water level in system • Check pumping unit operation and duty • Install up-stand pipes at the end of pressure lines to check distribution pump pressures • Pump out standing effluent in bed system • Add system to database for regular WOF inspections • Incorporate system into area-wide POMMS	• Install surface water and/or groundwater diversion trenches/swales • Overlay LPED with suitable soil, planting and fence from stock/vehicles • Plant evapotranspiration assisting vegetation/ plantings/shrubs • Install greywater diversion system to garden irrigation • Supplement topsoil cover • Change pump unit to higher performance system • Convert dosing system to sequential dosing by adding automatic sequencing valve (AutoSV) • Abandon original LPED lines system and construct new lines within the undisturbed soil between the original trenches • Provide secondary treatment level via ATP retrofit and dose original LPED lines • Abandon original primary treatment and LPED trench system, change treatment level to secondary with an ATP system and construct drip line irrigation within the undisturbed soil between the original trenches • Abandon the original LPED system, and construct new system at alternative location

Item	Type or component of system	Remedial maintenance actions	Remedial upgrade actions
D: Land application systems			
D9	Drip irrigation fields	• Check vegetation within and around system enclosing area and down slope • Check for “soggy” areas within irrigation field • Trim vegetation within and around system enclosing area and down slope • Check the performance of the ATP system providing treated effluent to the drip line system • Check the disc filter unit between pump and manifold feeding the drip line is suitably sized to restrict solids entering irrigation lines • Check for air locks in distribution system and that air valves are operating correctly • Check solids content in drip lines and flush all lines • Check if uniform distribution is being obtained through all emitters and over all drip lines • Replace non-operating emitters • Install standpipes to facilitate regular checking of effluent water level in system • Check pumping unit operation and duty • Add system to database for regular WOF inspections • Incorporate system into area-wide POMMS	• Install surface water and/or groundwater diversion trenches/swales • Plant evapotranspiration assisting vegetation/ plantings/shrubs • Install greywater diversion system to garden irrigation • Supplement topsoil cover • Install additional disc filter units or automatic backwashing units • Convert dosing system to sequential dosing by adding automatic sequencing valve (AutoSV) • Abandon the original drip line system, and construct new drip lines within the undisturbed soil between the original drip lines • Abandon the original drip line system, and construct new drip lines system at alternative location

Acknowledgement: On-Site NewZ acknowledges the contribution of Kevin Maney of KJ Wastewater Solutions, Auckland, in reviewing the draft of the document from which this Appendix is sourced.

Appendix J1.0 System inspection record template

The following generic form contains a list that should be checked for in any basic on-site system compliance and maintenance site inspection. The lists are not comprehensive but can be used as a basis for developing system check lists.

Any checklist should also provide space for sketches of system layout/problem areas and room for comment on matters of concern specific to each particular site and system and for response and follow-up actions required.

A: Inspection details

Company name:	Contact person:
Inspector/contractor:	Mobile number:
Email:	Area of expertise:
Inspection date:	Time:

General weather conditions – (on day of inspection and previous three days):

B: Reason for inspection

☐ Routine inspection for ☐ Septic tank (3 yearly) ☐ Secondary system (annual)

☐ Complaint - *specify*

☐ Maintenance issue - *specify*

☐ Other - *specify*

C: Property information

Property address:

☐ Household – *Specify number of regular occupants*

☐ Public facility – *Specify type*

☐ Commercial – *Specify type*

☐ Other – *Specify*

Water supply	Fixtures
☐ Reticulated water supply	☐ Garbage grinder
☐ Rainwater tank	☐ Dual flush toilets
☐ Bore water	☐ Auto shut off taps
Meter reading at time of inspection (m^3):_______________	☐ Low flow shower head/s
Previous meter readings available for inspection: ☐ Yes ☐ No	☐ Bath
Comments:	☐ Front loader washing machine
	☐ Other:

D: System information

Maximum system design capacity –

Flow volume *(if known)*: ____(L/day)

Occupancy volume *(if known):*____________________________________persons

Actual occupancy/average usage –

Flow volume *(if known)*: ____(L/day)

Occupancy volume *(if known):*____________________________________persons

SITE SKETCH

Show approximate location of treatment system and land application system components in relation to boundary, edges of dwelling and other buildings, impervious areas, and any stormwater drains or streams.

E: Wastewater treatment system

☐ Long drop
☐ Vault toilet or holding tank
☐ Primary system (septic tank)
☐ Aerated tank
☐ Membrane/textile filter
☐ Vermiculture system
☐ Proprietary device – *specify and provide design details*
☐ Other - *specify*

System commissioning date *(if known)*: (dd) (mm) (yyyy)

☐ System layout in accordance with approved design plans

Comments:

System filters

☐ Not part of system
☐ Present - satisfactory
☐ Present - unsatisfactory
☐ Not clean ☐ Missing ☐ Damaged

Pumps

☐ Not part of system
☐ Present - satisfactory
☐ Present - unsatisfactory
☐ Leaking ☐ Damaged ☐ Other

Siphon

☐ Not part of system
☐ Present - satisfactory
☐ Present - unsatisfactory
☐ Leaking ☐ Damaged ☐ Other

Effluent reuse system

☐ Not part of system
☐ Present - satisfactory
☐ Present - unsatisfactory
☐ Leaking ☐ Damaged ☐ Other

Disinfection - chemical

☐ Not part of system
☐ Present - satisfactory
☐ Present - unsatisfactory
☐ Leaking ☐ Damaged ☐ Insufficient chemical

Disinfection - UV

☐ Not part of system
☐ Present - satisfactory
☐ Present - unsatisfactory
☐ Missing/damaged bulb ☐ Electrical fault ☐ Other

Separated greywater system

☐ Not part of system
☐ Present - satisfactory
☐ Present - unsatisfactory
☐ Leaking ☐ Damaged ☐ Other

Grease trap

☐ Not part of system
☐ Present - satisfactory
☐ Present - unsatisfactory
☐ Not clean ☐ Damaged ☐ Other

F: Wastewater treatment system performance checks

Tank lid/s are secured, sealed, no sign of water entry

☐ Satisfactory ☐ Unsatisfactory

Specify defect:

Tank condition (including baffles and filters)

☐ Satisfactory ☐ Unsatisfactory

Specify defect:

Sludge removal (tank pump out) required

☐ No ☐ Yes

Sludge depth (mm):

Date of last pump out:

Observations

☐ Strong sewage odour

☐ Wet/boggy areas

☐ Other - *specify*

Overall assessment of wastewater treatment system performance:

☐ Satisfactory ☐ Unsatisfactory

Recommended remedial action/s:

Date of next inspection:

G: Electrical controls performance checks

All electrical connections and components in place and up to standard (or specify problems)

☐ Satisfactory ☐ Unsatisfactory

Comments:

Isolation switch is in place

☐ Satisfactory ☐ Unsatisfactory

Comments:

24-hours emergency storage available above high-level alarm sensor

☐ Satisfactory ☐ Unsatisfactory

Comments:

Alarm location and contact details are clearly visible/audible in event of activation

☐ Satisfactory ☐ Unsatisfactory

Comments:

Power connection to plant is properly installed

☐ Satisfactory ☐ Unsatisfactory

Comments:

Overall assessment of electricals: ☐ Satisfactory ☐ Unsatisfactory

Recommended remedial action/s

H: Land application systems		
☐ Pressure compensating drip irrigation (PCDI) ☐ Low pressure pipe (LPP) ☐ Low pressure effluent distribution (LPED)	☐ Trenches ☐ Beds ☐ Mounds ☐ Other - *specify*	
I: Land application system performance checks		
Even distribution is achieved throughout land application field, with no signs of breakout or ponding within the land application area.	☐ Yes ☐ No	Comments:
Land application area is boggy or wet	☐ Yes ☐ No	Comments:
Evidence of overland flow paths through land application area	☐ Yes ☐ No	Comments:
Evidence of cut-off drains around land application area	☐ Yes ☐ No	Comments:
Distribution lines are not located within 15 m of surface water (stream)	☐ Yes ☐ No	Comments:
Plant growth is even and dense	☐ Yes ☐ No	Comments:
Appropriate species planted for evapotranspiration	☐ Yes ☐ No	Planting details:
There is ponding or breakout downslope of the land application area	☐ Yes ☐ No	Comments:
Evidence of disturbance in land application area (construction, rubbish, dumping, machinery etc.)	☐ Yes ☐ No	Comments:
Evidence of soil compaction in land application area	☐ Yes ☐ No	Comments:
Distribution pipe systems are covered or pinned down, are connected and are not damaged	☐ Yes ☐ No	Comments:
Distribution pipe systems follow the contour of the land	☐ Yes ☐ No	Comments:
Top soil depth is assessed to be >250 mm	☐ Yes ☐ No	Comments:
Auto-flush valve is installed with appropriate discharge point	☐ Yes ☐ No	Comments:

