Soil and Water Conservation Guideline



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This Guideline supersedes Appendix 6 of the Forest Management Plan 2004 – 2013 (FMP). The Guideline content is the amalgamation of the 2007 revision of Appendix 6 of the FMP, sections of the 2007 Interim Manual of Procedures for the Management of Soils Associated with Timber Harvesting in Native Forests (Department of Conservation and Land Management, Sustainable Forest Management Series, SFM Manual No. 1.), a technical review of surface water management and other new material.

Cover

Main picture	*Blackwood river, fringing vegetation and jarrah forest.*
Left	*Karri thinning harvest operation, near Pemberton.*
Centre	*Overflow and spillway, Wellington Dam.*
Right	*Silviculture burn in the southern jarrah forest.*

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Abbreviations and Acronyms

AEP	Annual Exceedence Probability
ANZECC	Australian and New Zealand Environment and Conservation Council
ARI	Average recurrence interval
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
CALM	Department of Conservation & Land Management (now DEC)
CALM Act	Conservation and Land Management Act 1984
CAWS Act	Country Areas Water Supply Act 1947
CC	Conservation Commission of Western Australia
CEO	Chief Executive Officer
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEC	Department of Environment and Conservation (formerly CALM)
SFM	Sustainable Forest Management Division (DEC)
DOH	Department of Health
DoW	Department of Water
EC	Electrical Conductivity
EMS	Environmental Management System
EP Act	Environmental Protection Act 1986
FMP	Forest Management Plan
FMS	Fire Management Services Branch (DEC)
FOG	Fire Operational Guideline
FPC	Forest Products Commission
IRZ	Intermediate Rainfall Zone
kPa	Kilopascals
MWSSD Act	Metropolitan Water Supply, Sewerage and Drainage Act 1909
NHMRC	National Health and Medical Research Council
NRMMC	Natural Resource Management Ministerial Council
OIC	Officer in charge
PDWSA	Public Drinking Water Supply Area
PeAC	Pesticides Advisory Committee
PSC	Public Service Circular
PVC	Polyvinyl chloride
RPZ	Reservoir protection zone
t/ha	Tonnes per hectare
USCS	Unified Soil Classification System
WC	Water Corporation
WHPZ	Wellhead protection zone

Table of Contents

1 Framework for this guideline

1.1 Purpose and scope

The purpose of this guideline is to provide guidance to forest managers, contractors and operators undertaking disturbance activities in native forest, on practices to promote the conservation of soil and water values. The development of this guideline is a requirement of the Forest Management Plan 2004-2013 (FMP) which requires a more proactive approach to management than under previous arrangements.

This guideline primarily applies to State forest, timber reserve and freehold land that contains indigenous vegetation and which is held in the name of the *Conservation and Land Management Act (1984)* (CALM Act) Executive body. It may also be a useful guide for activities on other Department of Environment and Conservation (DEC) managed lands such as national parks, conservation parks and nature reserves.

This guideline is a controlled document. It applies to all activities unless there is an authority that overrides the provisions of the CALM Act or the FMP.

1.2 Context

It is important to emphasise that this is an operational guideline. For the field user to effectively resolve the complex series of interacting factors he or she is faced with, application of the guideline needs to be supported with training, enhanced by field experience and tempered by informed judgement and the advice of senior staff.

Achievement of the overall management objectives for State forest and timber reserves is approached by using three scales of management (whole of forest, landscape and operational). These scales involve the consideration of areas and tenures with different management purposes, only some of which are affected by this guideline. This includes the management of:

Whole of Forest

- Formal reserves such as national parks, nature reserves and conservation parks. These areas are not available for disturbance activities such as timber harvesting. This guideline does not apply to such areas;
- State forest and timber reserves, which are subject to this guideline.

Landscape

- Informal reserves embedded within State forest, such as diverse ecotype zones (includes rock outcrops, swamps, flats, sedgelands, jarrah woodlands), river and stream zones, travel routes zones, and old growth forest. This guideline applies to such areas;
- Fauna habitat zones which are embedded within State forest. This guideline applies to such areas; and
- Freehold land held in the name of the CALM Act Chief Executive Officer (CEO) where native timber harvesting occurs. This guideline applies to such areas.

Operational

- Areas protected by prescription such as the sites of rare and endangered species. This guideline applies to such areas.

1.3 Legislative requirements

All areas of indigenous State forest and timber reserve within DEC's Swan, South West and Warren Regions, other than those identified in Appendix 2 of the FMP, are reserved for the purposes of conservation, recreation, timber production on a sustained yield basis, water catchment protection and other purposes being a purpose prescribed by the regulations. To date no additional purposes for State forest and timber reserves have been prescribed in regulations.

The *Soil and Land Conservation Act (1945)* provides measures for the conservation of soil and land resources principally through mitigation of the effects of erosion, salinity and flooding. A Soil Conservation Notice may be placed on private property (including freehold land held in the name of CALM Act Executive Body), where it is the Commissioner's belief that land degradation has occurred, or may foreseeably occur, due to the failure of any person to take adequate precautions to prevent or control soil erosion, salinity or flooding (*S. 31)*.

A Soil Conservation Notice may be placed on land in order to:

- Prevent further degradation on that property or elsewhere;
- Aid regeneration of vegetation; and
- Require the landholder to undertake any activities that may be required to address land degradation concerns.

Where a landholder contravenes or fails to comply with a soil conservation notice, a penalty of $3000 applies (*S. 35*).

Under amendments of 8 July 2004 to the *Environmental Protection Act (1986)* (EP Act), all clearing of native vegetation requires a clearing permit, unless subject to an exemption. Exemptions are of two classes:

1. Requirements or approvals under another law (Schedule 6); and
2. Clearing for routine land management activities that have a low impact (regulations).

In deciding whether to issue a clearing permit, the CEO must consider ten clearing principles outlined in the Act, one of which is directly concerned with soil values (Principle "g" in Schedule 5), and three of which are concerned with water values (Principles "f", "i" and "j" in Schedule 5).

The harvesting of flora is included in the definition of 'clearing' under the EP Act and a permit to clear is required. However, under the *Forest Products Act (2000)*, clearing of vegetation maintained, or established and maintained, under section *10(1) (g)* of that Act, or under a production contract or road contract, is exempt from the EP Act clearing permit requirements. DEC's activities are exempt from requiring a clearing permit where the management is in accordance with the CALM Act. This exemption applies to all management of land in accordance with a management plan, or where no plan exists, as necessary operations (nature reserves) or compatible operations (national parks, conservation parks). Exemptions also exist for other areas of legislation, such as the *Bush Fires Act (1954)*, which may relate to the Department's operations in relation to fire management.

A Licence to Clear is required from the Department of Water (DoW) (formerly the Water and Rivers Commission) if proposed clearing of native vegetation is located in a catchment controlled under Part IIA of the *Country Areas Water Supply Act (1947)* (CAWS Act). Controlled catchments proclaimed under the First Schedule of this Act include the Wellington Dam

Catchment Area, Harris River Dam Catchment Area, Mundaring Weir Catchment Area, Denmark River Catchment Area, Kent River Water Reserve, and Warren River Water Reserve.

Following an amendment to the *Country Areas Water Supply Regulations (1981)*, if a clearing permit under the EP Act has been issued, it is no longer necessary to obtain a licence under the CAWS Act, unless compensation for the refusal of a licence has been paid to a previous applicant.

The *Metropolitan Water Supply, Sewerage and Drainage Act (1909)* (MWSSD Act) constitutes the Metropolitan Water, Sewerage and Drainage Area (for the Perth region and surrounds), establishes the method of control (of catchment and supply areas) and other relevant purposes (e.g. preventing pollution and protecting public health). By-laws made under Part XI of this Act enable DoW to control potentially polluting activities, to regulate land use, inspect premises and to take steps to clean up pollution. Such by-laws apply in proclaimed areas collectively termed Public Drinking Water Source Areas (PDWSAs). A PDWSA collectively describes declared Catchment Areas, Water Reserves (CAWS Act) or Underground Water Pollution Control Areas under the MWSSD Act or CAWS Act. The use of chemicals (e.g. petroleum hydrocarbon, fertilisers and pesticides) in any PDWSA (Perth metropolitan and country regions) is subject to arrangements with the DoW The Department may oppose or place conditions on specific chemical use where such use is considered likely to cause a significant risk to water resources.

Water allocation plans *(Rights in Water and Irrigation Act (1914))* and source protection plans (defining land planning and use strategies to implement the provisions of the MWSSD Act and CAWS Act) are prepared by the Water and Rivers Commission or its delegate. These plans include objectives and policies that the Department takes into account when planning at strategic and operational levels.

The CALM Act (*s. 20(6)*, and *s. 101(1a)* and (*1e*)) and the FMP (21.4) provide for DEC to take water and issue permits for taking water. The CALM Regulations (*s. 81* revised 29/1/08) allow indigenous State forest and timber reserve to be reserved for purposes including the removal of water, storage of water and location of infrastructure and facilities.

Note: It is anticipated that a number of water related acts may be changed in 2008.

The *Aerial Spraying Control Act (1966)* regulates the aerial spraying of agricultural chemicals. Weed control and fertilising activities should be compliant with the requirements of this Act.

The *Health Act (1911)* (Health Act) is an enabling Act that provides for the establishment of the Pesticides Advisory Committee (PeAC) and the creation of regulations considered necessary for the protection of health in relation to pesticides. The objectives of the regulations are to regulate the use of agricultural chemicals in relation to human health issues rather than environmental effects. Regulations deal with the storage, transport and use of pesticides. Public Service Circular No.88 (PSC 88) (Appendix 3 of this Guideline) *Use of Herbicides in Water Catchment Areas* is a government circular which is designed to provide advice to Government Departments on the use of herbicides in drinking water catchment areas, including approved chemicals, application methods, safe storage and disposal. PSC 88 was established to protect Western Australian drinking water resources from unnecessary exposure to herbicides. It is overseen by the Department of Health (DOH) and is binding to Government Departments. The Pesticides Advisory Committee (PeAC), a statutory committee established under the Health Act, is currently undertaking a review of PSC 88 with the view of replacing it with a Code of Practice that will cover all pesticides, and to have it apply to all of the population and not just Government Departments. Water and Rivers Commission (now DoW) policy on *Pesticide Use in Public Drinking Water Source Areas (2000)* is also relevant (Appendix 2).

The *Waterways Conservation Act (1976)* provides for the conservation and management of certain waters and of the associated land and environment. There are 5 conservation management areas to be aware of when planning or conducting works: Peel/Harvey estuaries; Leschenault estuary and associated rivers; Albany harbour and associated rivers; Avon River; and Wilson Inlet and associated rivers.

1.4 Roles and responsibilities in management

All users of State forest and timber reserve are required to comply with the relevant legislation, the FMP and conditions of approval for access issued by DEC or other government departments. This guideline was produced to guide forest users in the management of soil and water primarily associated with timber harvesting in native forests. Adherence to the procedures outlined in this document will assist forest managers and their contractors in being compliant with the relevant legislation. Where there are specific responsibilities for a particular activity or organisation, these are outlined in Sections 5 to 7. Mandatory actions are identified in four phases based on an Environmental Management System (EMS) approach. The phases are:

Planning - Implementation - Monitoring - Review

1.5 Structure of this guideline

There are two main parts to this guideline. The first part provides background information on soil and water values and how they may be protected (Sections 1 to 4). The second part prescribes requirements for forest management activities and contains supporting information (Sections 5 to 11). A summary of the structure of this guideline is shown in Table 1.

Section 1 outlines the framework and structure for this guideline together with relevant legislation.

Sections 2 and 3 provide background information on key processes and threats to soil and water values. These are explained in relation to causes, effects, assessment of risk and preventative or remedial actions.

Section 4 provides best practice advice and tips on surface water management.

Sections 5 to 7 outline requirements for key forest management activities including mandatory actions or outcomes within an EMS framework.

Section 8 is a Glossary providing definition of terms.

Sections 9 and 10 provide references and schedules of technical specifications, standards and requirements.

Section 11 provides information from external agencies to support the Schedules.

Table 1 Structure of this guideline

Section	Contents and structure
1 Framework for this guideline	Purpose, legislative requirements, roles & responsibilities
2 Conservation of soil values	Key processes and threats to soil and water values
3 Conservation of water values	Causes – Effects – Assessment of risk – Remedial treatments
4 Surface water management	Best practice advice on surface water management
5 Timber harvesting	Operational requirements for key forest management activities
6 Public Drinking Water Supply Areas	Definition of mandatory requirements Advice on recommended practices
7 Fire Management	Planing – Implementation – Monitoring - Review
8 Glossary	Definition of terms used in the guideline
9 References and suggested reading	Background and follow-up reading
10 Schedules	Technical specifications, standards and requirements
11 Appendices	Information from external agencies to support schedules

1.6 Custodianship and management of this guideline

The custodian of this document is the Manager of the Forest Policy and Practices Branch of the Sustainable Forest Management (SFM) Division of the Department of Environment and Conservation.

The FMP provides for the Soil and Water Conservation Guidelines to be prepared by DEC with public consultation, submitted to the Conservation Commission for advice and approval by the Minister for the Environment. The operational requirements documented in Sections 5 to 7 will be reviewed periodically and if necessary, revised, subject to this process. It is anticipated that this will occur on a five-yearly cycle. The background sections 1 to 4 and supporting documentation in Sections 8 to 11, will be subject to review and revision as required, with approval by the Director of SFM so as to provide timely continuous improvement to better meet the overall objective of the FMP whilst also better meeting the soil and water objective of the FMP.

2 Conservation of soil values

Maintaining soil structure, and the soil processes responsible for nutrient cycling, is fundamental to forest health. Soil is far more than grains of mineral earth. Soil contains a diverse range of biota including; earthworms, ants, beetles, termites, spiders, nematodes, mites, centipedes, protozoa, mosses, bacteria, actinomycetes, algae, and fungi. Though small and obscure, these life forms perform essential ecosystem processes, breaking down and redistributing organic matter, cycling nutrients, fixing nitrogen and aerating the soil. Without these life forms, and the soil structure that supports them, the forest ecosystem would collapse.

As the time taken to repair damaged soil is often longer than planning or operational timeframes, soils are sometimes referred to as non-renewable resources. Consequently the prevention of damage through active planning and management is preferable to seeking a cost effective cure after the damage has occurred.

This chapter outlines key soil values and the threats to these values from forest management activities. Information is provided on causes, effects, assessment of risk and remediation. The threats to soil values covered include:

- Compaction;
- Other physical impacts - profile disturbance, rutting, puddling and mixing;
- Erosion;
- Nutrient depletion; and
- Soil salinity.

2.1 Soil compaction

Soil is compacted when it is compressed, or subject to some other physical force that reduces the pore spaces between soil particles, increasing the soil bulk density.

2.1.1 Causes of Soil compaction

Compaction most commonly occurs when the soil is compressed and the compressive force exceeds the soils strength. Any mechanism that rearranges the soil particles to reduce soil pore space will increase the soil bulk density, causing compaction.

For engineering purposes, such as the construction of roads, banks, drains, and foundations, the ability of soil to compact is a positive characteristic. From an ecological point of view, soil compaction is a damaging process. In forests managed for timber production, compaction is largely caused by the movement of vehicles and logs over the soil. The main processes of compaction are:

Compression	Packing of the soil resulting from a vertical force from wheels or tracks;
Shearing	Deformation of the soil resulting from horizontal force such as spinning or slipping wheels or tracks; and
Smearing	Realignment of soil particles in a thin layer from random to parallel orientation by slipping tracks or wheels and sliding logs.

The amount and depth of compaction damage sustained by a soil depends on a number of factors including:

- Physical properties of the soil - particularly the particle sizes (soil texture), bulk density and organic matter content;
- Soil moisture at the time of activity;
- The number of times a vehicle passes over the site;
- Ground pressure of the machinery; and
- Operator skill.