All valves are clearly marked or protected	☐ Yes ☐ No	Comments:
Pump/s installed correctly for required head	☐ Yes ☐ No	Comments:
In-line filter/s installed correctly and operative	☐ Yes ☐ No	Comments:
If pumping uphill: non-return valve/s installed near the top of the manifold and TNL/DNL1 valves and air release valves are in place	☐ Yes ☐ No	Comments:
If pumping uphill, then downhill to same field: manifold has been connected correctly to the lower field AND both non-return valves and T&N valves are installed in the manifold. Wastewater is discharged to the top field first before the lower field	☐ Yes ☐ No	Comments:
If pumping downhill into PCDI/LPED system, an anti-siphon break is installed.	☐ Yes ☐ No	Comments:
Reserve area maintained available as specified on approved site plan	☐ Yes ☐ No	Comments:
All wastewater/recycled water pipes coloured and clearly marked as "non-potable".	☐ Yes ☐ No	Comments:
Overall assessment of land application system:	☐ Satisfactory	☐ Unsatisfactory
Recommended remedial action/s		

J: Final assessment

☐ **Pass**

– Complete "Records Check"

☐ **Fail**

– Complete "Actions Required", "Follow-up Date" & "Records Check"

Signature:

Printed name: **Date:**

K: Follow-up actions required

Instructions of any system remedial/upgrade actions required provided to site owner (and to Auckland Council and other parties where required).

List items	Completed/scheduled
1:	
2:	
3:	
4:	
5:	

Notes: Documentation

Copies of the following documentation should be available on the site and/or in Auckland Council files for the system:

- Inspection Records – Location: Onsite/Council files
- Design Report – Location: Onsite/Council files
- Installation checklist for installation of all key system components, including Installer's Certificate for whole system and also for water saving devices if included in system design – Location: Onsite/Council files
- As-built Drainage Plan & Engineer's Certificate/Producer Statement - Location: Onsite/Council files
- Current Maintenance Contract - – Location: Onsite
- System Operation and Maintenance Plan – Location: Onsite/Council files
- Copy of Building Consent and if relevant, discharge consent from Regional Council – Location: Onsite/Council files
- Loading certificate – Location: Onsite/Council files

Notes: Record check

Following site inspection, it is critical clear records of are maintained of all site visits:

- An on-site wastewater inspection form completed for the site inspection
- Site plan available with sketch provided of any differences
- From design report and/or
- From last inspection record and/or
- Showing locations of land application system faults
- Copy provided to site owner and to Auckland Council and other parties where required
- Loaded site inspection details into relevant on-site system inspections database

Appendix K1.0 Risk assessment template

Table 81: Risk management summary response schedule pro-forma

Item	Risk identification		Risk evaluation				Risk reduction measures
	Design feature	Risk element	Potential risk scenario	Likelihood	Consequence	Risk level (L/M/H)	
1	Site and soil investigation	• Constraints (soil, slope, groundwater, surface water, clearances) • Impacts on soil, subsoil and vegetation • Groundwater and surface water effects • Off-property cumulative effects • Stakeholder consultation (if required)					
2	Design	• System selection • Performance certification • Under-design • Over-design • Energy use					
3	Installation	• System siting • Integrity of pipe network • Workmanship • Inspection process					
4	Commissioning	• Distribution effectiveness • Inspection process					

Item	Risk identification		Risk evaluation				Risk reduction measures
	Design feature	Risk element	Potential risk scenario	Likelihood	Consequence	Risk level (L/M/H)	
5	Operation	• Influent variability • Power outages; potential blockages • Alarm responses • System malfunctions • Overflows from treatment and land application systems • Effluent surfacing through land application system					
6	Maintenance and monitoring	• Inadequate inspections • Lack of monitoring • Non-renewal of maintenance contracts					
7	Usage	• Under-loading • Overloading • Household chemicals • Medications					
8	Regulatory/ administrative	• Capacity of owner/occupier to manage use and oversight of the system during its life period • System documentation (e.g. assessments, installation methodology) • Resource and building consenting requirements • Any other matter					

Appendix L1.0 Sand and textile filter dose loading

Sand and textile filters must be dose loaded to achieve optimum performance. They should be dose loaded by a timer-controlled pump over 24 hours to even out the daily peak flows.

Timer dose loading buffers wastewater production peaks by storing excess peak production in the septic tank, recirculation chamber or pump chamber. It is then pumped out at predetermined dose volumes and intervals over 24 hours allowing uniform loading. This ensures the wastewater doses and resting times are equal, allowing for a thin film flow around the sand grains and maintenance of open pore space optimising wastewater treatment and virus reduction. Advantages of timer dose loading are that:

- It provides for maintenance of, and enhances, aerobic conditions in the sand filter
- It enables the systems to be more robust, ensuring a more consistently high-quality final effluent
- It enables consistent long-term treatment performance levels
- The sand filter units have lower maintenance requirements.

The use of siphons or pumps operated by a float switch to dose the sand filter is not appropriate unless there are power supply problems. If sand filters are loaded by a siphon or float-switch operated pump, all the wastewater load will be concentrated during the daily production peaks. Where the hydraulic, solids or organic loading rate exceeds the capacity of the sand filter, this can lead to the development of anaerobic conditions, clogging of the pore spaces between sand grains and wastewater ponding on the surface between applications. When siphon loading is proposed, the loading rate should be reduced to minimise the impact from concentrated loading.

Demand dose loading means applied wastewater movement through the sand filter is loaded as a concentrated plug rather than a thin film flow which maintains aerobic conditions better in the sand media, retains the biomass better and significantly improves the long-term treated wastewater quality. For these reasons, demand dosing is considered a significantly inferior design feature compared to timer-controlled dosing.

Dosing control by float switches is not recommended because the resulting wastewater doses and resting times are unequal which can lead to the sand filter clogging. Concentrated plug flow through the filter results in saturation of the filter porous media, incomplete treatment of wastewater and development of organic and inorganic materials to the extent that pore space becomes increasingly clogged.

Appendix M1.0 LPED design examples

The main focus of this example calculation is the design of the pressure pipe distribution system. The source of the engineering formula and supporting information is the paper by Eric Ball of Umpqua Community College, Roseburg, Oregon, USA, titled "*Pressure Dosing: Attention to Detail*" (1995).

The steps in designing an LPED irrigation and distribution system are:

1. Determine the length of the line, based on daily flow, loading rates etc.
2. Determine if a siphon can be used
3. Determine the total design head (TDH) of the pump required if a siphon cannot be used
4. Choose a pump and determine flow rate at TDH from flow curves (from the pump supplier)
5. Calculate number of holes in laterals (and therefore, spacing)
6. Calculate lateral length and pipe diameter
7. Calculate orifice hole sizing.

Ball notes that it is very difficult to theoretically determine head losses through discharge assemblies, and thus the total design head, because of the interdependence of the various types and positions of fittings and valves. Simple addition of K values for fittings and valves gives very inaccurate results. Empirically derived equations and curves for specific types of discharge assemblies are much more accurate. Equations and relevant coefficients for head-loss calculations through discharge assemblies have been derived by measuring actual head losses that occur under operating conditions and summaries of the application of relevant equations are provided in Appendix M1.1.

Setting up a computer-based spreadsheet allows quick, simple calculations of such parameters as head loss, velocity, and flows for design of LPED systems. Alternatively, the manual method outlined below can be used. Details of the engineering calculations involved in each of the above steps are outlined, with a worked example included in each step to demonstrate the applications of the relevant formula.

Calculating the total length of LPED trenches

a) Determine the appropriate LPED loading rate (DIR) for the soil type (the areal loading rate, as specified in Section E)

b) Determine the effective area required as follows:

$$AE\ (m^2) = F\ (L/d)\ /\ LR\ (mm/d)$$

Where:	AE	=	Effective area
	F	=	Wastewater design flow rate
	LR	=	Loading rate

c) Determine the total length of LPED trenches (assume effective area along the length of trench is 1 m)

$$L_T\ (m) = AE\ (m^2)\ /\ W_A\ (m)$$

Where:	L_T	=	Length of trench
	W_A	=	Width of effective areal area along trench

d) Determine the total area required, including the buffer area between lines. (Standard trench spacing is usually 1.5 m, providing an additional 0.5 m between lines as buffer area)

$$A_T\ (m^2) = L_T \times (W_E + W_B)$$

Where:	A_T	=	Total area required
	W_E	=	Width effective area along each trench
	W_B	=	Width additional buffer area between trenches)

Example

Adopt total design flow	=	1,080 L/day
Design loading rate	=	4 mm/day
Proposed LPED lines to be 1.5 m apart (with an effective area of 1 m)		

Calculation:	Effective areal area	=	1,080 L/day / 4 L/m²/day	= 270 m²
	Lineal metres of LPED trenches and lines	=	270 m² / 1.0 m	= 270 m
	Total area required	=	270 m x 1.5 m	= 405 m²

Decide whether a siphon can be used to dose the trenches

a) Determine the height difference between the outlet of the tank and the highest distribution lateral

b) Determine the squirt hole spacing along the LPED laterals

$$SqH\ Spacing\ (m) = L_T\ (m)\ /\ SqH\ No.$$

Where:	SqH Spacing	=	Squirt hole spacing
	L_T	=	Total length of trenches
	SqH No.	=	Squirt hole number

c) Determine the total number of squirt holes required

d) Determine if a siphon is an option; if not, a pump will be necessary.

Note: A standard siphon normally requires a drop of 2.5 m or more and spacing between holes of not greater than 2.5 m with a maximum number of holes of 70. (The maximum spacing between holes and the maximum number of holes may vary for particular siphon brands. If a spacing greater than 2.5 m is proposed, or more than 70 holes are proposed, the supplier will need to verify that the siphon will still achieve the design flow at each orifice.)

Example

From the calculation above, determine the squirt hole spacing (SqH Spacing) and whether or not a siphon is an option (assuming the total number of squirt holes is 70):

SqH Spacing = 270 / 70 = 3.8 m

Siphon or pump: 3.8 m > 2.5 m

So, a pump is required

The diameter of all the squirt holes is 3 mm. The self-cleansing velocity for a 3 mm hole in PVC pipe has been determined empirically as corresponding to a 1.5 m squirt height. This squirt height requires a flow per squirt hole of 1.45 L/minute (which is the necessary scouring velocity for a 3 mm hole based on the Squirt Orifice Equation – refer to "Relevant Engineering Equations for LPED Design" in Appendix M1.1 below).

Since there is a limitation on the flow rate of the dosing devices, there is a limitation on the number of squirt holes that can be "serviced" if the minimum flow of 1.45 L/min per squirt hole is to be achieved.

If a pump is required, determine the required flow rate from the pump

The Total Dynamic Head (TDH) needs to be determined in order to then determine the flow required from the pump.

The minimum flow required will result in an orifice hole spacing of 2.5 m. This is the maximum spacing specified above, although preferably the holes will be closer together. The pump should also be able to support at least 70 squirt holes at the TDH.1.45 L/min, which is the flow rate required for each 3 mm hole.

Example

Determine the total pump flow rate required to achieve the necessary scouring velocity per hole (assuming 70 holes at 1.45 L/min):

F = 1.45 L/min x 70 = 101.5 L/min

In all cases, the designer should consider controlling pump dose loading by timer-control rather than via demand-control (float control). Timer-control can be set at short doses sufficient to load one LPED lateral (using an automatic sequencing valve) at each dose throughout the day, e.g. a maximum of 8 to 12 doses per day.

Refer to Section E for sizing the dose volume.

A non-conservative option for sizing the dose volume is to use a minimum dose of ten times the volume capacity of the distribution manifold and laterals. This enables adequate pressure to build up in the system to achieve adequate squirt height from each orifice and thus uniform distribution throughout the land application field. However, whether the laterals are timer dosed or demand dosed makes no difference to the design calculations.

Comment: It can make a difference if an automatic sequencing valve is used for dosing either the individual laterals in sequence, or groups of laterals split into zones.

Calculate the total dynamic head of the pump

The total dynamic head of the pump is determined using the following equation:

$$TDH = H_{el} + h_{trans} + h_{man} + h_{hv} + h_{res}$$

Where:

Where:	H_{el}	=	Elevation from the septic tank liquid level to the highest distribution trench
	h_{trans}	=	Head loss due to friction through the transport pipe (use Hazen-Williams formula)
	h_{man}	=	Manifold head loss ≈ 0
	h_{hv}	=	Head loss through the pump hose and valve assembly Consult the supplier of the hose and valve assembly to determine the head loss – most have been determined empirically
	h_{res}	=	The residual pressure at the highest lateral (i.e. the minimum squirt height)
		=	1.5 m

Example

Determine TDH assuming the highest lateral is 5 m above outlet of tank and the 32 mm (NB) transport pipe is 40 m long, from the tank to the lateral manifold:

H_{el}	=	5 m
h_{trans}	=	3.4 m (Hazen-Williams formula with Q = 110 L/min, d = 6.2 mm (Assume PVC pipe PN15. 32 NB, 36.2 mm ID)
h_{man}	=	0
h_{hv}	=	1.3 m (from H=0.000106.Q2, assuming Q around 6600 L/hour hres (i.e. 70 x 1.45 = 101.5 plus contingency = 110 L/min = 6600 L/hour)
h_{res}	=	1.5 m
TDH	=	$H_{el} + h_{trans} + h_{man} + h_{hv} + h_{res}$ = 11.2 m

Determine the number of squirt holes required

e) Refer to pump curve for a range of pumps and choose the pump that can achieve the minimum flow required at the total design head (as determined in part 4 above).

f) The number of squirt holes is based on the pump flow rate for the total dynamic head and the flow through the orifice:

SqH No. = F (L/min) / Qo (L/min)

g) The spacing required is based on the total length of the laterals divided by the number of squirt holes:

SqH Spacing (m) = L_T (m) / SqH No.

Example

Examine pump flow curves for available pumps and choose a suitable pump that can achieve at least the minimum flow rate at TDH.

Determine the number of squirt holes the pump can service based on the pump flow above (assuming the flow required per squirt hole is 1.45 L/min) and then determine the exact number of holes and the hole spacing:

SqH No.	=	110 / 1.45	=	76 squirt holes
SqH Spacing (m)	=	270 m / 76	=	3.6 m

Typically, squirt hole spacing is in the order of 0.5 m to 3 m, with a maximum number of 70.

If split the LPED irrigation area into 2 zones, the squirt hold spacing will be:

SqH Spacing (m)	=	135 m / 70	=	1.9 m (This is suitable)

Hence, adopt squirt hole spacing of 2 m.

Number of squirt holes:

SqH No.	=	270 m / 2 m	=	135

Number of squirt holes per zone: 135/2 = 68

Check the total flow capacity:

68 x 1.45 L/min	=	98.6 L/min
(Acceptable when compared to the flow capacity estimate)		

Each zone is thus dosed in sequence via a two-way automatic sequencing valve. If required, each zone can be further divided into groups of laterals dosed by their own automatic sequencing valves.