Physical properties

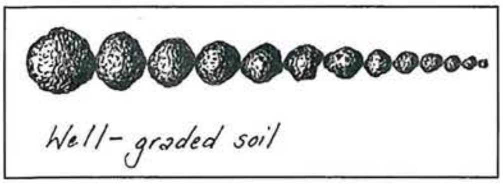
The physical properties of the soil indicate susceptibility to compaction and how this may be managed. Table 2 lists these physical properties and their relationship to compaction.

Table 2 Soil physical factors that affect compaction

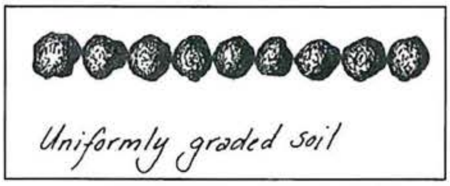
Physical soil factor affecting compaction	Description
Soil texture	Generally, very coarse textured soils such as sands and gravels are more resistant to compaction, particularly when poorly graded (low variation in particle size). Soils with a range of particle sizes (well graded) are more susceptible to compaction, particularly when they contain high amounts of fine sand and silt. Fine textured soils (high in clay content) are resistant to compaction when they are dry because they contain many very fine pores which are resistant to compression. However, clay soils become highly susceptible to compaction when they are wet.
Organic matter	Soils high in organic matter are more difficult to compact, compared to soils with low organic matter. Organic matter reduces susceptibility to compaction by providing resistance to deformation and also by increasing the soils ability to rebound after a compressive load.
Bulk Density	In general, soils with higher bulk density are more resistant to compaction. However, bulk density as an indicator of susceptibility to compaction should be used with caution because it does not reflect the compressibility of a soil. For example, some sandy soils have a naturally high bulk density, but a low compressibility. When subject to load, these soils may exhibit a small increase in bulk density with a large increase in soil strength which can adversely affect root growth. Some clay soils (e.g. Wandoo clays) have a relatively high bulk density, but will become unsuitable for root growth following a very small increase in bulk density above natural levels.

A schematic comparison of well graded and uniformly graded soils is shown in Figure 1 below.

Figure 1: Comparison of well graded and uniformly graded soils



A well graded soil such as a karri loam has a range of particle sizes. These soils are more



A uniformly (or poorly) graded soil such as a lateritic gravel or uniform sand contains particles of susceptible to compaction.

similar size. These soils are less susceptible to compaction.

Soil moisture

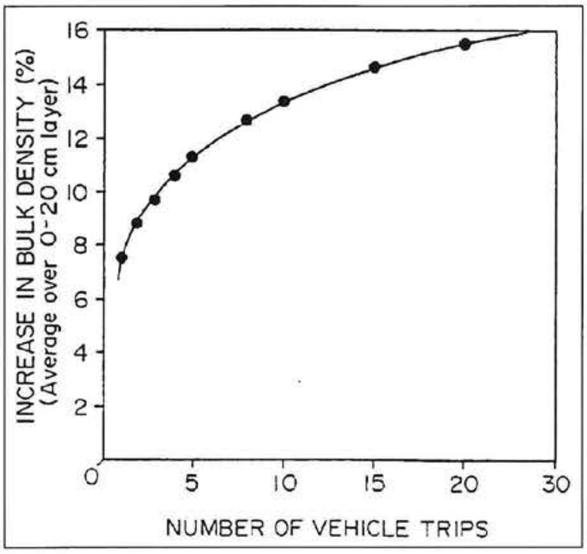
Virtually all soils become increasingly prone to compaction as they become wetter. The strength of a soil can decrease ten to one hundred times when it becomes wet. Water films are formed around each soil particle weakening the bonds between them and reducing the soil's strength. Water also lubricates soil particles, allowing them to slide together.

When soil is moist in winter and spring, soil strength is greatly decreased, and soil compacts readily. At this time of year soil compaction is greatly influenced by soil moisture - the ground pressure of the vehicle is of less concern. During winter and spring when soil is moist it is most important to manage compaction by operating in drier or less susceptible soil types.

Number of vehicle passes

Compaction increases as vehicles repeatedly pass over the soil. Most of the compaction occurs with the first few passes. The general nature of this relationship is shown in Figure 2 below.

Figure 2: The effect of the number of vehicle passes on soil bulk density.



Source of picture Froehlich *et. al*, (1980)

Figure 2 is indicative of the general response. The shape of this curve will change for different operating conditions and soil types. A similar response has been measured during winter harvesting in jarrah and karri forests with a range of soils and harvesting machinery. In these studies, soil compaction was primarily related to the total load of timber hauled over the extraction tracks, and the greatest increases in soil compaction occurred after relatively little timber had been hauled over the extraction track.

Since the initial passes of machinery cause the greatest increases in soil compaction:

The most effective way of minimising the extent of soil compaction is by minimising the number of extraction tracks and forcing all machinery traffic on to as few tracks as possible.

See Figures 3 and 4 below.

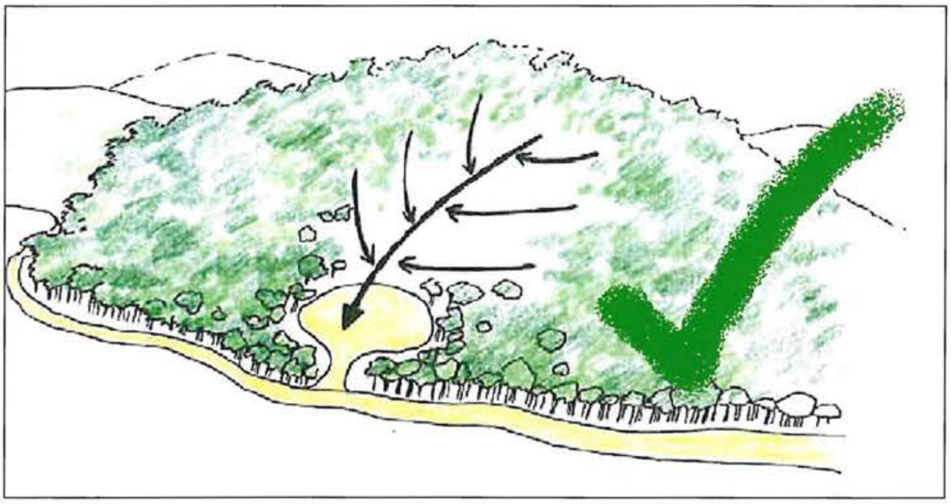


Figure 3: **A "herringbone" extraction network is an efficient way to minimise the number of tracks used to extract logs.**

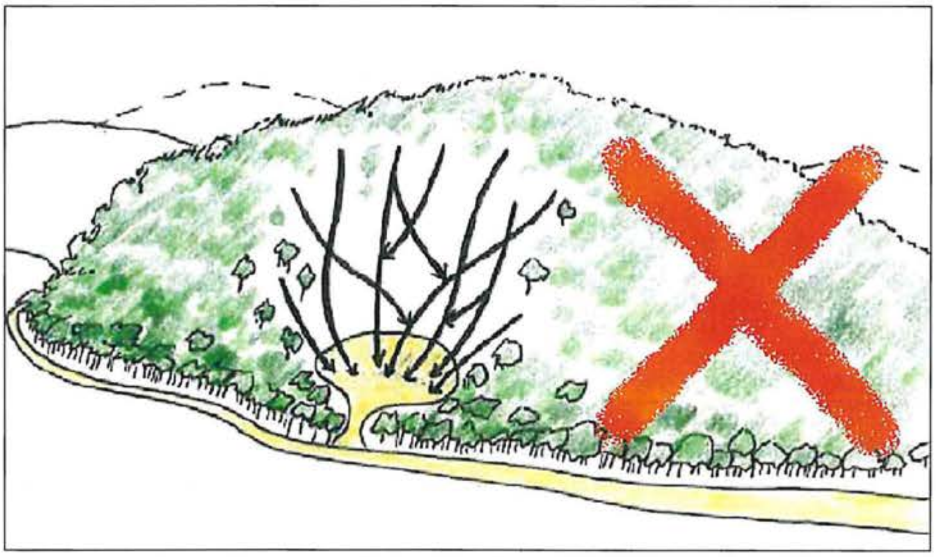


Figure 4: **Avoid duplicate, parallel and criss-crossing extraction tracks as these cause unnecessary multiplication of disturbance.**

Ground pressure

Ground pressure is a way of expressing the force applied to the soil by a particular machine and is expressed in Kilopascals (kPa). The use of machines with lower ground pressure can contribute to minimising compaction. However, low ground pressure machines do not provide a solution to the reduction of soil compaction. There are two aspects of compaction: intensity and extent. Lower ground pressure machines may slightly decrease the intensity of compaction but will not decrease the extent of compaction. A field officer should be wary of believing that a machine with lower ground pressure will cause less compaction as he/she may be less concerned about the extent of the damage, which could lead to more extensive (though slightly less severe) compaction.

Examples of typical ground pressures for harvesting equipment used in the south-west of Western Australia are shown in Table 3 below. The bearing pressure of a soil is also expressed in kilopascals ranging from low bearing capacity (40 kPa) to high bearing capacity (more than 80 kPa). To minimise the risk of damaging soil, the ground pressure of machines can be matched to the bearing capacity of the soils they are operating on. This theoretical proposition should be used as a starting point for machine choice, but must be supplemented by field observation of soil disturbance. For example, tracked machines generally distribute ground pressure better than wheeled machines but have the disadvantage of causing greater soil disturbance.

Table 3: Indicative ground pressures of logging equipment used in the south-west of Western Australia

Machine type	Application	Wheeled or tracked	Approx. loaded ground pressure (kPa)
Skidders	Snigging	Wheeled	255
Loader	Landing loader	Wheeled	310
Barkmate	Loads/docks	Tracked	40 (unloaded)
Harvester – 45 t	Harvesting mature trees	Tracked	70
Harvester – 27 t	Harvesting regrowth	Tracked	~70
Forwarder 8 wheel	Carrying out regrowth and small logs	Wheeled	360
Forwarder 6 wheel	Carrying out regrowth and small logs	Wheeled	~360

Source Rab *et. al*, (2005).

Cording, matting and brushing have been used when soil is moist in an attempt to reduce soil disturbance by harvesting machines. These materials spread the ground pressure of the logging machinery and separate the soil surface from the tyres and tracks of machines on extraction tracks and landings. The materials can be used individually or in combination.

Matting is a layer of bark, wood chips or other vegetation that is commonly used to cover cording, and smooth out the track surface. Matting may be used alone as a means of reducing soil disturbance, however a substantial layer of material is needed for matting to be beneficial and the efficacy of the various types of matting material in reducing soil damage has not been established.

Brushing is a dense thick layer of small diameter log, branch and woody understorey material that is randomly laid to form an interlocked mat and distribute vehicle load over a wide area. Brushing is commonly used in karri thinning operations (Figure 5). A dense, even cover of brushing has been shown to effectively reduce soil damage (compaction, mixing, and rutting) in other forest types (Wood et al. 2003; McDonald and Siexas, 1997).

Corduroying, or cording, is round or split log material that is closely and continuously laid at right angles to the direction of the extraction tracks, or placed on landings, to distribute the machine load over a large area and reduce soil compaction, mixing, and rutting.

Corduroying can reduce soil compaction in jarrah and karri harvesting (Whitford *et al.*, 2008); however, the relatively small reduction in compaction provided by corduroying should be balanced against the cost and the associated negative environmental impacts of using corduroying.

From a soil management perspective, it is almost always best to harvest the forest at times when the soil is dry, and cording, brushing and matting are not necessary.

Figure 5: Brushing with tops and thinnings waste is successfully used in karri thinning operations to protect extraction tracks and reduce the incidence of rutting.

Operator skill

Reduced static ground pressures of machines will not automatically lead to reduced soil impacts. Other factors to consider include the machine configuration (e.g. articulated vs. skid steering) and the way in which they are operated. Skilled machine operators are highly valued for their role in increasing operational efficiency and minimising soil damage. The theoretical ground pressures shown in Table 3 above, increase significantly with the skidding, bouncing, spinning and twisting actions of loaded machines. Smooth machine operation plays an important part in reducing these actions as well as minimising operational, maintenance, repair and rehabilitation expenses.

2.1.2 Effects of soil compaction

Consequences of soil compaction include:

- Reduced biological activity which affects soil permeability and water relations, soil fertility and nutrient cycling;
- Lower biodiversity, particularly in micro-organisms, fungi and invertebrates;
- Loss of forest productivity due to decreased germination success, lower soil volume available to roots, less feeder root surface area due to lower root growth, resulting in significantly lower growth rates for vegetation; and
- Increased potential for erosion and subsequent deposition leading to soil movement and loss, off site impacts on aquatic systems due to deposition, stream turbidity, lower oxygen levels and potential eutrophication.

These consequences occur because compaction damages soil structure and decreases the size of pores in the soil (see Figure 6).

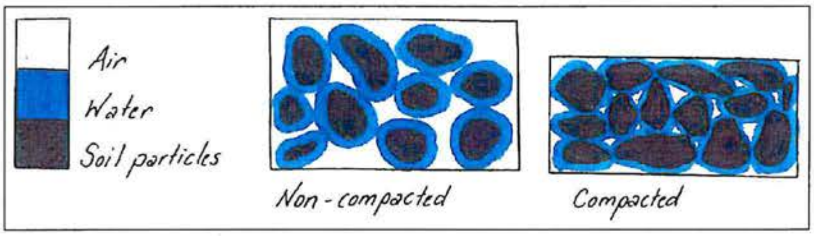


Figure 6: Effects of compaction on pore space

Reducing the pore size diminishes the water holding capacity of the soil and limits both the flow of water into the soil and the exchange of gases such as oxygen, with the outside atmosphere. Compaction also restricts the growth of roots and fungal hyphae in the soil and diminishes the movement of soil microbes and invertebrates through the soil. The activity of soil fungi and microorganisms declines, impacting soil processes such as the breakdown and incorporation of organic matter into the soil, nitrogen fixing and nutrient cycling. Water availability and root growth are restricted, and nutrient and water uptake by plants is reduced, lowering plant growth rates. These changes reduce biological activity in the soil, lowering forest productivity and potentially reducing biodiversity. The decreased infiltration rates can also increase surface water ponding, puddling, waterlogging and surface runoff, potentially causing erosion and increasing stream turbidity.

2.1.3 Assessment of risk

The ability to determine when soils are at risk of compaction is highly desirable in forest managers. The assessment of risk can be applied from planning through to completion of operations. An integrated approach includes planning based on known soil properties (Table 4 below), education and training and by the predictive use of seasonal information (e.g. climate and soil moisture) supplemented by assessment in the field and monitoring during operations. Many of these activities are mandatory requirements for approval to operate on DEC managed lands (Section 5). Access to forests is conditional on planning (Schedules 2 to 4) and operational standards (Schedules 6 to 24) being achieved.

A typical planning and operational sequence for timber harvesting should contain the following:

- Plan the allocation of resources to enable shutdown during wet months. Prepare contingency strategies for wet weather in advance;
- Review available forest areas in relation to expected trafficability (landform and soil type);
- Allocate areas with regard to seasonal workflow and machine type;
- Plan and mark the layout of extraction tracks;
- Maximise the use of old extraction tracks;
- Ensure operators are trained to observe soil moisture damage and are aware of potential damage and acceptable limits;
- Monitor soil moisture and look for damage at increased frequency as the risk of damage increases;

- Use easily observable indicators such as the onset of rutting on primary extraction tracks to signal that damage is occurring elsewhere (Note: as soil moisture increases, subsoil compaction may be occurring without being visually apparent);
- Become familiar with indicative field methods of assessment such as the recognition of plastic limit; and
- Use forward planning to maximise the use of resources in low risk periods. Regularly review progress in relation to target volumes and trigger contingency strategies if required.