Decide on the diameter of the pipe manifolds based on the site constraints

a) Determine the longest length of laterals based on site constraints. (The site constraints will usually dictate the longest trench length able to be easily installed. To ensure the required flow rate is achieved along the laterals, trench lengths are normally in the order of 20 m and should not exceed 30 m.)

b) Next, determine the pipe size required, based on the orifice hole spacing and on the length of the laterals

Example

Determine the pipe diameter size required for an assumed pipe lateral length of 20 m and hole spacing of 2 m. Then use the table below to determine the size of pipe to be used, for the proposed hole spacing, then the length of the laterals. (The data in the table have been derived using the engineering flow equations - refer to “Relevant Engineering Equations for LPED Design” at the end of this Appendix in M1.1)

- For a 20 m trench and hole spacing of 2.0 m, a 20 mm diameter pipe is required
- If the holes were closer together (e.g. 1 m spacing), 25 mm pipe would be required.

Table 82: Lateral pipe sizing (for PN15 or Class E pressure pipe)

Nominal pipe diameter	15 mm	20 mm	25 mm	32 mm	40 mm
Hole Spacing	Max. pipe length	Max. pipe length	Max. pipe length	Max. pipe length	Max. pipe length
0.4	6	9	14	20	20
0.5	7	11	16	24	30
0.6	8	12	18	27	34
0.7	8	13	20	29	37
0.8	10	14	22	32	40
0.9	10	15	23	35	43
1	11	16	25	37	47
1.1	11	18	26	40	50
1.2	12	18	28	42	53
1.3	13	20	30	44	55
1.4	14	21	31	46	57
1.5	14	21	32	48	60
1.6	14	22	34	51	62
1.7	15	24	36	53	66
1.8	16	23	36	54	68
1.9	17	25	38	57	70
2	16	26	38	58	74
2.1	17	27	40	61	76
2.2	18	26	42	62	77
2.3	18	28	44	64	81
2.4	19	29	43	65	82
2.5	20	30	45	68	85

Source: Jim Buchan, Innoflow Technologies NZ Ltd. Data in this table come from determining the difference in flow through each squirt hole, based on head losses. A lateral length that will not reduce flow rates by any more than 10% is required.

Check the dose volume, pumping time and depth of flooded aggregate

1) Check dose volume required.

Total distribution pipe volume:

$270 \text{ m} \times \pi (0.02 \text{ m}/2)^2 = 85 \text{ L}$

2) Check the ratio of daily dose volume and distribution system capacity:

1080 L/85 L = 12.7

This is greater than the 10 times dose volume. Hence OK.

3) Check pump run time.

With two zones and pump capacity of 110 L/min, daily flow of 540 L per zone requires a pump run time at 110 L/min of 5 minutes per dose – dosing timer to be set accordingly. Each zone is thus dosed once daily.

4) Check flooded depth each dose in trench distribution aggregate.

Total trench area: length of trench per zone x trench width

$135 \text{ m} \times 200 \text{ mm} = 27 \text{ m}^2$

Depth of water in trenches each dose:

$(540 \text{ L}/25 \text{ m}^2) \times 2 = 43$ mm (assuming 50% void space of distribution aggregate). Hence, OK.

Table 83. Orifice flow coefficients

Flow orifice, d (mm)	Coefficient, C*
9.5	0.66
12.5	0.69
16	0.73
19	0.77
22	0.81
Based on empirical formula: C = 0.012d + 0.542	

Finally, calculate the orifice size in the distribution laterals

In an LPED system, the length and height of individual trenches can vary considerably. A non-return valve should be installed at the start of each line to ensure the higher elevation laterals do not drain to the lowest laterals between doses and overload the lower lines. To prevent preferential loading of certain laterals, flow control plates should be installed at the start of each lateral. Each of these plates has a hole drilled into it to restrict the flow appropriately. The highest lateral is not restricted by an orifice plate. Further comment on loading of the lateral network is provided in Section E.

The calculations below are for designing the hole size in the flow orifice at the start of each lateral, to achieve the same flow in the lower laterals as the natural flow in the highest lateral.

Flow orifice equation

Used to calculate the diameter of hole needed to control the flow into a distribution lateral:

$$d = \left[\frac{Q}{0.2088C\sqrt{h}}\right]^{1/2}$$

Where: d = Diameter of hole in flow control plate (mm)

Q = Flow into lateral (L/min)

h = Difference in pressure (drop from highest lateral) (m)

C = Constant (derived empirically)

Because the orifice size is not known, the appropriate coefficient to use is also not clear. This is circumvented by using each coefficient from Table 83. These estimated diameters are then averaged to give a new estimate, and this new estimate is used to calculate an estimated coefficient, based on the empirical coefficient formula shown above. An example is shown below (Table 84). The line in bold indicates the averaged diameter and the first calculated coefficient.

The new coefficient is then used to calculate a new flow orifice diameter. This new diameter is refined mathematically in iterative steps; i.e. each new diameter is used to calculate a new coefficient, which is then used to calculate the next diameter, until the difference between iterations is negligible.

The input values in the second column of the table below are as follows:

Lateral length = Maximum length of lateral as determined on-site

Lateral squirt hole spacing = As determined above (2 m)

Lateral squirt hole diameter = 3 mm

Residual pressure = 1.5 m (minimum squirt height)

Flow per orifice = Calculate using equation above

Lateral flow = Flow per orifice x number of orifices

Pressure drop (m) = Vertical drop to trench from highest trench (measured)

Table 84: Example flow control orifice calculations* (for an LPED system)

	SI enter	Diameter (mm)	C	
Lateral length (m)	20	10.2585338	0.6600000	delta d
Lat orifice spacing (m)	2	10.0330439	0.6900000	
		9.7542937	0.7300000	
		9.4975567	0.7700000	
Lateral orifice diameter (mm)	3	9.2600802	0.8100000	

Residual pressure(m)	1.5	**9.7607017**	**0.6591284**	**GUESS**
Flow per orifice(L/min)	1.450257	10.2653141	0.6651838	-0.0517
Number of orifices	**10**	10.2184833	0.6646218	0.004562
Lateral flow (L/min)	**14.50257**	10.2228025	0.6646736	-0.00042
Pressure (DROP) (m)	**1**	10.2224039	0.6646688	3.9E-05
Calculated diameter (mm)	10.22	10.2224407	0.6646693	-3.6E-06
Conversion factors		10.2224373	0.6646692	3.32E-07
Feet to metres	0.3048	10.2224376	0.6646693	-3.1E-08
US gals to litres	3.785412	10.2224375	0.6646693	2.83E-09
Inches to mm	25.4	10.2224375	0.6646693	-2.6E-10
		10.2224375	0.6646693	2.41E-11
		10.2224375	0.6646693	-2.2E-12

Source: Eric S. Ball (1995)

* The steps above are purely mathematical, based on the key coefficients table.

Note: These flow control calculations cannot be completed until the system has been installed, when the actual vertical drop in metres from the top trench down to each lower trench is known. This should be measured as accurately as possible. The length of the trenches can also vary between individual trenches in a system – as long as the length and number of orifices per lateral are known the calculations should still achieve even distribution.

Appendix M1.1 Relevant engineering equations for LPED design

Squirt orifice equation

Used to calculate the flow required to produce a given squirt height

$$Q_o = 0.13157 d^2 \sqrt{h}$$

Where:	Q_o	=	Flow through the orifice (litres per minute)
	d	=	Orifice diameter (mm)
	h	=	Pressure (squirt height) (m)

Hazen-Williams equation

Used to calculate the head loss due to friction in a section of pipe

$$h_f = \frac{6.245 \times 10^6}{D^{4.87}} \times L \times \left(\frac{Q}{C}\right)^{1.85}$$

Where:	h_f	=	Head loss (m)
	D	=	Inside diameter of pipe (mm)
	L	=	Length of pipe segment (m)
	Q	=	Flow through pipe segment (litres/minute)
	C	=	Hazen-Williams constant (150 for smooth PVC pipes)

Flow orifice equation

Used to calculate the diameter of hole needed to control the flow into a distribution lateral

$$d = \left(\frac{Q}{0.2088\, C\, \sqrt{h}}\right)^{\frac{1}{2}}$$

Where:	d	=	Diameter of hole in flow control plate (mm)
	Q	=	Flow into lateral (L/min)
	h	=	Difference in pressure (lateral drop from highest lateral) (m)
	C	=	Constant (derived empirically)

Appendix N1.0 Wisconsin Mound design example

Following is a worked example for calculating mound dimensions.

Wisconsin Mound design example

Soil type:	Category 3
Site slope:	6%
Wastewater flow:	1000 L/day (5 persons living in a three-bedroom dwelling at a 200 L/p/d flow allowance)
Wastewater quality:	Septic tank effluent with outlet filter.

Step 1:

Select a suitable site for locating the mound and pick the best site.

Step 2:

Select the fill media material. If finer size sand is used than the recommended size the loading rate must be reduced.

Step 3:

Estimate the design wastewater flow volume based on flow allowances specified in Section D. In this case, the design wastewater flow rate is assumed to be 1000 L/day.

Step 4:

Select the relevant design loading rates

Select the sand fill loading rate:	30 mm/day	Refer to Section E3.3.2.2
Select the basal loading rate:	16 mm/day	Refer to Section E3.3.2.2
Select toe linear loading rate:	50 L/d/m	Refer to Section E3.3.2.2

Step 5:

Calculate the distribution bed dimension

Size absorption area width (A)	$\frac{Linear\ loading\ rate}{Sand\ loading\ rate} = \frac{50\ L/d/m}{30\ mm/d}$[5]	A = 1.67 m
Size the absorption area length (B)	$\frac{Design\ flow\ rate}{Linear\ loading\ rate} = \frac{1000\ L/d}{50\ L/d/m}$	B = 20 m

[5] Units of sand fill loading rate are $L/m^2/d$ for purposes of calculation

Step 6:

Calculate the Mound dimensions

a) Mound height:

Fill depth (D)	D = 600 mm (min)	Refer Figure 37
Fill depth (E)		
E = D +(slope x A)	E = 0.6 + (0.06x1.67) = 700 mm	
Bed depth (F)	F = 225 mm	
Cap at edge of bed (G)	G = 150 mm	
Cap at centre of bed (H)	H = 300 mm	

b) Mound perimeter

Downslope setback (I)	I = (E+F+G) x 3 x 1.22	(0.72+0.225+0.3) x3 x1.22	I= 4.5 m
Upslope setback (J)	J = (D+F+G)x 3 x 0.85	(0.6+0.225+0.15) x 3 x 0.85	J = 2.5 m
Sideslope setback (K)	K = (Mound height at centre of bed) x (3:1 slope) = [(D+E)/2+F+H]x3	(0.6+0.7)/2 + 0.225 + 0.3]x3	K = 3.52 m

Slope corrections factors for 6% [Table 85]

I x 1.22

J x 0.85

Mound length (L) and Width (W)

Mound toe length L = B + 2xK	20 + 2 x 3.52	L = 27 m
Mound width W = J + A + I	2.5 + 1.67 + 4.5	W = 8.7 m

Step 7:

Basal loading check

Basal loading rate for Category 3 soil   Basal area = B x (A+I)   = 20 x (1.67 + 4.5)   Basal area = 123 m^2

Basal loading rate = 16 mm/day

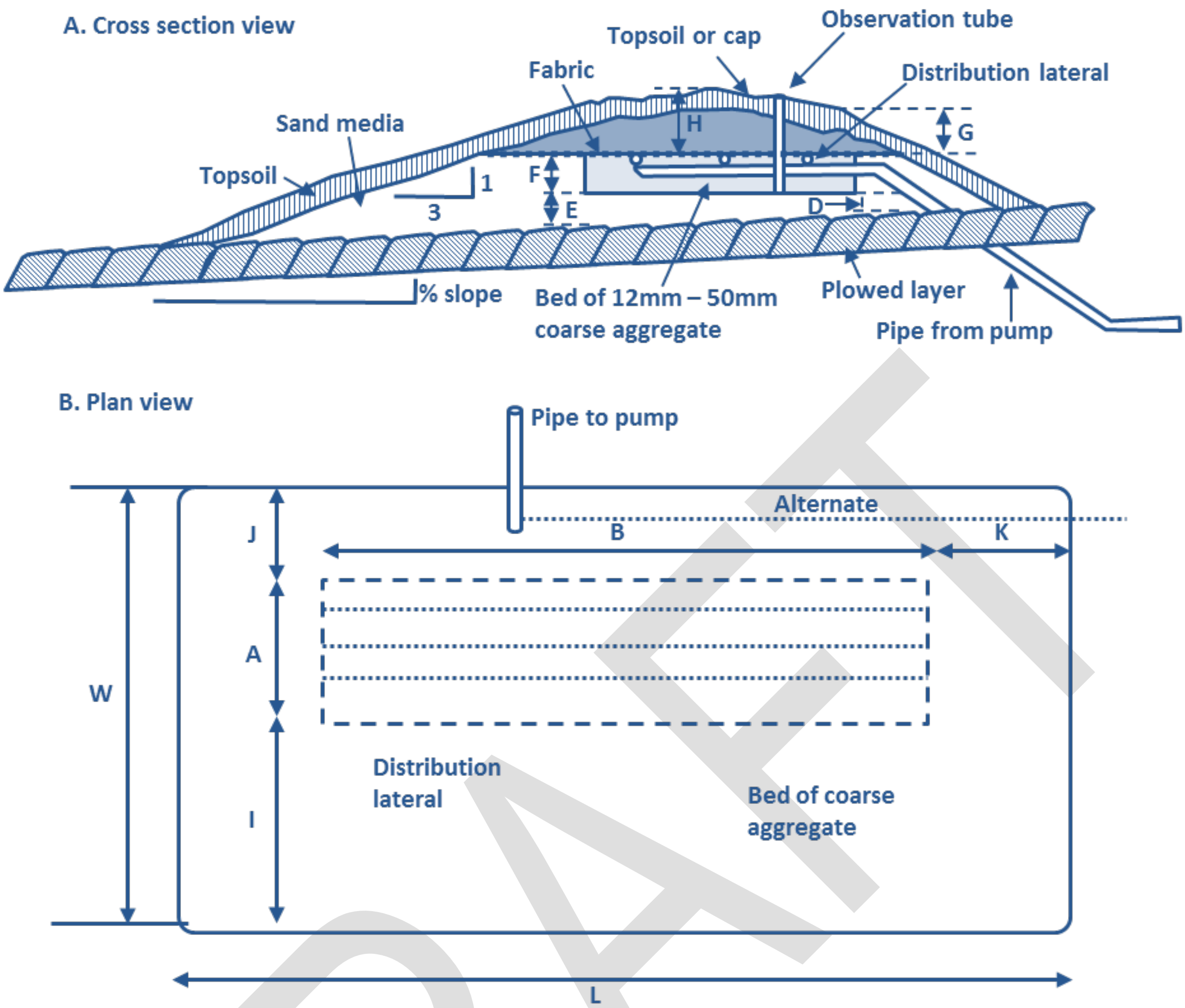
Basal area = Q/DLR = Bx(I+A) $Basal\ loading\ rate = \frac{Q}{Basal\ area} = \frac{1000L/d}{123m^2}$

Loading rate = 8.13 mm/d;   < 16 mm/d;   Okay

The basal area should be large enough so that the basal loading rate is less than selected 16 mm/day.