An example of risk assessment in relation to compaction risk for common forest soil types in the south-west of Western Australia is shown in Table 4 below.

Table 4: Trafficability and compactibility of various south-west Western Australian forest soils for combined texture and local soil groups.

Trafficability	Compactibility	Texture groupings			Local soil groupings	
		4 texture groups	5 texture groups	6 texture groups	6 soil groups	4 soil groups
Excellent	Low	Stony/ Sandy	Rocky or Stony Sand-Gravel/ Duricrust Shallow Sand/Cemented Layer Deep Sandy Gravel Deep Sands	Sand Loamy sand Clayey sand	Lateritic uplands	Lateritic uplands Upland sands, Blackwood Plateau uplands
				Sandy loam Fine sandy loam Light sandy clay loam	Upland sands	
		Loam	Shallow Loam Duplex Shallow Loam/Hardpan Deep Loam Duplex Loamy Earths and Gravels	Loam Loam, fine sandy Silt loam Sandy clay loam	Blackwood Plateau uplands	Red loams (karri loam)
		Sandy duplex/ Clay loam	Earthy Sands Shallow Sandy Duplex Duplex Sandy Gravel Deep Sand Duplex	Clay loam Silty clay loam Fine sandy clay loam	Red loams (karri loam)	Shallow to clay (duplex soils under jarrah and karri, Blackwood Plateau shallow to clay)
		Clay	Clay	Sandy clay Silty clay loam Light clay Light medium clay	Shallow to clay (duplex soils under jarrah and karri, Blackwood Plateau shallow to clay)	Clay (orange earths under wandoo)

Very poor	**Very high**			**Medium clay** **Heavy clay**	**Clay (orange earths under wandoo)**	

Source – Rab *et. al*, (2005)

A simple field test to estimate when a soil is prone to compaction (plastic limit):

Maximum soil damage usually occurs when soil is at or near its lower plastic limit.

Lower plastic limit: This is the moisture content when soil changes from being brittle to plastic and is the minimum moisture content at which the soil can be moulded. It is also the maximum moisture content at which the soil is friable. In most soils it is at or near the upper limit of water storage (field capacity). Puddling begins to occur at the lower plastic limit.

A test for lower plastic limit: At the lower plastic limit there is just enough moisture in the soil to allow a rod of about 3 mm diameter to be formed by rolling the soil between the palms of your hands. All gravel must be removed from the soil, and this test does not work with sands. If a 3 mm diameter rod 75 mm long can easily be formed then the soil is too moist to bear traffic from harvest machinery, and ripping and cultivation to ameliorate the effects of compaction will not be successful.

If the soil will not form rods of 3 mm in diameter and breaks apart and crumbles when rolled by hand, then it is dry enough to bear traffic and can be cultivated or ripped. (The soil sample has to be taken from a depth of 20-30 cm to be representative of the soil to be ripped. Use an auger or mattock to obtain this sample.)

Upper plastic limit (or liquid limit): This the moisture content at which the soil changes from a plastic solid to a viscous liquid.

How to tell if a soil is saturated: After squeezing the soil sample, if there is a sign of water between the finger gaps then it may be assumed that the soil is saturated.

Implications for management on saturated soil

Soils are highly prone to puddling and severe rutting damage when they are saturated (Section 2.2.)

Table 5 Implications of plastic limit for soil management

Soil Factor	Implications
Compaction	Soil wetter than the lower plastic limit, but not saturated is easily compacted.
Tillage	For coherent soils, the lower plastic limit is the optimum moisture content for tillage operations. Scarifying when the soil is wetter than the lower plastic limit can cause major structural degradation.
Soil workability	The closer the lower plastic limit is to the upper storage limit (field capacity) the greater the workability. A small difference between the two means the soil will be suitable for traffic or scarification soon after free drainage has ceased. A large difference indicates the soil has to dry for a considerable time before it can be trafficked or scarified safely.

Source Adapted from Moore, (2001)

Note: These limits are also known as Atterberg limits.
Coarse textured (sandy and gravelly) soils are non plastic and the limits are not applicable.

2.1.4 Remedial treatments

Natural recovery from compaction damage is very slow. The primary method of repair is by biological activity (roots, soil flora and fauna). Recovery may take as little as 20 years for light damage at shallow depth, but more typically tens to hundreds of years depending on soil type, vegetation, moisture conditions, depth of the compacted layer and degree of compaction. Remedial treatments are designed to facilitate the onset of the biological processes of repair.

Ripping and scarification are commonly used remedial treatments to facilitate the increase in biological activity on compacted sites. DEC documents recommend and FPC documents specify the use of a winged tyne ripper. This configuration increases lift and improves aeration. Ripping may be beneficial in improving drainage and aeration. While it helps to facilitate the onset of biological processes, ripping is not an immediate cure for the structural damage. Scarification improves the aeration and drainage of the soil surface and is used to create a favourable seed bed for seed which is either broadcast or falls naturally from the surrounding forest. Stockpiling topsoil before disturbance activities commence and replacing it during rehabilitation has been demonstrated to be a highly successful practice for landings and gravel pits in the south-west of the State.

To optimise effectiveness and reduce the chance of further soil damage, it is important that ripping and scarification are conducted at the correct levels of soil moisture (Schedule 24).

2.1.5 Summary (soil compaction)

- Soil compaction causes damage that is difficult to repair and long lasting;
- Compaction damage is usually caused by vehicles and sliding logs;
- Soils are more prone to damage when wet;
- Soils vary in trafficability under moist conditions e.g. upland gravels and sands > deep duplex > karri loam > shallow duplex > clay soil;
- Planning and monitoring substantially reduces the risk of causing damage;
- The most effective way of minimising the extent of soil compaction is by minimising the number of extraction tracks and forcing all machinery traffic on to as few tracks as possible;
- The most effective way of minimising the severity of soil compaction is by avoiding heavy vehicle movement on susceptible soil types during moist soil conditions; and
- Operators in the forest are responsible for limiting and controlling damage. Allowable limits are shown in Schedule 6. Damage must be rehabilitated according to Schedules 23 and 24.

2.2 Other physical impacts - Soil profile disturbance, rutting and puddling

Soil profile disturbance is the mixing and/or removal of soil layers which may be caused by machine activity or the movement of logs.

Mixing describes a type of soil profile disturbance which occurs when soil horizons such as the topsoil and subsoil are mixed together by mechanical action.

Rutting is a term given to the creation of depressed channels or grooves in the soil surface, usually by the action of vehicle tyres or tracks.

Puddling describes the combination of water and repeated mechanical disturbance of soil, often as a slurry or under saturated conditions. Puddling breaks down natural aggregates and realigns soil particles, resulting in dramatically poorer aeration and drainage and exacerbating the effects of compaction.

Figure 7: This landing is showing both puddling and mixing.

2.2.1 Causes of soil profile disturbance, rutting and puddling

Profile disturbance, rutting and puddling are often interrelated and may occur together.

The type and severity of profile disturbance is dependent on the type of machinery or vehicles in operation in the forest. Profile disturbance may occur across various soil types and seasonal conditions as a result of the intensity and type of equipment in use, or the nature of the operation being carried out. Common causes of profile disturbance are the action of vehicle tracks or tyres, the impact of falling or pushing trees and the dragging of trees or logs across the ground.

Rutting and puddling often occur together. They are usually associated with moist soil conditions, and often occur where there is heavy traffic load. Soils that are prone to damage and are at or near saturation may become rutted after a single pass.

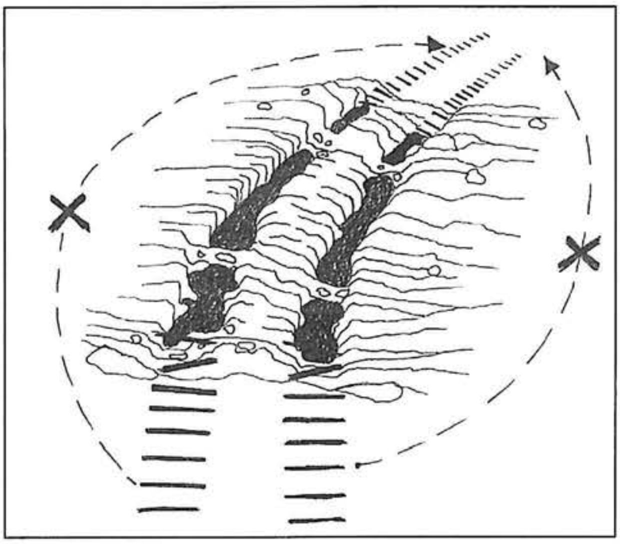
2.2.2 Effects of soil profile disturbance, rutting and puddling

Profile disturbance and mixing can change the physical, chemical or biological properties of a soil. Bulk density is increased when subsoil is exposed and organic matter is removed or redistributed. Porosity and saturated hydraulic conductivity are usually reduced, which causes a reduction in drainage and biological activity. Fertility is reduced where organic matter, soil organisms and topsoil are buried or removed. Soil profile disturbance is an important factor in determining how prone to erosion a soil becomes after disturbance.

Puddling and rutting are severe forms of soil structural decline which inhibit plant growth due to reduced aeration and drainage. Rutted and puddled soils may become anaerobic, leading to a higher chance of fungal infection. Tracks that are rutted and puddled may become pathways for the spread of disease. As water entry into the soil is retarded, this may contribute to runoff and erosion. When they dry, puddled or rutted soils usually have a hard surface crust which can prevent germination.

2.2.3 Assessing the risk of soil profile disturbance, rutting and puddling

As with compaction, the risk of physical damage can be predicted and managed. Damage is related to soil type, moisture status, machine configuration, load and type of operation. The planning process of coupe design and layout can be used to effectively limit the number of extraction tracks (puddling and rutting) as well as identifying and avoiding soils that are most likely to be prone to damage under moist soil conditions so that they may be restricted to dry conditions only, or protected by cording, matting or brushing.



For activities such as timber harvesting and extraction, it is recognised that some damage is unavoidable. Management strategies are required to focus on minimising the spatial extent of this damage. Wherever possible, duplication of roads or tracks should be avoided and old extraction tracks should be re-used. On some soil types, the use of cording, brushing or matting may effectively reduce puddling and rutting.

Figure 8: Do not create new tracks (replication) to avoid damaged areas.

In many cases a few strategically placed surface water management structures will dramatically reduce the incidence of rutting or puddling (Section 4). At other times, it may be more cost effective to cease operations until dry soil conditions return.

2.2.4 Remedial treatment of profile disturbance, rutting and puddling

Profile-mixed, rutted and puddled soils do not easily repair naturally. Rehabilitation is useful, but will not generally return heavily damaged areas to full productivity in realistic time scales. As with compaction, the primary objective is to facilitate aeration and drainage in order to reinstate some level of biological activity and repair. Ripping, scarification and the storage and redistribution of topsoil are commonly used techniques to facilitate repair. Schedules 23 and 24 indicate rehabilitation requirements and standards.

2.2.5 Summary (soil profile disturbance, rutting and puddling)

- Common causes of profile disturbance are the action of vehicle tracks or tyres, the impact of falling or pushing trees and dragging trees or logs across the ground;
- Rutting and puddling often occur together. They are usually associated with moist soil conditions and often occur where there is heavy traffic load;
- The risk of physical damage to soils can be predicted and managed; and
- Soils that are damaged require rehabilitation according to Schedules 23 and 24.

2.3 Soil erosion

Soil erosion is both a natural phenomenon and a consequence of land use in managed forests. Like compaction, the erosion of soil causes damage that is not easily repairable in conventional timeframes. Soil erosion removes fertile topsoil and organic matter from forest areas and can reduce forest productivity and biodiversity. Erosion causes offsite effects when the materials removed are deposited at another site. The offsite effects of soil erosion include turbidity, silting and the eutrophication of streams and water bodies.

The potential rate of erosion which may occur following disturbance within forest ecosystems is many times greater than the natural wearing away of the earths surface. In the south-west forest region, the potential for erosion is accentuated by the seasonal nature of the Mediterranean climate. Estimates of the fastest rates of soil formation in the forested hills of the south-west are around 1 mm every 500 years. Rates of erosion due to soil disturbance may range from as low as 1 mm per decade to many cm per day. Remedial works are generally expensive and only partially effective. Natural biological means of stabilisation are generally insufficient on their own. The occurrence of erosion due to soil disturbance activities is generally easy to predict, manage and avoid.

2.3.1 Types of soil erosion

Soil erosion is the detachment of soil particles and their transportation by water, wind or gravity. The most common types of erosion are described below. Each has a different cause.

Sheet Erosion (or inter-rill erosion) is the removal of a uniform layer of soil by raindrop splash and/or runoff. No perceptible channels are formed and soil particles are either transported to rills, gullies and streams, or moved further downslope where they are liable to be displaced by subsequent erosion. Rates of soil loss with sheet erosion are sometimes relatively difficult to notice, such as a few millimetres per decade.

Rill erosion is the removal of soil by runoff in numerous small channels (rills) which are commonly around 5 to 10 mm deep (but may be much greater). Rills typically form on cultivated or disturbed soils. Sandy soils are particularly prone to rill erosion. Rill erosion can be easily seen because a number of millimetres of soil may be removed per year.

Gully erosion is the removal of soil in large channels called gullies. Gullies are often defined as being more than 30 cm deep and can incise up to several metres into the soil. They are typically steep sided and have branches. Gully formation occurs as a result of runoff or a combination of runoff and seepage. Gully erosion may take place in response to a single runoff event and may remove hundreds to thousands of millimetres of soil per day.

Headward erosion is a form of gully or rill enlargement in an upstream direction due to incision by concentrated runoff and the formation of a waterfall and splash pool. The action of water at the waterfall and splash pool will lead to undercutting and slumping of the gully head. This type of erosion is commonly associated with roadside table drains and culverts. It is an indicator of potential rapid escalation of damage and should be addressed promptly.

Streambank erosion involves the removal of soil from the banks of streams by the action of water or sediment flowing in the stream. It is usually most severe on outside bends during high flows as this is where energy is most concentrated.

Tunnel erosion (or tunnelling) occurs where sub-surface soil is less stable than the topsoil and is removed by erosion while the topsoil remains intact (until the tunnel collapses and a gully is formed). Field and laboratory tests are available to detect the presence of unstable subsoil.

Mass movement includes slumps, earth flows, soil creep and landslides. Mass movement is a form of erosion where water is often involved but the primary agent of movement is gravity. It is most common in high rainfall areas on steep slopes with gradients in excess of 27 per cent (15°), that have been cleared or have had significant amounts of vegetation removed.

Wind erosion is a process in which soil is detached and transported from the land surface by the action of wind.

2.3.2 Causes of soil erosion

Forest management activities that can increase the rate of soil erosion above natural levels are those which:

1. Reduce the natural stability of the soil surface; or
2. Increase the erosive power (usually through an increase in the volume or intensity of water flowing over the soil surface, or poor design or maintenance of surface water management structures).

Soil stability can be reduced by:

- The removal of vegetation;
- Change of surface roughness and cover due to scrub rolling, firebreak cultivation or machine traffic;
- Modification of the natural path of surface water movement, particularly where surface water is concentrated by structures such as roads or tracks;
- Ripping, mounding and cultivation;
- Modification of the natural soil profile by exposing the subsoil through the removal of organic matter, or reducing the infiltration rate through compaction;
- Structures in riparian zones such as dams, boardwalks and creek crossings; and
- The effects of salinity, acidity, waterlogging, dispersive or non-wetting soil characteristics or agents.

Increased erosive power by runoff can be caused by:

- Vegetation modification such as thinning, clearing or the spread of disease;
- Concentrating runoff by creating barriers to the natural flow of water such as roads or tracks;

- Discharge of water from drainage structures such as culverts, table drains, mitre drains or spreaders;
- The effects of fire including non-wetting behaviour, reduced cover and reduced evapotranspiration;
- Reduced infiltration due to soil compaction, puddling or mixing; and
- Insufficient or ineffectively designed, installed or maintained surface water management structures.

Figure 9: **After a fire, the combination of increased overland flow of water together with reduced soil stability and ineffective road drainage structures can result in severe erosion events.**

In addition to erosion caused by management activities, natural soil and landscape factors which increase erosion include:

- Non-wetting characteristics (particularly sands in the south-west of WA);
- Steep slopes;
- Dispersive clays; and
- Saline, degraded or exposed soils.

2.3.3 Effects of soil erosion

Soil erosion can lead to physical, chemical and management effects including:

- Stream silting or turbidity leading to decreased biodiversity and reduced water quality;
- Eutrophication of waterways and water bodies leading to decreased biodiversity and reduced water quality;
- Reduced soil fertility due to the removal of fine clay and organic matter which subsequently lowers forest productivity;
- Transfer of chemical and microbial contaminants attached to soil particles into streams;
- Deterioration of the quality of drinking water;
- Damage to, and increased maintenance costs of, infrastructure such as water storage facilities, buildings and roads;
- Reduced access and trafficability; and

- Decreased visual or scenic value.

2.3.4 Assessment of risk

The assessment of erosion risk needs to be considered in relation to:

1. The natural resistance of the soil/landscape to erosion, and
2. The degree to which management activity is likely to increase the risk of erosion.

2.3.4.1 Natural stability of the soil or landscape

Landscape

The natural resistance of a landscape to erosion is related to factors such as slope, soil type, vegetation cover and climate which are generally easy to identify and categorise when planning control or prevention measures. Where the natural resistance of the landscape to erosion is low, restrictive or preventative measures may be required. For example, harvesting may be restricted or operate under special conditions where slopes are greater than 10° to 14° (17% to 24%). The frequency of installation of surface water management structures such as mitre drains and spreaders should be increased as the slope of the land increases or its stability decreases (Schedules 19 and 20). Slopes of greater than 20% are recognised as being at greatest risk to erosion following disturbance activity. Ninety-eight per cent of Western Australia's south-west forest is comprised of slopes that are less than 10° (17 %).

Soil type

The resistance of different soil types depends on factors such as texture, structure and chemistry. These can be summed up as the aggregate stability. A guide to interpreting soil stability using some general statements is given below (Modified from Charman, 1978).

a) Coarse-grained (sandy) soils tend to be poorly aggregated and therefore highly detachable. They can suffer high rates of erosion when saturated under heavy rainfall (especially water repellent sands). However, they have high rates of infiltration and can absorb amounts of rainfall that would erode finer textured soils. Because of their relative large size, sand grains are less susceptible to movement by splash or runoff action compared with finer textured soils.
b) In general, the more clayey soils have better aggregated profiles and are more resistant to erosion.
c) As clay contents in soil increase, the erosion characteristics of soils is determined more by the type of clay present than anything else.
d) Dispersible soils are generally clayey, and their normally large aggregates are very stable when dry, but become highly unstable when wet.
e) Soils with high silt and fine sand contents tend to lack coherence and be very unstable when wet and therefore highly erodible.
f) The most erosion-resistant soils are often well-structured non-dispersible clay loams. These have enough clay to ensure aggregation, and well graded texture which ensures reasonable infiltration rates.

2.3.4.2 The influence of management activity on erosion risk

Forest management activities that increase the risk of erosion are those which reduce vegetation cover, increase the volume of water flowing over the surface, or change the physical or chemical composition of soils. Some things to watch out for include:

- Roads or firebreaks built on steep slopes, especially if they are long enough to generate significant runoff;
- Areas receiving concentrated run-on such as water diverted from roads, earthworks or below rock outcrops;
- Heavily trafficked areas such as extraction tracks or landings; and
- Areas of forest that have recently been burnt.

Overland flow

Overland flow generation (often called runoff) is a primary agent for soil erosion. Estimating the potential flow generation from a particular area or the likely change in flow following a change in surface condition, is an excellent method of assessing the risk of erosion. Significant losses of soil are associated with infrequent but extreme events. Effective assessment and management of erosion risk should focus on these events.

Rainfall amount and intensity has a large influence on runoff generation. The frequency of a rainfall or flood event is expressed in terms of the Average Recurrence Interval (ARI) and the Annual Exceedence Probability (AEP). In forest applications, it may be appropriate to design erosion control structures for an ARI of between 5 and 50 years depending on the consequences of failure. Where safety or structures of high value are potentially at risk, an ARI of 100 or greater may be appropriate. See Section 4.4.1.3 for further details.

In order to determine whether earthworks are required to convey water safely, an estimate of peak flow (or peak discharge) is required. Peak flow is estimated based on ARI using catchment size and contributing area, rainfall data, surface condition and vegetative cover. It is important to consider the nature of the surface in question as this has an important influence on flow generation:

- Forested areas yield less overland flow than cleared areas;
- Dense vigorous forest yields less runoff than sparse forest;
- Cultivated soil generates less runoff than uncultivated soil,
- Vegetated and mulched areas yield less runoff than unvegetated and bare areas;
- Well structured soils yield less runoff than massive, compacted or hardsetting soils;
- Loose sandy soils generate less runoff than compacted, hard, clayey soils (e.g. landings); and
- Deep soils generate less runoff than shallow soils (e.g. with significant rock outcrop). See section 4.4.1.3 for further details.

2.3.5 Preventative measures

- Apply design principles for soil conservation earthworks;
- Design for highest flow (e.g. post tops-burn runoff);
- Minimise trafficked areas, compaction and profile damage;
- Promote understory retention during operations and regeneration following operations;
- Follow procedures to reduce the spread of dieback (DEC PC manual No. 1);
- Ensure that surface water management structures discharge onto undisturbed ground;
- Landings should be located in well drained areas. Water flowing to landings (or from landings) should be diverted;
- Plan the location and use of tracks in relation to soil type and weather conditions;
- Install surface water management structures according to risk as soon as possible after disturbance activities such as harvesting and fire; and

- Monitor erosion and ensure it is within the limits specified in Schedule 7.

2.3.6 Summary (soil erosion)

- Soil erosion is caused by activities which reduce the natural stability of the soil surface; or increase erosive power (e.g. volume or intensity of water flowing over the soil surface);
- Soil types prone to erosion are those which have high silt or fine sand fractions or are poorly structured or dispersive;
- Activities which increase the risk of erosion include removal of vegetation, cultivation, vehicle traffic and modification of the natural path of water movement;
- A planned approach to surface water management is an effective way to manage risk; and
- Allowable limits for erosion are specified in Schedule 7.

2.4 Nutrient depletion

The soils in the south-west of the State are some of the most inherently infertile in the world. So why is there so much productive forest growing on these soils? The productivity of the forests is achieved through the internal cycling of nutrients, mainly through the action of soil micro-organisms on organic matter. Because a high proportion of the nutrients are held within the plants themselves, changes imposed by management of the forest can have important implications on its nutrient balance.

The jarrah forest is adapted to very infertile soil, summer drought and recurrent fires. This ecosystem contains especially small amounts of nitrogen and extractable phosphorous. The primary adaptation of the forest to these conditions is a very slow growth rate (the lowest of any commercially managed hardwood at around 1 t/ha annually) together with an efficient and conservative biochemical and biogeochemical nutrient cycle.

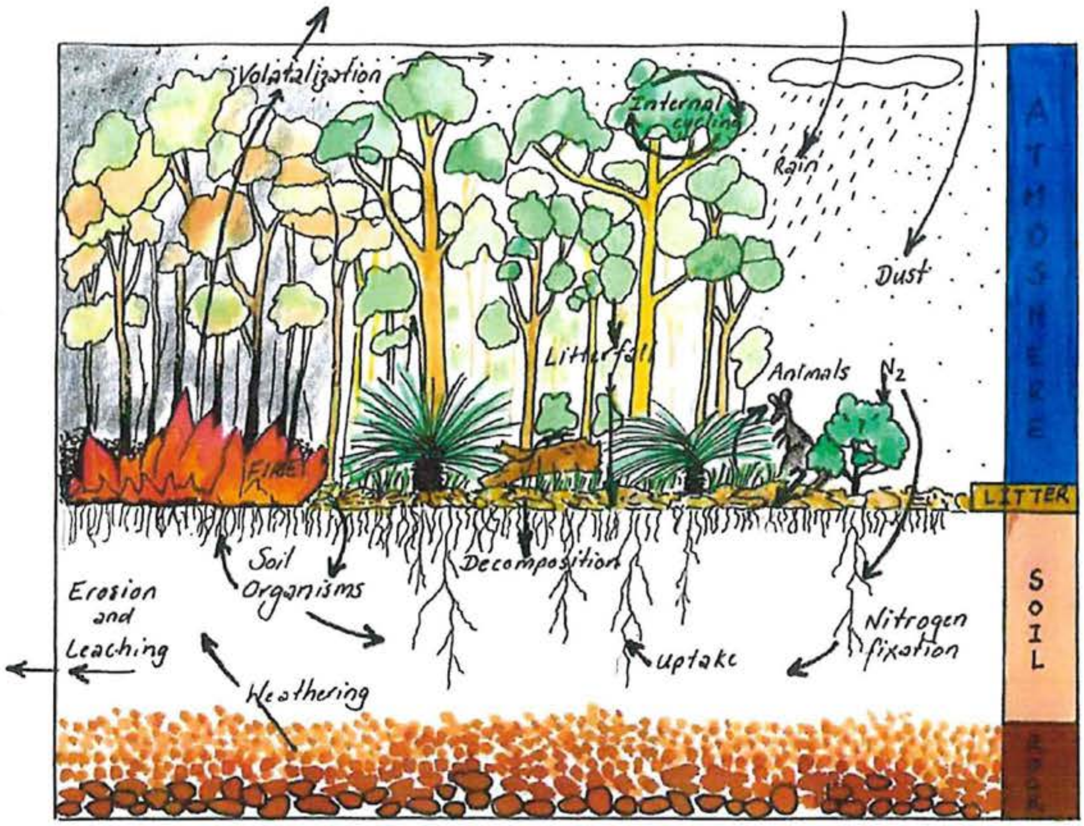


Figure 10: Schematic representation of nutrient cycling in the forest

Nutrient input to the forest system occurs very slowly from the weathering of rock and via the atmosphere through rainfall, aerosols and nitrogen fixed by bacteria. Nutrients are present in a variety of forms – plant and animal tissue, dead organic matter (humus), in soil water, and attached to soil particles. Nutrients move from the soil and humus to soil organisms to soil water to plants and back to the soil. As they cycle, nutrients change their availability status. Soluble (readily available) nutrients are the most vulnerable to loss from the system. Another form of loss is volatilization (release to the atmosphere) by fire. Uptake by plants or soil microbes competes against loss by erosion and leaching. Factors which contribute to biological activity help to prevent nutrient loss. Rapid uptake (from soluble states) relies on healthy levels of biological activity. Efficient storage (capture and holding) relies heavily on organic matter. Nutrients (particularly P and S) are made more available to plants after fire and are utilised very effectively by regenerating vegetation – most of which has adaptations such as adventitious surface root systems, to efficiently capture these mobilised nutrients. Fire is an important mechanism for nutrient cycling.

The jarrah forest is particularly vulnerable to the loss of Nitrogen. Jarrah forest has a very low nitrogen status, approximately a quarter the levels found in karri forest and an order of magnitude less than the *E. regnans* and *E. obliqua* forests of the south-east of Australia. The jarrah forest also has a scattered distribution and low abundance of nitrogen fixing flora. Approximately 20% of the total nitrogen in the jarrah ecosystem is contained in the trees, which is much greater than for other eucalypt ecosystems where between 1 and 8% is contained in the trees compared to the soil.

Total nitrogen in jarrah, and available phosphorous in both jarrah and karri forest are critical characteristics of these systems in determining capacity to meet demands for forest growth and the maintenance of a stable ecosystem following disturbance. (O'Connell and Grove, 1996).

2.4.1 Causes of nutrient depletion

Nutrient loss may occur in managed forests through the hydrological cycle (by water), fire, or the removal of products (e.g. logs and bark). In addition to permanent removal, forest nutrition can be affected by management processes that make nutrients unavailable for a long time (such as profile mixing) or that reduce biological activity (such as compaction or the spread of disease). Organic matter has a high importance in all of these processes.

The role of organic matter

As well as being one of the primary sources of nutrients in the forest, organic matter also acts as a "bank" which captures, holds and redistributes nutrients according to supply and demand. Organic matter helps to buffer fluctuations in supply such as when a forest is burnt or harvested and nutrients are mobilised. Where higher proportions of organic matter are retained, more nutrient is captured to supply the regeneration phase. Soils low in organic matter, particularly those with low clay contents, are prone to nutrient loss.

Erosion and leaching

The loss of soil and organic matter through erosion is one of the most preventable forms of nutrient depletion. What may appear visually to be a relatively small loss may equate to a large permanent removal of mineral and/or organic matter from the forest system. Surface water management influences the loss of nutrients in both particle form and in solution (dissolved in the water). Following disturbance activities such as fire or harvesting when forest water use is decreased, there is increased potential for nutrients in soluble form to be leached downwards into groundwater systems.

In undisturbed forest, it is estimated that the per hectare export of nutrients from the forest to streams is of the order of 15kg Mg, 9kg Ca, 7kg S and 3kg K (Sharma *et. al.*, 1980). This amount is approximately balanced by input through rainfall. The export of N and P to streams is particularly low due to microbial immobilisation.

Harvesting

Removal of forest product results in the loss of nutrients from the forest system. The consequences for future productivity vary across different sites and climatic regions. It depends on the relative amount of nutrient removed in the harvested product compared to what remains in the soil and ecosystem. For example, the removal of 200 t/ha of logs would have a greater impact on the nutritional balance of a sparse forest with a low basal area on banksia sands near Boyup Brook, than it would on a dense forest on karri loam near Pemberton.

Fire

The effects of fire on nutrition are significant. In addition to removing nutrients, fire alters their physical status (more prone to erosion) and chemical status (more soluble). Some nutrients such as N, S and possibly P may be lost into the atmosphere. After a fire, nutrients are more available to plants, but are also more prone to loss through erosion or leaching. In relation to nutrition, fire may be regenerative or destructive depending on the intensity and frequency of burning in relation to the forest ecology.

After fire, litter builds up on the forest floor to reach an equilibrium value of around 40 t/ha in karri and 10 to 20t/ha in jarrah. The build-up is rapid in early years reaching 23 – 30 t/ha in around 8 years for karri forest and 8t/ha in 5 – 7 years in jarrah forest (the average interfere period for prescribed burning). The accumulation of nutrients in litter is rapid following fire and for all elements reaches about 50% of equilibrium amounts within 3 to 5 years. The rate of transfer of nutrients from litter to soil may be grouped into 3 categories:

Table 6: The relative rates at which nutrients are transferred from litter to soil

Nutrient	Rate of transport from litter to soil
K, Na	Released rapidly (direct leaching by rain and throughfall)
Ca and Mg	Released at similar rate to dry weight loss.
N, P, S	Release rate less than dry weight loss. Litter contains a substantial proportion of total above ground stores

Source (O'Connell and Grove, 1996)

Because litter contains a substantial proportion of total above ground stores, and because N and possibly P may be volatilized during fire, these elements are the most likely to be affected by regular burning.

Reduction of biological activity

Plants and animals in the forest consume, immobilise, transfer, create and change the form and availability of nutrients. Because the nutrient cycle is so dependent on biological activity, it is easily affected by influences on species composition and health. Disease and destructive levels of compaction, puddling and mixing do not immediately remove nutrients from the system. However, they alter the status of nutrients, causing them to be less available and also to be produced or accumulated at slower rates.