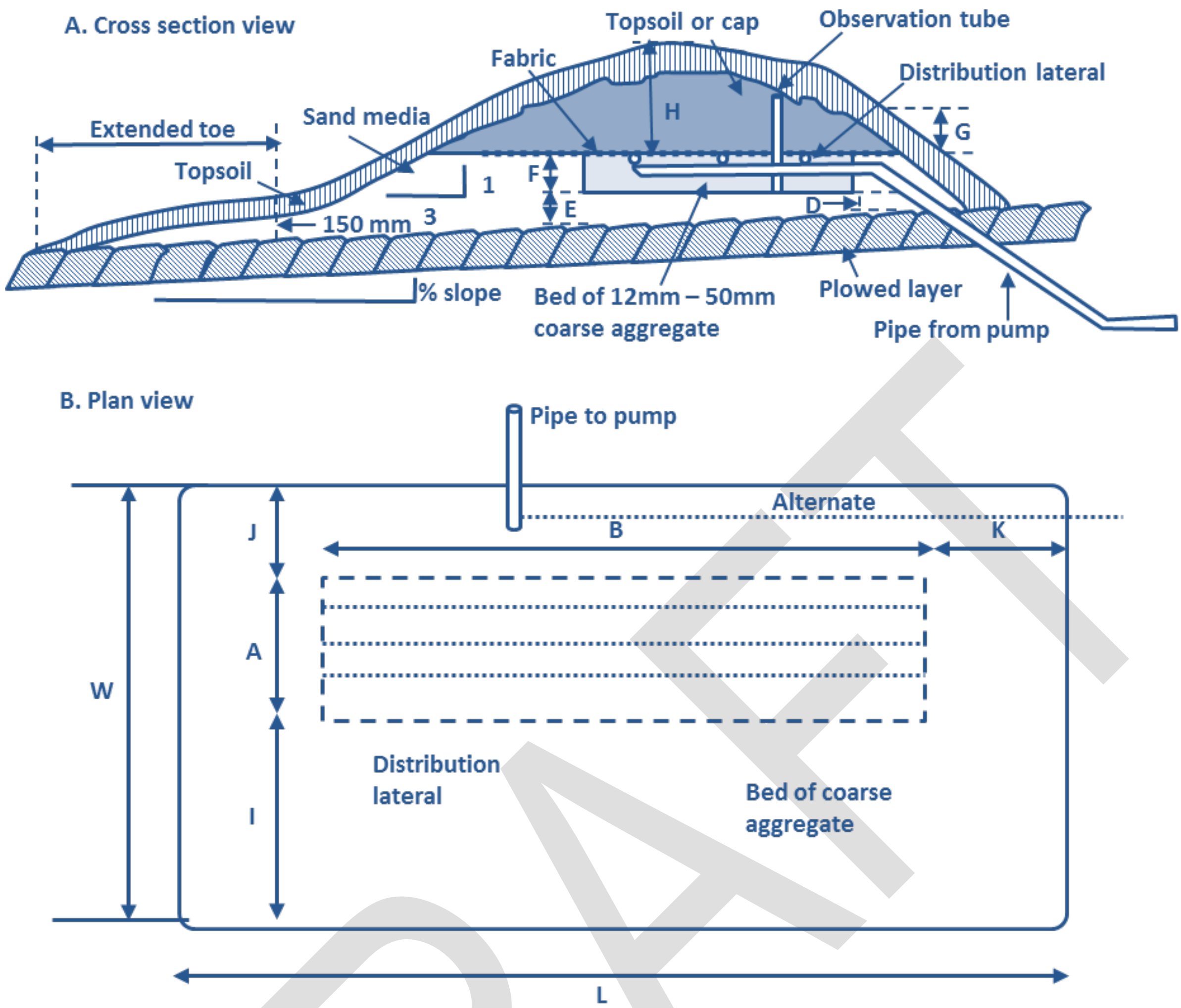
Table 85: Slope down and slope up correction factors

Slope %	Down slope correction factor	Up slope correction factor
0	1.00	1.00
1	1.03	0.97
2	1.06	0.94
3	1.10	0.92
4	1.14	0.89
5	118	0.88
6	1.22	0.85
7	1.27	0.83
8	1.32	0.80
9	1.38	0.79
10	1.44	0.77
11	1.51	0.75
12	1.57	0.73
13	1.64	0.72
14	1.72	0.71
15	1.82	0.69
16	1.92	0.68
17	2.04	0.66
18	2.17	0.65
19	2.33	0.64
20	2.50	0.62
21	2.70	0.61
22	2.94	0.60
23	3.23	0.59
24	3.57	0.58
25	4.00	0.57



Basal area sizing: Flat site, enclosed by (B x W)
Typical dimensions
Distribution bed: A = 1200 to 2000mm
F = 225mm
G = 150mm
H = 300mm
Mound: D = 600mm;
E = 600mm on flat ground and >600mm on sloping ground
J = 3m on flat ground at 1 in 3 side slope
I = J on flat ground
K is determined by height of finished mound and 1 in 3 side slope

Figure 36: Wisconsin Mound details for a flat site [less than 3%]



Basal area sizing:	Sloping site, enclosed by B x (A + I)
Typical dimensions	
Distribution bed:	A = 1200 to 2000mm
	F = 225mm
	G = 150mm
	H = 300mm
Mound:	D = 600mm;
	E = 600mm on flat ground and >600mm on sloping ground
	J and I are determined by ground slope and 1 in 3 mound face slope, and then adjusted by slope correction factors for sloping ground
	K is determined by height of finished mound and 1 in 3 side slope

Figure 37: Wisconsin Mound details for a sloping site [between 3 and 15%]

Appendix O1.0 Literature review of mound loading rates

USEPA, (1980) and Crites and Tchobanoglous (1998) recommend a maximum sand-fill loading rate of 50 mm/day for sand having more than 25% of the grain size, being 0.25 – 2 mm. AS/NZS 1547:2012 requires 0.25 to 1 mm and uniformity coefficient less than 4.

James Converse (inventor of the Wisconsin Mound systems) recommends sand-fill grain size grading such as that used for intermittent sand filters is appropriate and having a D10 of 0.3 to 0.5 mm (Converse, 1988). Converse also recommends a conservative sand-fill wastewater loading rate of 30 to 40 mm/d to minimise the potential for the development of a clogging layer. If the sand infiltration surface develops a clogging layer over time, Converse recommends aerating the wastewater prior to its discharge into the mound (Converse, 1988).

Table 86: Comparison of recommended sand fill media distribution bed loading rates

(in the literature)

Wisconsin Mound distribution bed loading rates		
Design source	**Media specification**	**Distribution bed and sand fill loading rate (mm/d) [Notes 1, 2 and 3]**
Sand fill		
AS/NZS/1547:2012 (Standards Australia/New Zealand, 2000)	Medium sand 0.25 – 1 mm UC ≤ 4 Less than 3% by weight (#200 sieve, 0.074 mm) Free of clay, limestone, and organic matter	Max 40
USEPA 1980* & Crites and Tchobanoglous (USEPA, 1980, Crites and Tchobanoglous, 1998)	Medium sand >25% 0.25 – 2 mm <30 – 35% 0.05 – 0.25 mm <5 – 10% 0.002 – 0.05 mm	Max 50
Converse (pers.com)	D10 0.3 – 0.5 mm UC 1 – 4 (Intermittent sand filter grading)	30 to 40
Distribution aggregate		
AS/NZS/1547:2012 (Standards Australia/New Zealand, 2000)	20 – 60 mm non-crushed	Max 40 [Note 4]
USEPA, 1980	18 – 64 mm	

Bibliography

Bibliography

Standards

Standards Australia / Standards New Zealand. (2008). '*Australian/New Zealand Standard™, On-site domestic wastewater treatment units Part 1: Septic tanks*.' AS/NZS 1546.1: 2008. Standards New Zealand, Wellington, New Zealand.

Standards Australia / Standards New Zealand. (2008). '*Australian/New Zealand Standard™, On-site domestic wastewater treatment units Part 2: Waterless composting toilets*.' AS/NZS 1546.2: 2008. Standards New Zealand, Wellington, New Zealand.

Standards Australia / Standards New Zealand. (2008). '*Australian/New Zealand Standard™, On-site domestic wastewater units Part 3: Aerated wastewater treatment systems*.' AS/NZS 1546.3: 2008. Standards New Zealand, Wellington, New Zealand.

Standards Australia / Standards New Zealand. (2012). '*Australian/New Zealand Standard™, On-site domestic wastewater management*.' AS/NZS 1547:2012. Standards New Zealand, Wellington, New Zealand.

Standards Australia. (2004). '*Design, construction and fit-out of food premises*', AS 4674-2004.

Standards Australia / Standards New Zealand. (2006). '*Australian/New Zealand Standard™, PVC pipes and fittings for pressure application*.' AS/NZS 1477: 2006. Standards New Zealand, Wellington, New Zealand.

Standards Australia/Standards New Zealand. (2007). '*Australian/New Zealand Standard™,, Electrical installations*.' AS/NZS 3000:2007. Standards New Zealand, Wellington, New Zealand.

Standards Australia/Standards New Zealand. (2007). '*Australian/New Zealand Standard™,, Plumbing and drainage – Sanitary plumbing and drainage*.' AS/NZS 3000:2007. Standards New Zealand, Wellington, New Zealand.