2.4.2 Effects of nutrient depletion

Over the long term, activities which continually remove nutrients from a site have the potential to reduce site productivity. In extreme cases on sensitive sites, the species mix and biodiversity may also change. The effects of nutrient depletion may appear within decades on highly sensitive sites, but may not appear for many thousands of years, if at all on stable, inherently fertile sites.

In the short term, nutrient depletion has important consequences for water quality and aquatic biodiversity. Stream and catchment systems have the ability to concentrate very small amounts of nutrient removed per hectare of forest to levels which may influence aquatic ecosystems.

2.4.3 Assessment of risk

- Nutrient depletion is more likely to occur on soils that have a poor capacity to hold nutrients. These are usually sandy soils that are low in clay content, iron oxides and organic matter;
- Activities that change the nutrients to more available forms increase the risk of loss. These are often disturbance activities such as harvesting, thinning or burning;
- Sites that have low levels of biological activity are more prone to suffer from the effects of nutrient depletion;
- Sites where high amounts of product are removed are more likely to suffer from nutrient depletion. This could include sites that have been burned with high frequency and

intensity, or where large volumes of harvested product have been removed in short rotations. Extreme cases include mining or the extraction of gravel; and

- Sites that have been damaged, poorly drained or are prone to erosion have potential for high levels of nutrient loss. The potential risk increases with factors such as rainfall intensity and slope as well as the extent of compaction or profile mixing.

Fire Management

In the karri forest, it has been estimated (O'Connell and Grove, 1996) that low intensity fires potentially remove around 600 to 700 kg/ha of nitrogen which is equivalent to a replacement rate of around 5 to 10 kg/ha/year. This rate is approximately equivalent to measured input by legumes, non-legumes and non symbiotic N fixing organisms in the soil and litter. O'Connell and Grove suggested that more accurate data would be required to draw firm conclusions, but if the loss of Nitrogen in fuels (volatilization) could be restricted to about 50%, then the karri forest would be in equilibrium with an interfere period of 9 years. The effect of fire on both nitrogen and phosphorous was considered an important area for further research in both karri and jarrah forest. Legumes were identified as an important contributor to nutrient balance in relation to fire.

Harvesting

Each 100 t of jarrah product removed from the forest equates to a loss of around 84, 3, 75, and 52 kg/ha of N, P, K and Ca respectively (Hingston *et al.*, 1980). While these amounts are considered to be insignificant in the short to medium term, they require further investigation into the long term effects on the nutrient balance of the forest. The redistribution or retention of bark and unutilised wood significantly helps to reduce this nutrient loss.

2.4.4 Remedial and preventative treatments

Preserve intact sources of nutrient

- Manage erosion risk, particularly in susceptible areas;
- In high impact areas (gravel pits, roads and landings), stockpile topsoil for redistribution at rehabilitation phase;
- Manage disease risk at all times; and
- Where possible, manage fire to avoid repeated high intensity fire events.

Remove minimal amounts of nutrient

- Establish and maintain stream reserves to assist in capturing and harnessing nutrients that would otherwise be lost – particularly adjacent to streams (Schedule 17); and
- During harvest, retain as much bark, leaves and branchwood as possible on site, particularly on nutrient poor sites. Try not to concentrate bark at landings and log stockpiles.

Encourage restoration of biological functioning after disturbance

- Achieve well-stocked vigorous regeneration as quickly as possible;
- Repair disturbed areas as soon as possible (Schedules 23 and 24; and
- Reduce erosion and waterlogging (see Section 4 and Schedules 19 – 22).

Replace nutrients

- For some revegetation or remedial treatments it may be appropriate to apply fertiliser. Recommended fertiliser input for rehabilitation operations is shown is Schedule 24.

2.4.5 Summary (Nutrient depletion)

- A large amount of the nutrient in forest systems is contained in plants (live or decaying organic matter);
- The forest system is more prone to nutrient losses following disturbance and when high proportions of nutrients are in soluble forms;
- Periods of high risk include harvesting, burning, when erosion occurs or when biological activity is reduced such as by disease;
- The main consequence of nutrient loss is reduced productivity. Eutrophication of waterways is a potential offsite effect; and
- Nutrient depletion can be managed by preserving intact sources, removing minimal amounts, managing the intensity of prescribed fire and encouraging regeneration after disturbance.

2.5 Salinity

Although salinity is often viewed as an issue affecting cleared agricultural land, managed forests are also at risk of developing or being affected by soil salinity. In the context of this guideline, discussion refers to secondary salinity, which is where salinity has been increased above natural levels, generally as a result of human activities. In Australia, soils are usually considered saline if they contain more than 0.1 – 0.2% sodium chloride in the topsoil or 0.3% sodium chloride in the subsoil (Northcote and Skene, 1972).

2.5.1 Causes of soil salinity

In the south-west of Western Australia, secondary salinity is generally caused by rising groundwater levels initiated by the clearing of native vegetation. This region carries a moderate to high risk of generating salinity because large amounts of salt (tens to thousands of tonnes per hectare) are present in the sub-soil. These salts are dissolved in groundwater if it rises and can have a devastating effect when they reach the root zone of the forest or are able to enter streams via saline discharge.

Rising groundwater is usually caused by a change in the water balance following clearing or heavy thinning of native perennial vegetation. Under these conditions, rainfall that was previously used by the forest and returned to the atmosphere (by evapotranspiration) is able to infiltrate into the soil past the root zone and becomes groundwater recharge. The amount of groundwater rise potentially induced by forest management depends on how much of the forest canopy is removed and what proportion of the catchment is cleared.

Although much of the forest area has the potential to become saline should vegetation clearing occur, no evidence of soil salinisation has been detected in association with timber harvesting operations. Small temporary rises in stream salinity have been detected in the intermediate and low rainfall parts of the forest.

Extensive research has been conducted in the south-west of Western Australia into the impacts of clearing, timber harvesting and regeneration on hydrology. A summary of the current knowledge is given below:

- *Increases in groundwater levels of 3.5 – 4.5 m in high (greater than 1100 mm mean annual rainfall) and intermediate rainfall zones (900 – 1100 mm mean annual rainfall), and 1 m in the low rainfall zone (less than 900 mm mean annual rainfall;*

- *Increases in stream salinity have been greatest from catchments without stream buffers or phased logging;*

- *Return to pre-logging conditions is expected to take 10 to 15 years, depending on regeneration; and*

- *The potential for increases in stream salinity resulting from logging is greatest in the intermediate rainfall zone (IRZ) due to the possible shallow depth to groundwater and the high salt storage.*

Stream salinity continues to increase in most streams emanating from areas that are at least partially cleared for agriculture. In streams that emanate from catchments where clearing for agriculture is not a factor influencing the trend in stream salinity, the salinity for these streams is generally steady, or with very small fluctuations.

2.5.2 Effects of soil salinity

The effects of soil salinity cover a range from slight effects such as periodic or seasonal decline in sensitive species, through to complete decline of the local forest and its ecology. Early signs of salinity include slow tree growth and the yellowing of leaves with scorching around the leaf margins. As salinity increases, trees followed by understory will start to lose leaves and die. Sensitive species such as karri will be affected sooner or more severely than moderately sensitive species such as wandoo. The development of salinity is often associated with increased waterlogging which may be noticed by reduced trafficability in particular areas. The combination of waterlogging and salinity is particularly harmful to plants.

In addition to decline in forest health and productivity, salinity usually causes an accelerated structural decline in soils. When this is combined with waterlogging and reduced ground cover it causes higher rates of soil erosion. Infrastructure such as roads and dwellings can become less stable or degraded resulting in increased costs of maintenance and repair. When saline discharge enters streams, it degrades aquatic ecosystems and the quality of water resources including raw water quality used for drinking water (Section 3).

2.5.3 Assessment of risk

The risk of forest management contributing to the development of salinity is related to:

- The rainfall zone (higher rainfall zone has lower risk);
- The intermediate rainfall zone (900-1100 mm) has the highest risk as the groundwater level is very close to stream invert;
- The proportion of a catchment that is harvested; and
- The level or intensity of cutting, in order of decreasing risk - clearfell > shelterwood (if minimum basal areas retained) > heavy selection cutting > light selection cutting.

The introduction of jarrah dieback disease can also decrease evapotranspiration and consequently may contribute to groundwater rise.

2.5.4 Preventative treatments

Once salinity has developed, there are very few examples of successful remedial treatment. Management is most effective when focused on prevention.

Silvicultural prescription

DEC policy for salinity management is based around mandatory requirements for the reservation of stream zones, together with silvicultural prescription to be applied during harvest planning and operations. The prescription varies according to rainfall zones. The higher risk area is the intermediate rainfall zone where more precautionary management is prescribed, including phased logging and basal area targets. Within the intermediate rainfall zone, a number of high risk catchments have been identified on the basis of soil salt concentration and depth to groundwater. Additional controls such as increased stream reserves are placed on these catchments. Key requirements for the management of salt risk are shown in Schedule 18. River and stream reserve requirements are shown in Schedule 17.

Promote vigorous healthy regrowth

The rate and extent to which disturbances in hydrology can be reversed depends on how quickly and how well the forest canopy and understory recovers after disturbance such as harvesting or burning. Management to promote vigorous, healthy regrowth as soon as possible contributes significantly to the restoration of water balance because young regrowth can consume as much or even more water than a mature forest. Attention should be paid to:

- Repairing areas of damaged soil;
- Ripping, scarifying, seeding and planting landings and rehabilitated tracks as soon as possible;
- Monitoring to ensure regeneration is on target; and
- Following hygiene protocols to reduce the introduction of disease.

2.5.5 Summary (Soil salinity)

- Harvesting and other forest activities cause a disturbance in the water (and potentially salt) regime of a catchment through decreased transpiration leading to groundwater recharge and subsequent rise in groundwater;
- The introduction of disease may also affect water balance;
- Once it occurs, the onset of salinity is very difficult to reverse; and
- Forest management techniques to reduce the risk of salinity include setting and applying silvicultural prescriptions based on the extent and intensity of cutting, retention of unharvested stream reserves, disease management and promotion of healthy, vigorous regrowth after disturbance activities.

3 Conservation of water values

Rivers, streams, lakes and wetlands provide important services to the community. They supply water for drinking, irrigation, industrial and mining use and are a very important part of the landscape for biodiversity. Waterways provide important drainage services to the landscape while supporting productive fisheries and providing recreational opportunities. They also create and support the environment in which we live, including visual, social, cultural and spiritual values.

A waterway in the south-west typically drains thousands to tens of thousands of square kilometres of land and is influenced by the way in which all of the land in its catchment is managed. Waterways are sensitive to changes in land management practices. Hazardous or harmful effects accumulate within a river system and the plants and animals that inhabit it. The FMP indicates that it is necessary to recognise water values and manage forested land in a way which has the minimum negative impact on those values. Some of the water values potentially influenced by forest management are described in the following chapter along with methods for managing them.

The values covered are:

- Biodiversity;
- Sediments;
- Erosion;
- Salinity;
- Nutrients and other contaminants; and
- Water quantity.

3.1 Aquatic biodiversity

Biodiversity describes the number or variety of species in an environment or ecosystem. The diversity of aquatic life is an important value that is linked to the ability of a waterway to be stable and provide ecosystem services. The range of aquatic life in waterways of the south-west and their surrounds is unique and ranges from tiny aquatic plankton, small invertebrates and fish, and larger creatures such as frogs, turtles, snakes, waterbirds and water rats.

3.1.1 Causes of degradation

The main cause of biodiversity decline within aquatic systems is the loss of habitat (the set of conditions required for a population to effectively survive). Habitat varies in relation to the life cycle strategies of each of the different creatures involved and can be very specific. Important elements of habitat include food source, light, exposure, flow regime and depth.

Due to a Mediterranean climate, the life cycle of many south-west Australian aquatic plants and animals have evolved to deal with considerable change such as variation in seasonal flow, mild changes in water temperature, oxygen availability, salt and nutrient levels or even to deal with different sources of food. Native populations have the ability to shrink and expand or move in order to persist, provided that there are zones of favourable habitat to move to and a means of getting there.

The condition of most south-west rivers is in a state of flux greater than the natural levels that flora and fauna are used to dealing with. Major components of change at present include a declining rainfall trend, increased domestic and commercial extraction, increasing salinity, recreational use, rising groundwater, high levels of nutrients and fragmentation due to clearing. For many plants and animals, forested areas are the best remaining source of intact habitat and therefore require considerable care in their management.

Some of the factors contributing to decline in aquatic biodiversity include:

- Habitat loss and fragmentation leading to loss or inbreeding of isolated populations;
- The introduction and spread of weeds;
- Eutrophication (artificially high nutrient levels);
- Pollution (aquatic systems are very effective at magnifying pollutants);
- Salinisation (serious effects on population presence and dynamics);
- Structures such as weirs, culverts, diversions, and dams creating barriers to fauna movement;
- Dams capturing sediment and organic matter, starving downstream areas of resources, changing flow and temperatures and creating new habitat often suited to introduced species;
- Altered flow regimes;
- Altered light regimes;
- Waterlogging;
- Introduction of exotic species such as redfin perch, carp and mosquitofish and disease such as phytophthora; and
- Feral animals (terrestrial) or livestock causing streamzone compaction, erosion, introduction of weeds and competition with, or predation on, native animals.

The role of fringing vegetation

Fringing vegetation is the growth that occurs around rivers lakes and wetlands. In addition to its biodiversity value, the physical and chemical stability of aquatic systems is highly dependent on the presence of intact and continuous fringing vegetation. Some of the important functions of fringing vegetation are listed below:

Shade – Provides an essential refuge for aquatic animals from the hot summer sun. Shade helps to protect animals such as small fish and crustaceans from predators. It also influences water temperature and reduces the growth of aquatic plants and algae.

Habitat - Branches and litter provide shelter and micro-habitats for a large range of aquatic animals. Tannins released from leaves cut down light penetration and hide animals.

Food – Leaves, twigs and woody debris are the main source of energy, carbon and nutrients for the aquatic ecosystem which is geared to breakdown the hard leaves of native species.

Coarse woody debris – greatly increases the extent and diversity of habitat. It also influences flow and increases variation in the range, depth and velocity of water.

Corridors – Intact fringing vegetation provides corridors along which many animals can move e.g. frogs, turtles and crayfish.

Protection – Vegetation helps maintain stream bank integrity by protecting against erosion and subsidence. During high flow it increases roughness which dissipates the energy of running water. Roots and rhizomes bind the soil of the embankment together. Large roots of trees anchor the embankment in place and smaller roots or rhizomes hold the surface soil in place. The cohesion of a vegetated bank is around 10 times greater than that of bare soil.

Filters – Vegetation has a protective role in filtering sediment and nutrient that may otherwise enter waterways. Dissolved nutrients (especially nitrate) are readily taken up by plants. Fringing vegetation also slows the rate of flow in the stream channel and facilitates sedimentation, thus decreasing erosive potential.

Landscape value – Fringing vegetation enhances visual amenity through form, colour and pattern.

3.1.2 Effects of degradation

The loss of species or population richness is permanent. By allowing biodiversity to become eroded we pass a poorer environment on to future generations. The loss of biodiversity also leads to the instability of natural systems and processes. The plants and animals that comprise aquatic ecosystems have an important role in regulating nutrient levels, water quality, flood mitigation and the maintenance of stream and river bank stability.

3.1.3 Assessment of risk

Regardless of their location, stream zones, wetlands and drainage lines are always sensitive areas at high risk of damage by inappropriate management. Most areas in the south-west that have high biodiversity values have been identified and mapped. Access to land within these areas is restricted or governed by conditions. All stream zones in State forest and timber reserve are protected by stream reserves.