Standards Australis/Standards New Zealand. (2007). '*Australian/New Zealand Standard™,, Essential safety requirements for low voltage electrical equipment*.' AS/NZS 3000:2007. Standards New Zealand, Wellington, New Zealand.

Standards New Zealand. (1982). '*Specification for household septic tank systems.'* NZS 4610:1982. Standards New Zealand, Wellington, New Zealand.

Statutes

Hauraki Gulf Marine Park Act 2000

Building Act 2004

Health and Safety at Work Act 2015

Resource Management Act 1991

Health Act 1956

Heritage New Zealand Pouhere Taonga Act 2014

References

Auckland Regional Council. (2004). '*On-site wastewater systems: Design and management manual*.' Third edition. ARC Technical Publication No. 58 (TP58).

Ball, E.S. (1995). 'Pressure dosing: Attention to detail.' *8th Northwest On-site Wastewater Treatment Short Course and Equipment Exhibition, Seattle, Washington*.

Bernhart, A.P. (1973). *Treatment and disposal of wastewater from homes by soil infiltration and evapo-transpiration.* University of Toronto Press, Toronto, Canada.

Bullermann, M., Lucke, F.-K., Mehlhart, G. and Klaus, U. (2001). '*Grau- und Regenwassernutzung Kassel-Hasenhecke: Hygienische und Betriebstechnische Begleituntersuchungen.'* Schriften der fbr, Band 7 ('Grey and rainwater reuse in Kassel-Hasenhecke – Hygienic and process management study')

Colliar, J.; Sukias, J.; Tanner, C.; Bellingham, M., Stott, R. (2015). 'A marae water-use monitoring network: preliminary assessment of water use.' *New Zealand Land Treatment Collective: Proceedings for the 2015 Annual Conference.*

Converse, J. (2004). 'On-site basics, an introduction to on-site wastewater treatment.' Pre-symposium Workshop, *10th National Symposium of Individual and Small Community Sewage Systems, ASAE, Sacramento, California*, United States of America.

Converse, J.C., Tyler, E.J., and Peterson, J.0. (1998). 'The Wisconsin at-grade soil absorption system for septic tank effluent.' Conference proceedings, '*Fifth National Symposium on Individual and Small Community Sewage Systems', ASAE, St. Joseph Michigan,* United States of America.

Cook, B. (1991). '*In-depth design and maintenance manual for vault toilets*.' Forest Services, US Department of Agriculture 1991.

Crites, R. and Tchobanoglous, G. (1998). *Small and decentralized wastewater management systems*. McGraw-Hill, Boston, Maine, United States of America.

Gisborne District Council. (2012). '*Guidelines for on-site wastewater management*.' n-218973 v6. GDC, Gisborne, New Zealand.

Gunn, I. (2004). 'On-site wastewater futures – A New Zealand perspective.' Conference proceedings, *'First International Conference on Onsite Wastewater Treatment and Recycling', NOWRA, NOSSIG & Onsite New Zealand, Perth,* Australia.

Hammond, D., and Tyson, T., (2004). 'Septic tank design and construction.' Feature Article in *Water and Wastes in NZ, Issue #134, May 2004*, New Zealand Water and Wastes Association, New Zealand.

Hanson, A. L. DeMouche, B. Lesikar and A. Dreager. (2013). '*Onsite wastewater management: A manual for tribes*.' Circular 667. New Mexico State University.

Lavery, J.M., (2009). 'Choosing the right design irrigation rate: Tools of the trade', *New Zealand Land Treatment Collective: Proceedings for the 2009 Annual Conference, Rotorua,* New Zealand.

Metcalf & Eddy. (2004). '*Wastewater engineering, treatment and reuse*.' 4th Edition. McGraw-Hill 2004.

Metcalf & Eddy. (2006). *Water reuse: issues, technologies, and applications*. McGraw-Hill 2006.

Milne, J.D.G., Clayden, B., Singleton, P.L., and Wilson, A.D. (1991) *Soil Description Handbook.* DSIR Land Resources, Lower Hutt.

Ministry for the Environment. (2004). *National Environmental Standards for Air Quality.* Wellington, New Zealand.

Ministry for the Environment. (2010). '*New Zealand coastal policy statement*.' Wellington, New Zealand.

Ministry for the Environment. (2014), '*National policy statement for freshwater management 2014*.' Wellington, New Zealand.

National Small Flows Clearinghouse. (NSFC). (1998). *'Low-pressure pipe systems*.' Fact sheet, USEPA National Small Flows Clearinghouse, University of West Virginia, Morgantown, United States of America.

New York State Department of Health, (2012) 'Design Handbook: Residential Onsite Wastewater Treatment Systems.

New Zealand Land Treatment Collective. (2018). Technical Review 35 "*Daily impact of climate change on land application of waste*".

NIWA. (2006). '*Suitability of peat filters for on-site wastewater treatment in the Gisborne region*.' Report prepared for Gisborne District Council.

NIWA (2011). *Guideline for the use of horizontal sub-surface flow constructed wetlands in on-site treatment of household wastewaters*. Report prepared for Gisborne District Council.

New York State Department of Health (2012). *Residential Onsite Wastewater Treatment Systems Handbook*. New York State. United States

Nolde, E. (1995). 'Betriebswassernutzung im Haushalt durch Aufbereitung von Grauwasser.' *wwt1/95: 17–25.*

Oyama, M and M. Takehara. (1972). *Revised Standard Soil Charts*. Agricultural and Forestry Ministry, Japan.

Richard, T. (1996). *Cornell composting: On farm composting handbook*. New York State College of Agriculture and Life Sciences, Cornell University, United States of America.

Silyn Roberts, G. (2002). '*Health risk assessment of composting human waste*.' URS, Auckland, New Zealand.

Sinclair, D., (2004). '*Further comments on TP58 3rd Edition draf*t.' Correspondence from Medical Officer of Health to R. Floyd ARC on 28 April 2004. Auckland Regional Public Health Service, Auckland, New Zealand.

Tanner C.C., Headley T.R., Dakers A. (2011). *Guideline for the use of horizontal subsurface-flow constructed wetlands in on-site treatment of household wastewaters*. Hamilton: National Institute of Water & Atmospheric Research Ltd

Tanner, C.C., Sukias, J.P.S., and Dall, C. (2000). 'Constructed wetlands in New Zealand – Evaluation of an emerging 'natural' wastewater technology.' Conference proceedings, *'Water 2000', New Zealand Waste Water Association, New Zealand*.

Tanner, C. C.,Champion, P.D., Kloosterman, V. 2006. *New Zealand Constructed Wetland Planting Guidelines.* National Institute of Water and Atmospheric Research report published in association with the New Zealand Water & Wastes Association

Tennessee Valley Authority. (2004). '*Wastewater subsurface drip distribution, peer reviewed guidelines for design operation and maintenance*.' United States of America.

Thien S.J. (1979). *A flow diagram for teaching texture by feel analysis.* Journal of Agronomic Education. 8:54-55.

United States Department of Agriculture. (1991). '*In-depth design and maintenance manual for vault toilets*.' Technology & Development Center, San Dimas, California.

United States Department of Agriculture, (USDA). (1993). Chapter 3 Examination and description of soils in '*Soil survey manual*.' Soil Conservation Service. U.S. Department of Agriculture Handbook 18. Website: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/ref/?cid=nrcs142p2_054253.

United States Environmental Protection Agency, (USEPA). (1980). '*Design manual, onsite wastewater treatment and disposal systems*.' United States Environmental Protection Agency (USEPA), United States of America.

United States Environmental Protection Agency, (USEPA). (1992). '*Guidelines for water reuse*.' (EPA/625/R-92/004 - September 1992). United States Environmental Protection Agency (USEPA), United States of America.

United States Environmental Protection Agency, (USEPA). (1999). '*Manual for constructed wetlands – treatment of municipal wastewater*.' United States Environmental Protection Agency (USEPA), United States of America.

United States Environmental Protection Agency, (USEPA). (1999). '*Wastewater technology fact sheet – Ultraviolet disinfection*.' EPA/832/F-99/064 - September 1999). United States Environmental Protection Agency (USEPA), United States of America.