A stream zone requires room to move – for plant and animal communities to expand or contract and recolonize according to seasonal conditions such as the range between dry summers and winter floods. It also needs to be as continuous as possible to allow the movement of fauna between different seasonal habitats. Larger streams require a greater stream reserve zone than smaller streams. The required stream reserve widths for various stream categories are shown in Schedule 17.

Land-based forest management activities which represent a high risk to biodiversity include the use of herbicides, pesticides and associated adjuvants, wetting or sticking agents, activities which generate erosion or alter catchment water balance, and activities which degrade or fragment the habitat used by aquatic species that spend part of their life-cycle on land. Best practice management of spray application is an important way to manage risk to waterways.

3.1.4 Remedial or preventative treatments

- Design and maintain road drainage infrastructure such as bridges and culverts to facilitate the movement of aquatic fauna and avoid significantly modifying flow pattern;
- Reduce disturbance by minimising the amount of stream or creek crossings used (see DEC SFM Advisory Note 3);
- Incorporate stream zones into vehicle movement strategies and general management plans;
- Check equipment for presence of weeds and seeds prior to operation, particularly when coming from areas where weeds are present; and
- Strictly adhere to quarantine protocols and procedures for dieback (*Phytophthora cinnamomi*) management.

3.1.5 Summary (Aquatic biodiversity)

- The main cause of biodiversity decline within aquatic systems is the loss of habitat;
- Contributing factors include fragmentation, eutrophication, salinisation and altered flow regimes;
- The biology, physical and chemical stability of aquatic systems is highly dependent on the presence of intact and continuous fringing vegetation;
- Forest management activities with potential to influence aquatic biodiversity include the use of herbicides, pesticides and associated adjuvants, wetting or sticking agents, structures in stream zones and activities which generate erosion or alter catchment water balance; and
- All streams in State forest and timber reserve are protected by stream reserves.

3.2 Stream sediments

Sediment is sometimes referred to as "the currency of rivers" (Pen, 1999). Natural erosion constantly delivers small amounts of sediment to streams which always contain some amount of sediment. The amount and movement of sediment in a particular stream varies greatly over time and space. Streams have deep and shallow zones known as pools and riffles. When the stream channel is in flood, pools are scoured of their sediment which was built up in times of low and moderate flow. In low and moderate flow, water is only moving in riffles and these are scoured of fine sediment which settles out in the next pool downstream. In flood, fine sediment collected in the pools during times of low flow is carried far downstream and swept up onto the point bars.

A river or stream is in equilibrium when erosion and deposition (sedimentation) are in balance. Stream systems can be thrown out of equilibrium when the supply of sediment from their catchment increases. Conversely, a channel may be starved of sediment (for example when a tributary is diverted or cut off), leading to channel incision and subsequent widening through bank collapse. Increased sediment concentration (mainly fine particles causing turbidity) is one of the most common undesirable side effects that forest management activity can have on aquatic systems. The type, depth, location and periodicity of sediment substrate has a significant effect on the spatial and temporal distribution of aquatic biota that inhabit these substrates.

3.2.1 Causes of sediment related degradation

Harvesting or thinning reduces forest water use in the catchment

Under natural conditions in forested catchments, very small volumes of water move slowly over the land surface, carrying very little sediment and only during heavy rainfall events. A large proportion of stream base-flow actually enters via groundwater in the lower reaches of the catchment. Following clearing, thinning or burning, if surface water is not managed there is increased potential for larger volumes of water to move faster and carry more sediment.

Roads and vehicle movement

Unsealed roads and highly trafficked areas have the capacity to generate turbid (cloudy) water. As roads are compacted surfaces, most of the rain that falls on them is converted to runoff. The potential for roads to generate turbid runoff increases with the number of vehicle passes and their loads and is related to moisture and the type of clay present. The most common cause of turbid runoff entering streams is where features such as roads or extraction tracks concentrate runoff which is not subsequently dissipated in small regular volumes over stable land surfaces.

Clearing or disturbance of fringing vegetation

Fringing vegetation has an important role in reducing sediment load to rivers. In these areas, surface flow is slowed and filtered, allowing suspended sediment loads to settle out before entering waterways. This filtering effect can be disrupted where fringing vegetation is cleared or disturbed. The risk is increased where vehicle tracks concentrate runoff and directly cross the fringing vegetation into streams.

Management of surface water

Techniques available for forest managers to control surface water are discussed in Section 4. Surface water management greatly reduces the risk of both erosion and the generation of sediments and turbid overland flow. Surface water management is particularly important after disturbance activities which potentially increase runoff such as harvesting and wildfires.

3.2.2 Effects of sediment-related degradation

Depending on the nature of soils and the extent of erosion contributing to sedimentation, there will be a mix of coarse and fine particles entering the waterway. Finer particles are usually carried downstream and are associated with problems of turbidity. Coarser particles are heavier and generally rolled along the stream bed and can cause problems such as the filling of natural pools along the river or stream, smothering habitat along the way.

Change in or loss of habitat

Even small amounts of sediment can change the nature of the stream floor which make it more or less suited to particular macroinvertebrates. For example, caddisflies, stoneflies and mayflies prefer coarse grain size on the stream bed; worms and midge larvae prefer fine grained sediments. Increased sediment can affect suitability of the stream bed for egg laying by fish or other aquatic organisms. Large changes such as the filling of river pools with sediment can be devastating for the local ecology. River pools are the only summer refuge available for many aquatic species and therefore essential to the maintenance of some populations.

Effects on streamflow and channel structure

Sediment accumulation can deflect flow into the streambank causing increased erosion. It can also retard streamflow and cause increased flooding risk further upstream. Large slugs of sediment may cause lateral erosion of the channel, which becomes broader and shallower.

Effects on light penetration

Fine sediment in suspension is able to block out light and reduce photosynthesis of aquatic plants and algae.

Abrasiveness

Suspended sediment increases the erosive power of a stream on the floor and bank, and can damage the fine gills and mouth parts of invertebrates and the gills of fish.

Change the rate of organic breakdown

The rate at which material is broken down is slowed by sediment smothering organic material on the stream floor and reducing oxygen to detrital processors.

Damage to infrastructure and resources

Sediment has a range of damaging effects on river infrastructure. For example, it can fill culverts, erode and undercut structures and reduce dam storage levels. Sediment also reduces the quality of raw water for drinking and potentially increases the cost of treatment.

Temperature and oxygen

Suspended particles absorb heat, so water temperature rises faster in turbid water than it does in clear water. Warm water holds less dissolved oxygen than cold water, so the concentration of dissolved oxygen decreases in turbid water.

3.2.3 Assessment of the risk of sediment related degradation

- The slope and erosion potential of forest land;
- The type of clay present (dispersive *vs*. stable);
- The nature and materials of road construction and associated water management;
- Surface water management in harvested areas;
- Fringing vegetation integrity and protection;
- Vehicle movement intensity and load;
- Moisture status;
- High input areas – haul roads, snig tracks and landings;
- High risk activities such as downhill snigging on steep land; and
- Maintenance of water management structures such as culverts.

3.2.4 Preventative and Remedial treatments

- Regularly inspect and maintain culverts;
- Carefully plan surface water management – use recommended structures in relation to volumes and risk (Schedules 21 - 24, Section 4);
- Adhere to stream reserve zone requirements (Schedule 17);
- Avoid all unauthorised activity in stream zones (Guidelines for the Management of Informal Reserves and Fauna Habitat Zones, in preparation);
- Wherever possible, minimise the use of roads adjacent to streams and stream reserves, particularly during moist soil conditions;
- Gravel pits – review or monitor surface water management while in operation and rehabilitate as soon as possible after use (Schedules 23 and 24); and
- Apply surface water management in a timely manner after disturbance such as harvesting or fire.

3.2.5 Summary (Stream sediments)

- Stream systems can be thrown out of equilibrium when the supply of sediment from their catchment increases;
- Sediment can have a range of damaging effects on river ecology, infrastructure and water quality;
- Risk is increased on steep slopes, after harvesting or wildfire and for high impact areas such as roads and landings; and
- Risk can be managed by carefully planing, installing and maintaining surface water management structures and adhering to stream reserve requirements.

3.3 Stream erosion

Erosion is a natural part of the aquatic environment. Stream channels are dynamic systems which constantly change. Under natural conditions, erosion and deposition are mostly limited to meander bends and point bars. Changes in flow magnitude and sediment load above those experienced under natural conditions can lead to significant changes in stream channel form.

3.3.1 Causes of degradation

Clearing of fringing vegetation

Where a stream is lined with vegetation the energy of water entering via surface flow is dissipated, reducing erosion and promoting the deposition of sediments. The result is that the water leaving the catchment is filtered. Where fringing vegetation is not maintained and disturbance activity in the forest creates surface flow, muddy water carrying sediment may be able to enter the stream system. The increased flow and sediment promotes erosion of streamline and scouring of the stream bed.

Clearing and/or hardening of the catchment area

This leads to increased runoff which means that a rainfall event can produce a larger pulse of water into streams. The larger pulse is more likely to carry sediment and cause erosion. The size and probability of flooding events is increased by clearing or hardening of the catchment area and may result in bank erosion and damage to structures and infrastructure adjacent to the stream. In managed forests, the main contributing areas include landings, gravel pits, roads and extraction tracks.

Stream bed incision and bank collapse

Increased stream velocity, sediment load, or channel depth can lead to banks becoming steeper and prone to erosion or mass collapse (particularly on meander bends).

Roads or firebreaks adjacent to streams

Adjacent roads or firebreaks can increase the chance of scouring occurring in these areas during high flow or flood events. The exposed areas are not protected by vegetation and at least 10 times less stable than vegetated soil containing root mass.

Feral animals

Pigs and rabbits can be particularly devastating to local areas where they expose and churn over bare soil making it more prone to erosion and weed infestation.

Where erosion is severe, a spiralling effect occurs. For example, where embankments become exposed and subject to increased erosion, stream sediments from the eroding embankment increase erosive power and alter flow pathways causing further erosion of embankments. The unstable surface is prone to rilling, sheet, gully erosion or collapse and infestation by weeds.

3.3.2 Effects of stream erosion

Sedimentation

As a result of erosion, sedimentation occurs downstream with consequences such as habitat loss, change in stream form and increase in the erosive potential of flows.

Gullying and headcuts

Gullying and headcuts, which move upstream and escalate, are a consequence of increased flow velocity and volume.

Lateral erosion

Where erosion spreads outwards from the streamline as water flowing directly from the land it causes sheet, rill and gully erosion as it enters the stream channel. Fringing vegetation may be lost as a result of lateral erosion, causing the process to escalate.

Log jams

Where undercutting of stream banks occurs, whole trees may fall into the channel. In times of flood, these increase damaging effects when they pile up against bridge pylons, culverts or submerged objects. Restriction in flow may cause flooding upstream. A particularly damaging effect occurs when floodwaters find a new pathway around such objects and create a new channel (avlusion).

Weed infestation

Where erosion leads to areas of bare soil, these can be opportunistically colonised by weed seeds which may be blown, washed or carried in.

3.3.3 Assessment of risk

Bank cover and moisture status

The banks of a river or stream are more likely to subside or erode when they are moist. Intact stream reserves of fringing vegetation help to avoid saturated conditions and also stabilise soil with root and rhizome systems.

Historic data

Historic data can be useful to identify the severity and regularity of erosion events in a particular area in relation to the stream form and catchment management.

Proximity

The closer structures or management activities are to the stream channel, the greater is their potential to cause damage.

Calculation

The best techniques for the safe delivery of water into streams and channels can be determined by the use of engineering spreadsheets and functions (Section 4).

Traffic

Riparian zones are more stable where traffic is excluded or minimised (Schedule 17).

Structures

Bridges, weirs, dams and other structures can increase the risk of erosion depending on how they are designed and placed in the stream zone.

3.3.4 Remedial treatments

Plan stream crossings

Where possible, do not cross streams with tracks. If a crossing is required, locate it on a straight section where stream power is low (e.g. below a stand of paperbarks) or where the river or stream bed is hard. Where the launching of boats or canoes is required, locate areas on stable, hard sections of bank or depositional areas such as the inside sections of meander bends.

Maintain intact stream reserves with fringing vegetation

The width of an appropriate stream reserve is related to the form and structure of the channel. It would usually incorporate the meander belt plus a bit more (Schedule 17).

Roads

Minimise the number and maximise the proximity of roads from stream areas.

Surface water management

Use planning to design and maintain appropriate surface water management structures, particularly for landings, extraction tracks, roads and culverts.

3.3.5 Summary (Stream erosion)

- Similar to sediments, stream erosion is a natural process in the aquatic environment;
- Stream erosion can be increased above natural levels by activities which disturb or reduce fringing vegetation or increase overland flow from the catchment area; and
- Intact fringing vegetation, minimal well planned and managed stream crossings, together with surface water management in the catchment, greatly reduce the potential for stream erosion.

3.4 Stream salinity

3.4.1 Causes of degradation

The primary cause of the salinisation of aquatic systems is groundwater rise caused by changes in catchment hydrology (mainly due to clearing) as discussed in Section 2.5.

3.4.2 Effects of degradation

Primary effects

The salinisation of waterways results in a shift in the composition of aquatic populations. Salt sensitive plants and animals are replaced by salt tolerant ones. This is usually associated with a decrease in overall diversity. Populations vary in their sensitivity to salt. As they are recently evolved from marine ancestors, most native fish species are able to tolerate brackish conditions. However, small or temporary changes in salinity can alter the composition of macroinvertebrate communities or affect sensitive insect species such as mayflies. Where salinity affects a particular reach of a stream the result may be a reduction in the gene pool. Where salinisation of waterways is extensive enough to affect the entire reach of a species, the result may be loss of the species.

Trigger values indicate the concentrations (or loads) of the key performance indicators measured for an ecosystem, below which there exists a low risk that adverse biological (ecological) effects will occur. They indicate a risk of impact if exceeded and should 'trigger' some action, either further ecosystem specific investigations or implementation of management/remedial actions. Trigger values for salinity in south-west Australia (ANZECC and ARMCANZ, (2000) *National Water Quality Management Strategy Paper No. 4,* Australian and New Zealand Guidelines for Fresh and Marine Water Quality Volume 1) are shown in Table 7 below.

Table 7: Range of default trigger values for conductivity (EC, salinity) indicative of slightly disturbed ecosystems in south-west Australia

Ecosystem Type	Salinity (uS/cm)	Explanatory notes
Upland and lowland rivers	120 - 300	Conductivity in upland streams will vary depending upon catchment geology. Values at the lower end of the range are typically found in upland rivers, with higher values found in lowland rivers. Lower conductivity values are often observed following seasonal rainfall.
Lakes, reservoirs and wetlands	300 - 1500	Values at the lower end of the range are observed during seasonal rainfall events. Values even higher than 1500uS/cm are often found in saltwater lakes and marshes. Wetlands typically have conductivity values in the range 500 – 1500 uS/cm over winter. Higher values (>3000 uS/cm) are often measured in wetlands in summer due to evaporative water loss.

Values reflect high site-specific and regional variability. Explanatory notes provide detail on specific variability issues for ecosystem types.

Secondary effects

Salt input may interact with other environmental factors to create harsh conditions such as stagnation, stratification, waterlogging and deoxygenation. Where fringing vegetation is lost, bank instability and an escalating process of erosion, sediment input and weed infestation commences. The salinisation of waterways can have water quality impacts that affect drinking water users. The National Health and Medical Research Council (NHMRC) (2004) Australian Drinking Water Guidelines define a health-based guideline for chloride and an aesthetic (taste) guideline for Sodium. These are shown in Table 8 below.

Table 8: Health based guideline for Sodium and Chloride drinking water

Element	NHMRC health-based guideline
Chloride	Not exceeding 250 mg/L
Sodium	No health based guideline. For aesthetic consideration (taste) the concentration should not exceed 180 mg/L. Medical practitioners treating people with severe hypertension or congestive heart failure should be aware if the sodium concentration in the patient's drinking water exceeds 20 mg/L

3.4.3 Assessment of risk

Studies into the effects of forest management on hydrogeology indicate that the greatest risk of inducing salinity is when leaf area is reduced over high percentages of a catchment, particularly where stream reserves are not present. The impacts are also greater where there is high soil salt storage, high groundwater and low to intermediate rainfall (800 to 1100 mm per year). Research has indicated that negligible salinity increases (transient, but small) occur in higher rainfall areas where the level of timber harvesting is managed.

3.4.4 Remedial treatments

The current silvicultural prescriptions indicate the appropriate management response to the risk of inducing salinity (particularly in the medium rainfall zone). The management requirements include stream reserves, phased logging and basal area limitations (Schedules 17 and 18).

3.4.5 Summary (Stream salinity)

- The primary cause of the salinisation of aquatic systems is groundwater rise caused by changes in catchment hydrology (mainly due to clearing);
- The salinisation of waterways results in reduced aquatic biodiversity and reduced water quality for human consumption;
- The risk is greatest where there is high soil salt storage, high groundwater and intermediate rainfall (900 to 1100 mm per year); and
- The main preventative measures relating to timber harvesting include mandatory requirements for stream reserves, phased logging and basal area limitations.

3.5 Stream nutrients and other contaminants

Under natural conditions, the river systems of south-western Australia function on very low nutrient levels and no significant input of contaminants. Most nutrients are naturally derived from the fringing vegetation together with a small contribution from overland flow. Nutrients are cycled within and between the plants and animals of the river system gradually passing downstream and into estuaries or the ocean. Nutrients and contaminants may be stored or tied up for considerable periods of time in sediments at the bottom of lakes or pools. Because the ecology of streams and rivers operates on very low nutrient levels, it is sensitive to changes that may be induced by forest management. Contaminants posing risks to water values include petroleum, hydrocarbons, toxic metals, surfactants, disinfectants, litter and oxygen scavengers and inputs which change the pH of the water.

3.5.1 Causes of water quality degradation

Broad scale forest management has a lower potential to impact on stream nutrient levels when compared to agriculture, horticulture, mining and industrial uses. However, without management certain activities have the potential to alter levels enough to affect the ecology of stream environments. The input of additional nutrients and contaminants into river systems usually occurs through surface flow, although groundwater may also be a source in some cases. Nutrients and other contaminants may be in solution or attached to particles of clay or organic matter. As water is required as a major vector for transport, the control of water movement over land is an important factor to consider.

3.5.2 Effects of water quality degradation

The effects of water quality degradation include:

- Algal blooms;
- Algal scum mats on the water surface;
- Oxygen depletion of the water;
- Destruction of seagrass meadows;
- Killing of fish and crustaceans;
- Death of waterbirds;
- Increased populations of bacteria;

- High concentrations of algal and bacterial toxins;
- Health risks to humans;
- Unpleasant odours;
- Loss of water supplies;
- Closure of recreation areas; and
- Loss of income.

Increased input of organic material into stream zones can result in oxygen depletion of river pools by decaying organic matter in the bottom sediments. Oxygen depletion alone is capable of killing most of the rivers animal and microbial life, especially during late summer.

3.5.3 Assessment of the risk of water quality degradation

Point sources

A point source is where nutrients or contaminants are concentrated in a defined area. Examples of point sources include rubbish tips and waste dumps, septic tanks, log stockpiles, buildings, storage areas and spillage of fuels, oils or other chemicals. The risk of contamination from point sources increases with proximity to waterways, as well as the volume of product and overland flow involved. The type of product (how mobile or how concentrated it is) is also a factor.

Where it is unavoidable to have point sources of potential contamination in proximity to waterways, the risk of causing damage can be assessed and managed by siting appropriately according to landscape and soil type, by building structures to defined standards and operating to defined procedures.

Diffuse sources

Diffuse sources of nutrient or contaminant are those that occur over a broad area. They are generally lower in concentration compared to point sources. Examples of diffuse sources include ash following a burning event, water draining from exposed acid sulphate soils, fertiliser that is broadcast on a regeneration area, or a sheet erosion event that occurs on a slope following a summer thunderstorm. The risk of input from diffuse sources often depends on how well the vector of transport (usually water) is managed. Examples of high risk situations include:

- Heavy rainfall is predicted for a steep, heavily cut forest coupe that has been recently burnt;
- Heavy rates of fertiliser are applied during winter to a rehabilitation area adjacent to a stream reserve;
- Roads running down a long slope where surface water control structures are not in place; and
- A landing is sited on clay soils adjacent to a stream reserve.

Acid Sulphate Soils

Some areas (particularly south and west coastal) are known to contain acid sulphate soils. Where these soils occur, there is a risk that management activities may cause on-site or off-site effects. The activities that are more likely to have environmental impacts include those which either cause a sustained lowering of the water table, or where acid sulphate soil is excavated and exposed to oxidation (such as road cuttings, de-watering, trenching or extraction of basic raw material). Water contamination risks from acid sulphate soil leachate include significant pH reduction, increased salinity and metals. Where acid sulphate soils occur, the best strategy is to avoid disturbance. Where this is not possible, specific management practices are required to reduce the risks. In some cases an acid sulphate soil management plan may be required.

Environmental parameters

For the assessment of aquatic ecosystem integrity and risk, guidelines have been developed focusing on the structural components of aquatic communities (biodiversity) and key ecological processes (ANZECC and ARMCANZ, (2000) *National Water Quality Management Strategy Paper No. 4,* Australian and New Zealand Guidelines for Fresh and Marine Water Quality Volume 1). If trigger values (Table 9) are exceeded, **decision trees can be used to determine the appropriate management response in a risk-based framework.**

Table 9: Default trigger values for physical and chemical stressors for south-west Australia for slightly disturbed ecosystems

Trigger values are used to assess risk of adverse effects due to nutrients, biodegradable organic matter and pH in various ecosystem types. Chl *a* = chlorophyll *a*, TP = total phosphorous, FRP = filterable reactive phosphate, TN = total nitrogen, NO_x = oxides of nitrogen, NH_4^+ = ammonium, DO = dissolved oxygen.

Ecosystem type		Chl *a* ($\mu g\ L^{-1}$)	TP ($\mu g\ P\ L^{-1}$)	FRP ($\mu g\ P\ L^{-1}$)	TN ($\mu g\ N\ L^{-1}$)	NO_x ($\mu g\ N\ L^{-1}$)	NH_4^+ ($\mu g\ N\ L^{-1}$)	DO (% saturation)[i] Lower limit	DO (% saturation)[i] Upper limit	pH Lower limit	pH Upper limit
Upland river[f]		na[a]	20	10	450	200	60	90	na	6.5	8.0
Lowland river[f]		3–5	65	40	1200	150	80	80	120	6.5	8.0
Freshwater lakes & reservoirs		3–5	10	5	350	10	10	90	no data	6.5	8.0
Wetlands[d]		30	60	30	1500	100	40	90	120	7.0[e]	8.5[e]
Estuaries		3	30	5	750	45	40	90	110	7.5	8.5
Marine[g,h]	Inshore[c]	0.7	20[b]	5[b]	230	5	5	90	na	8.0	8.4
	Offshore	0.3[b]	20[b]	5	230	5	5	90	na	8.2	8.2

na = not applicable

a = monitoring of periphyton and not phytoplankton biomass is recommended in upland rivers — values for periphyton biomass (mg Chl *a* m^{-2}) to be developed;

b = summer (low rainfall) values, values higher in winter for Chl *a* (1.0 μgL^{-1}), TP (40 $\mu g\ P\ L^{-1}$), FRP (10 $\mu g\ P\ L^{-1}$);

c = inshore waters defined as coastal lagoons (excluding estuaries) and embayments and waters less than 20 metres depth;

d = elevated nutrient concentrations in highly coloured wetlands (gilven >52 $g_{440}m^{-1}$) do not appear to stimulate algal growth;

e = in highly coloured wetlands (gilven >52 $g_{440}m^{-1}$) pH typically ranges 4.5–6.5;

f = all values derived during base river flow conditions not storm events;

g = nutrient concentrations alone are poor indicators of marine trophic status;

h = these trigger values are generic and therefore do not necessarily apply in all circumstances e.g. for some unprotected coastlines, such as Albany and Geographe Bay, it may be more appropriate to use offshore values for inshore waters;

i = dissolved oxygen values were derived from daytime measurements. Dissolved oxygen concentrations may vary diurnally and with depth. Monitoring programs should assess this potential variability

Drinking water quality parameters

Raw water (untreated) from Public Drinking Water Supply Areas (PDWSAs) is often tested to ascertain whether contamination due to activities in or adjacent to the catchment is occurring and to determine whether treatment is required prior to use. These parameters are classified as health parameters and aesthetic parameters. A comprehensive set of parameters for drinking water quality can be found in NHMRC and NRMMC (2004) Australian Drinking Water Guidelines (National Water Quality Management Strategy). Health related chemicals include inorganics, heavy metals, industrial hydrocarbons and pesticides. In addition, water is tested for the presence of biological pathogens. There are many pathogens that may contaminate water supplies, a number of which are known to contaminate water supplies worldwide. These include bacteria (e.g. *Salmonella*, *Escherichia coli* and *Cholera*), parasites (e.g. *Cryptosporidium*, *Giardia*) and viruses. These pathogens generally arise from faecal contamination. The use of chemical toilets during periods of activity in or around PDWSAs may help to minimise contamination.

The potential risks to water quality associated with forestry activities can be managed by the adoption of best management practices. Best management practices may include appropriate road construction and maintenance, use of sumps or drains for sediment control, avoiding activity in particular areas or at particular times, attention to hygiene and appropriate retention of stream reserves along water courses. Details of mandatory requirements are given in Section 6.

3.5.4 Preventative and remedial treatments

The management strategy adopted for the protection of Public Drinking Water Supply Areas (PDWSAs) is an example of a risk-based approach in which potential threats to water quality are identified and managed. The emphasis of this approach is on the need to protect drinking water through a combination of catchment protection and treatment measures which is known as a 'multiple-barrier approach'. The framework requires all potential hazards to the water supply to be identified and assessed in terms of the level of risk each poses. Measures to counter the risks are applied using the operational hierarchy of avoidance, minimisation then management.

The potential risks to water quality associated with activities in catchments include pathogen contamination, turbidity, pesticides, drainage from exposed acid sulphate soils and nutrient contamination. Of all contaminants, pathogens pose the most significant risk to public health. Human and domestic animal contact with the water represents an immediate threat of pathogen contamination. Preventing the presence of pathogens in the water source is the most effective barrier in avoiding a public health risk.

Exercise care with chemical and fertiliser application

- In PDWSAs the use of pesticides to be in accordance with Appendix 2 (extract from DoW's Statewide Policy No. 2 - Pesticides in PDWSA);
- In PDWSAs the use of herbicides to be in accordance with Appendix 3 (PSC 88);
- Match fertiliser needs to that of the growth stage of the vegetation (e.g. adding a little often) to minimise n and p leaching losses into water resources;
- Always use registered products;
- Check that the products are approved for use in the area where they are being applied;
- Use appropriately trained staff or contractors;
- Adhere to safety guidelines;
- Take special care with wetters and surfactants (particularly damaging to aquatic systems);
- Apply in accordance with weather conditions;
- Use appropriate spray nozzles and droplet size;
- Monitor effectiveness and watch for off target movement; and
- Beware, heavy metals are ingredients of some fungicides and are also found in many paints and building products.

Develop contingency strategies

Develop well-defined strategies and contingency plans for the containment of commonly used products. Also devise and implement methods of training staff in procedures for intercepting pollutants (e.g. burst storage tanks, vehicle accidents and fire.)

Maximise the buffer of point sources from waterways and store chemicals securely to minimise risk

- Storage of chemicals in PDWSAs must be approved by DoW;
- Do not store harmful products adjacent to waterways or low in the landscape;
- Do not discharge drainage water directly into waterways – wherever possible use stream reserves to filter water; and
- Where storage near waterways cannot be avoided, ensure approvals are obtained and bunding is in place.

Additional information

DoW provides guidance on water source protection practice via its Water Quality Protection Note series see www.water.wa.gov.au, (select *water quality > publications > water quality protection notes*). Notes are available on Toxic and hazardous substance storage, vegetated buffers to waterways and contaminant spill response.

3.5.5 Summary (Stream nutrients and other contaminants)

- Nutrients and contaminants posing risks to water quality include soil particles, fertiliser, petroleum, hydrocarbons, toxic metals, surfactants, disinfectants, litter and inputs which change the pH or oxygen status of the water;
- Trigger values can be used to monitor water quality for environmental and drinking water values and used to determine whether management response is required;
- Measures to counter the risks are applied using the operational hierarchy of avoidance, minimisation then management;
- Operational practice standards and approvals are required for the use of herbicides, pesticides and other chemicals within State forest and timber reserve; and
- Additional measures may also be required in Public Drinking Water Supply Areas.

3.6 Water quantity

Water is one of the most widely used products that comes from forests. Maintaining the quantity and quality of water runoff to streams and dams has increased in significance as the drying trend of the past 30 years in the south-west of the State continues, and the population increases. The FMP under Section 21 requires that the quantity and quality of water used for environmental and consumption purposes should be protected and, where necessary and practicable, enhanced. It also requires protection of the ecological integrity and quality of streams, wetlands and their associated vegetation.

An emerging issue relevant to the protection of wetlands, streams and the aquatic ecosystem within forested catchments is the impact of a drying climate. Recent monitoring indicates that it requires a greater depth of rainfall than previously before seasonal streams flow, and they are flowing for a shorter period. Also, some perennial streams are now ceasing to flow on occasions (for example, the historically perennial Wungong River ceased to flow for 15 weeks in 2007). Groundwater monitoring is also reflecting this drying trend. Records from monitored bores within the forest are showing sustained falls of two to four metres (and greater) over ten years.

The management of fire and silvicultural treatment are two of the main tools available to forest managers to influence forest water balance. The FMP 2004-2013 allows for trials of modified silvicultural practices to be applied on limited research areas to investigate the effectiveness of modified treatments, and study the conservation and biodiversity outcomes.

Experimental work on increasing water quantity

Thinning of the forest in some high rainfall experimental studies (Bari and Ruprecht, 2003) indicates the potential to significantly increase streamflow. Maximum increases ranging from 8 to 18% of mean annual rainfall (90 to 200 mm) have been achieved by forest thinning, depending on the level of reduction of vegetation cover and catchment characteristics. Increased water yields are transient and usually return to pre-harvest levels after around 12 to 15 years. The increase in yield is generally greater for higher levels of annual rainfall and higher intensity of forest thinning. Where forest is being managed to increase water yield the primary environmental considerations are to ensure that:

- The reduction in forest cover is not high enough to cause increase in stream salinity;
- The potential for the introduction of disease through increased intensity and frequency of operations is well managed;
- Habitat and biodiversity values are preserved; and
- Other environmental, social and cultural forest values are protected.

Abstraction of water from the environment

Proclaimed areas:
Abstraction of water from the environment and control of the bed and banks of streams is presently vested in the *Rights in Water and Irrigation Act (1914)* managed by DoW in proclaimed areas. Statutory approvals and licenses are required in these areas. For detailed information, contact any regional office of DoW or check the DoW website at:

http://portal.water.wa.gov.au/portal/page/portal/home/.

DEC managed lands:
The CALM Act (*s. 20(6)*, and *s. 101(1a)* and (*1e*)) and the FMP (21.4) provide for DEC to take water and issue permits for taking water. The CALM Regulations (*s. 81* revised 29/1/08) allow indigenous State forest and timber reserve to be reserved for purposes including the removal of water, storage of water and location of infrastructure and facilities.