United States Environmental Protection Agency, (USEPA). (1999), '*Water efficiency technology fact sheet – Composting toilets*.' (EPA/832/R-99/066 - September 1999). United States Environmental Protection Agency (USEPA), United States of America.

United States Environmental Protection Agency, (USEPA). (1999), '*Water efficiency technology fact sheet – Incinerating toilets*.' (EPA/832/F-99/072 - September 1999). United States Environmental Protection Agency (USEPA), United States of America.

United States Environmental Protection Agency, (USEPA). (2002). '*Onsite wastewater treatment systems manual*.' US Environmental Protection Agency (USEPA), United States of America.

United States Environmental Protection Agency, (USEPA). (2003). '*Voluntary national guidelines for management of onsite and clustered (decentralized) wastewater treatment systems*', US Environmental Protection Agency (USEPA), United States of America.

University of Minnesota, (2017). *Manual for Septic System Professionals in Minnesota*, Onsite Sewage Treatment Program. 3rd Ed. St. Paul, MN.

Water New South Wales. (2012). *Designing and installing on-site wastewater systems".* WaterNSW, Australia

Additional Bibliography

American National Standards Institute. (2014). '*NSF International Standard: Onsite residential and commercial water reuse treatment systems NSF/ANSI 350 - 2014*.' NSF International. Designated an ANSI standard, December 8, 2014.

American National Standards Institute. (2012). '*NSF International Standard: Onsite residential and commercial graywater treatment systems for subsurface discharge. NSF/ANSI 350 -1 - 2012*.' NSF International. Designated an ANSI standard, December 23, 2012.

Anderson, J.L., and Hasley, C.F. (1980). '*Evaluating soil texture for a house site*.' Agricultural Extension Service, University of Minnesota, United States of America. (Reviewed 1990). Accessed at: http://www.extension.umn.edu/environment/housing-technology/moisture-management/evaluating-soil-texture-for-a-house-site/index.html.

Auckland Council. (2015). '*Checklist 12 – Checklist for a permit to discharge domestic wastewater onto land*.' Auckland, New Zealand. Accessed at: http://www.aucklandcouncil.govt.nz/EN/ratesbuildingproperty/consents/Consent%20documents/Checklist12permittodischargedomesticwastewaterontoland.pdf.

Barton, L., Schipper, L., McLeod, M., Aislabie, J., and Lee, B. (2000). '*Soil processes that influence sewage effluent renovation*', In: New Zealand Land Treatment Collective, 'Guidelines for Utilisation of Sewage Effluent on Land', New Zealand Land Treatment Collective (NZLTC) & Forest Research, Rotorua, New Zealand.

Berger, W. (2011). '*Technology review of composting toilets: Basic overview of composting toilets (with or without urine diversion)*.' Federal Ministry for Economic Cooperation and Development, Germany.

Black & Veatch Corporation. (2010). *White's handbook of chlorination and alternative disinfectants*. 5th Edition. Wiley

Canter, L.W. (1985). *Septic tank system effects on groundwater quality*. Michigan, United States of America.

Converse, J.C. (1978). '*Design and construction manual for Wisconsin Mounds: Siting, design, construction, performance*.' Report No. 15.5, SSWMP. University of Wisconsin-Madison, United States of America. 225.

Converse, J.C., and Tyler, E.J. (1984). '*The Wisconsin Mound: Siting, design, construction, performance*.' Report No. 15.5A, SSWMP. University of Wisconsin-Madison, United States of America.

Converse, J.C. and Tyler, E.J. (2000). '*Wisconsin mound soil absorption system: Siting, design and construction manual*.' The University of Wisconsin-Madison, Small-Scale Waste Management Project.

Converse, J., (2004). 'Effluent quality from ATUs and packed bed filters receiving domestic wastewater under field conditions.' Conference proceedings, '*Tenth National Symposium on Individual and Small Community Sewage Systems', ASAE, Sacramento, California*, United States of America.

Department of Building and Housing. (2011). *Compliance document for New Zealand Building Code Clause G1 Personal hygiene – Second edition*. New Zealand Government.

Department of Conservation. (1995). '*Wastewater servicing for remote area recreational facilities – A New Zealand concept and design manua*l.' Auckland UniServices Ltd, Auckland, New Zealand.

Department of Health. (1992). '*Public health guidelines for the safe use of sewage effluent and sewage sludge on land.'* Public Health Services, Wellington, New Zealand.

Drizo, A., Comeau Y., Forget C. and Chapius, R. (2002). 'Phosphorus saturation potential: A parameter for estimating the longevity of constructed wetland systems.' In: *Environmental Science and Technology, Australia.*

Durie, M. (1998). 'Whaiora: *Maori health development*. Second Edition. Oxford University Press, Auckland, New Zealand.

EPA Victoria. (2013). '*Code of practice onsite wastewater management*.' Publication Number 891.3, February 2013.

Fletcher, J.C. (1983). 'Wastewater treatment for small communities: The use of septic tanks and intermittent biological sand filters.' In: *Water and Wastewater Treatment Operators Newsletter, Vol. 23, No. 1,* March 1983. Ministry of Works and Development, Wellington, New Zealand.

Gunn, I. (1998). '*A report to Waimauku Partnership – Solan Estate, reclaimed water as a non-potable water supply source for residential and urban uses*.' Auckland UniServices Ltd, Auckland, New Zealand.

Gunn, I. (2003). '*Environment Waikato - Overview of issues related to nutrient management of Lake Taupo wastewater treatment and disposal*.' Environment Waikato, Waikato, New Zealand.

Gunn, I. (2014). 'Performance ranking of on-site domestic wastewater treatment plant.' In: *Water New Zealand, Water, November 2014.*

Hall, S. (2003). '*Linear loading rates – Rule development committee issue research report*.' Washington State Department of Health, Wastewater Management Program.

Ministry of Business, Innovation and Employment. (2014). '*Acceptable solutions and verification methods for New Zealand Building Code Clause G13 Foul water*.'

Ministry of Health. (2000). '*New Zealand drinking water standards*.' Wellington, New Zealand.

NSW Government. (2008). '*NSW guidelines for greywater reuse in sewered, single household residential premis*es.'

Ormiston Associates Ltd. (2013). '*Greywater reuse review for Auckland Council*.' Report prepared for Auckland Council. April 2013.

Patterson, R. A. (1999). 'Peat treatment of septic tank effluent.' Conference proceedings, *'Onsite '99 Conference: Making On-Site Wastewater Systems Work, 13 to 15 July 1999*', University of New England, Armidale, New South Wales, Australia.

Radcliffe, D.E. and West, L.T. (2008). 'Design hydraulic loading rates for on-site wastewater systems.' In: *Vadose Zone Journal 8: 64-74, 2008*.

Rostad, C. (2002). 'Fate of disinfection by-products in the subsurface.' *U.S. Geological Survey, Artificial Recharge Workshop Proceedings, Sacramento, California. United States of America.* Accessed at: www.water.usgs.gov/ogw/pubs/ofr0289/cr_fatedisinfect.htm.

Seigrist, R. (2001). 'Advancing the science and engineering of on-site wastewater systems.' Conference proceedings, '*The Ninth National Symposium on Individual and Small Community Sewerage Systems', ASAE, Fort Worth, Texas*, United States of America.

Siegrist, R.L, Tyler E.L., and Jenssen P.D. (2000). 'Design and performance of on-site wastewater soil absorption systems.' Conference proceedings, '*The Decentralised Wastewater Management National Research Needs Conference'* St Louis, Missouri, United States of America.

University of Minnesota. *On-site sewage treatment program*. (2011). Manual for septic system professionals in Minnesota, 2nd Ed. St. Paul, MN.

Washington State Department of Health. (2012). '*Water conserving on-site wastewater treatment systems: recommended standards and guidance for performance, application, design, and operation & maintenance*.' July 2012.

Washington State Department of Health. (2012). '*Pressure distribution systems: recommended standards and guidance for performance, application, design, and operation & maintenance*', July 2012.

Water New Zealand. (2016). '*On-site effluent testing (OSET)*.' Wellington, New Zealand. Accessed at: https://www.waternz.org.nz/OSET.