3.6.1 Summary (Water quantity)

- Water is one of the most widely used products that comes from forests;
- The quantity of water used for environmental and consumption purposes is required to be protected and, where necessary and practicable, enhanced;
- An emerging issue for managing water quantity is the impact of a drying climate and increasing human consumptive demand;
- Increasing the quantity of water flowing into streams and harvested from forested catchments by thinning in high rainfall areas is being trialed in small scale experimental studies; and
- Abstraction of water from the environment and control of the bed and banks of streams in proclaimed areas managed by DoW. Statutory approvals and licenses are required in proclaimed areas.
- DEC may issue permits for the taking of water from State forest and timber reserves.

Note: Some of the information in this section was sourced from Pen, (1999) which is recommended as useful background reading on the nature and management of streams in the south-west of Western Australia .

4 Surface Water Management

4.1 General Principles

Surface water management is the process of managing the overland flow of water (often referred to as "runoff") in such a way as to protect resources and environmental values.

The management of surface water is a key skill that will go a long way to minimising many of the risks to soil and water values outlined in Sections 2 and 3 and will assist in achieving the mandatory outcomes required in a number of Schedules and Appendices in Sections 10 and 11.

Surface water management can be used to improve safety, prevent erosion and turbidity, and extend the seasonal working range and overall working life of infrastructure such as roads, trails, landings and extraction tracks. Surface water management reduces the cost of maintenance and repair of infrastructure and can reduce the spread of water borne diseases such as dieback. Some of the key principles to keep in mind while planning for surface water management are outlined in this section. A summary of key principles is given below.

Summary of key principles in surface water management

- Gently move surface water to a stable surface:
  - Move small amounts at regular intervals rather than large amounts less frequently (see Figure 11);
  - Divert water ahead of changes in slope, soil type or bends;
  - Choose the best place to divert water rather than sticking rigidly to predefined length intervals;
  - Keep the grade of structures designed to move water low (e.g. 0.5%);
  - Keep the water to be moved broad and shallow (this greatly reduces erosive potential); and
  - Avoid sharp bends or changes in the angle of structures.

- Choose a surface water management structure and design criteria that matches:
  - Safety requirements;
  - Ability to handle the anticipated traffic load (where access is required);
  - The cost of a potential failure;
  - The intended life (return interval) of the infrastructure;
  - The natural values to be protected;
  - Local knowledge regarding risk factors; and
  - The cost and ability to carry out the maintenance required for the structure.

The appropriate grade (fall/slope) of structures

Almost all surface water management structures that are designed to gently move water are constructed on a grade of about 0.5%. This applies to rolling dips, mitre drains, spreaders and culverts. This amount of fall (1 in 200 or approximately ⅓ of one degree) is almost impossible to see with the naked eye, but is enough to move water at a velocity that does not cause erosion or scouring of the structure and minimises damage at the out-fall end. The gradient may be as low as 0.3% and still work efficiently, but can only be increased on exceptionally stable soil types and short structures up to around 1% (1 in 100 or approximately ½ of one degree). Although a number of traditional forest applications measure slope in degrees, the industry standard unit for measurement of slope or fall is percent (%). Comparative values for measurement of slope (grade, gradient and angle) are shown in Table 10.

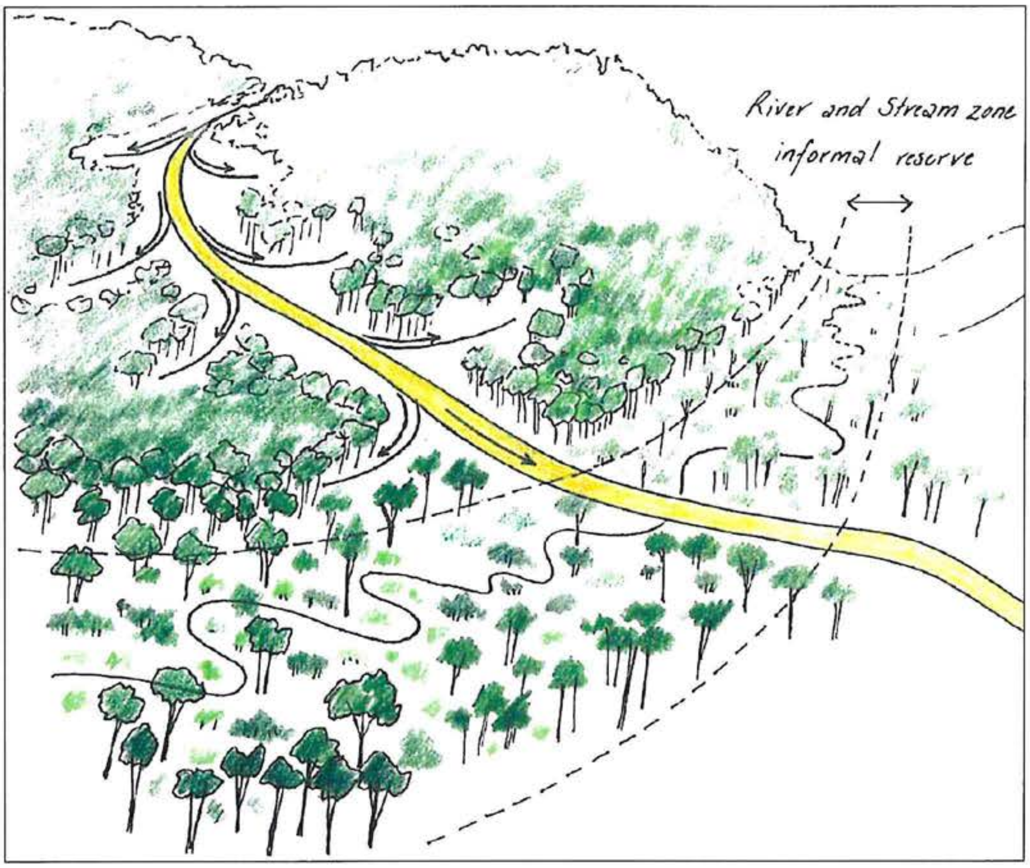


Figure 11: **Remove surface water at regular intervals to stable areas before the road enters an informal reserve. Install additional structures to control surface water in the informal reserve as required (within road corridor).**

Table 10: **Comparative table of gradient, grade and angle**

Gradient	Grade	Angle		Gradient	Grade	Angle
1:300	0.3%	0.19°		1:19	5.3%	3.01°
1:200	0.5%	0.29°		1:18	5.6%	3.18°
1:100	1.0%	0.57°		1:17	5.9%	3.37°
1:95	1.1%	0.60°		1:16	6.3%	3.58°
1:90	1.1%	0.64°		1:15	6.7%	3.81°
1:85	1.2%	0.67°		1:14	7.1%	4.09°
1:80	1.3%	0.72°		1:13	7.7%	4.40°
1:75	1.3%	0.76°		1:12	8.3%	4.76°
1:70	1.4%	0.82°		1:11	9.1%	5.19°
1:65	1.5%	0.88°		1:10	10.0%	5.71°
1:60	1.7%	0.95°		1:9	11.1%	6.34°
1:55	1.8%	1.04°		1:8	12.5%	7.13°
1:50	2.0%	1.15°		1:7	14.3%	8.13°
1:45	2.2%	1.27°		1:6	16.7%	9.46°
1:40	2.5%	1.43°		1:5	20.0%	11.31°
1:35	2.9%	1.64°		1:4	25.0%	14.04°
1:30	3.3%	1.91°		1:3	33.3%	18.43°
1:25	4.0%	2.29°		1:2	50.0%	26.57°
1:20	5.0%	2.86°		1:1	100.0%	45.00°

4.2 Surface water management structures commonly used for forest management

4.2.1 Mitre drains

Mitre drains (also known as cut-off drains, off-shoot drains, diversion drains and runoffs) are designed to prevent water flows building up in the table drain beside a road and causing erosion. They need to be spaced at intervals depending on slope and soil type (see Schedule 22). The greater the slope and the less stable the soil, the closer the interval. A mitre drain should have good capacity, not exceed 1% in grade (0.5% on less stable soils) and ideally have a level sill at its disposal point. It should intersect the road level with the edge of the running surface and have a flat, even bottom (not a V shape). Doubling the depth of running water increases its erosive power approximately ten fold. For this reason, wide, flat bottomed drains are preferred to narrow, vee bottomed drains, which increase depth, and therefore, erosive power. Mitre drain outlets effectively concentrate runoff, for this reason they should be located in stable, undisturbed areas.

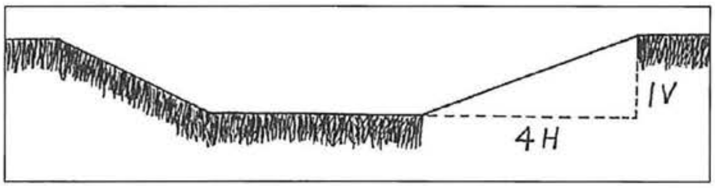


Figure 12: Ideal cross section for table and mitre drain channel (Trapezoidal)

Ideally, mitre drains (and table drains) should be constructed so that they have a broad flat base 2 – 2.5 m (1 grader width) wide (Figure 12). In some cases, such as where there is a need to reduce the width of a road corridor, a V-shaped table drain may be constructed. Where this occurs it is important to pay attention to soil stability and remember that additional relief drainage may be required to reduce soil erosion.

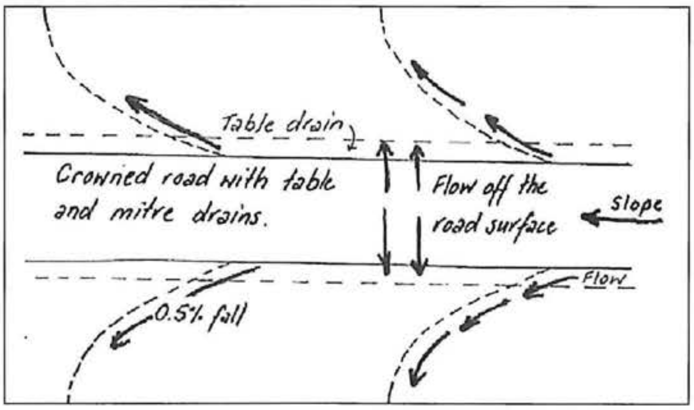


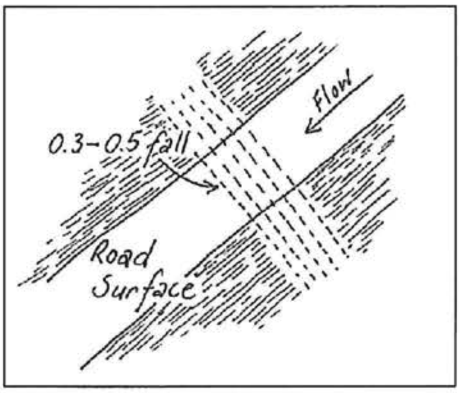
Figure 13: A crowned road with table drain and regularly spaced mitre drains.

Where a mitre drain cannot be constructed to relieve a table drain due to the unavailability of suitable downhill alignment, cross-road drainage will be required. The main forms of cross-road drainage are culverts and rolling dips. Spreaders may also be used where vehicular access is not required.

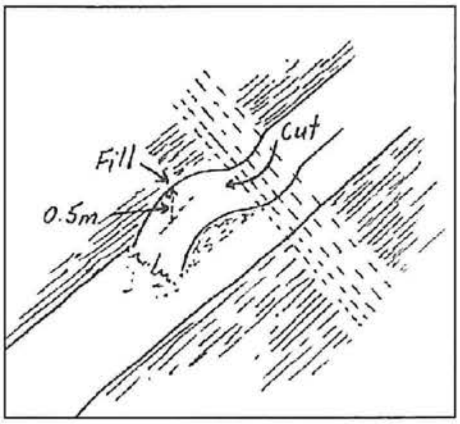
4.2.2 Rolling Dips

A rolling dip (also known as a cross bank, check bank, rollover bank, whoa-boy and humpty-doo) is like a broad, flat spreader bank. The advantage over a spreader bank is that although it takes a bit more work to construct, a rolling dip is trafficable. These structures are suitable for tracks sloping up to about 10%. Rolling dips are excavated on a grade and with a gentle side slope to divert water off a track or road. Spoil is run downhill from the dip on gentler slopes or incorporated into the side slopes of the downhill bund. Rolling dips (when correctly located and built) provide effective, cheap, long term, low maintenance road drainage. They are particularly useful where frequent cross-road drainage is required and the cost or maintenance requirements of culverts are prohibitive. Rolling dips are most suitable for roads that will mainly be used in drier weather and that have side slopes greater than three degrees (grade 1:20 or 5%). Rolling dips are most efficient when constructed at right angles to a road. However, diagonal banks may be constructed to obtain sufficient gradient or direct water to the most suitable outlet.

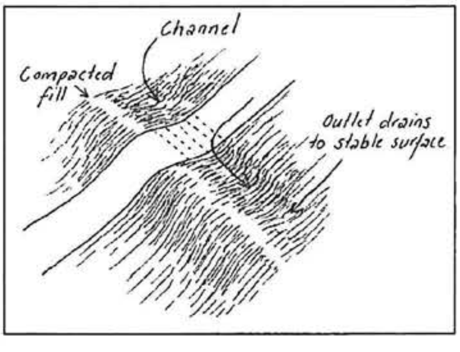
Figure 14: Sequence of construction for rolling dips



For construction, after surveying the grade of 0.3 to 0.5%, the road may require ripping to a depth of 20 to 30 cm for the required length back from the chosen outlet point. The loose earth is then pushed down the road into a bank.



Commence at the uphill side of the road and work across the road towards the outlet side. Sufficient loose earth must be used to give the required dimensions (recommend 0.5 m high) after shaping and compaction.



The bank can be shaped with the implement blade and the entire length of the bank should be track or wheel-rolled to obtain maximum compaction and a smooth, even bank. A sweep with the blade will clean the channel of the bank. The small bank of earth resulting at the outlet end should be pushed off the road onto the end of the bank so that draining water can clear the road effectively. Ideally, choose an outlet location that is stable and well vegetated. An armoured outlet or bank to a level sill can be used to discharge water where a stable surface is not immediately adjacent.

Diagrams adapted from Department of Natural Resources, Environment and the Arts (2006)

Figure 15 below illustrates the desired cross–section for rolling dips. Dimensions will vary depending on track slope. Dimensions shorten with steeper track slopes. As dimensions shorten, the rolling dip becomes less trafficable for larger vehicles.

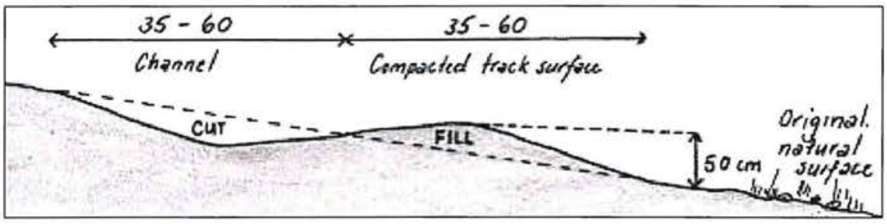


Figure 15: Cross section through a long rolling dip on a haul road suitable for log truck passage

Smaller (shorter) rolling dips may be constructed where only light vehicle traffic at slow speed is required, down to the size of a spreader bank. For example, the cut and fill sections could be as narrow as 3 to 5 m and still enable trafficability for light fire units. A photo sequence showing the construction of a small rolling dip (or spreader) trafficable to four wheel drive utilities and light firefighting units is shown in Figure 16 below:

Figure 16: Photo sequence for construction of a small rolling dip

1. Pegging the alignment

2. Cutting and pushing the bank

3. Compacting spoil on the bank

4. Inlet and outlet cleared and compacted

4.2.3 Culverts

A culvert is a relatively short section of drainage pipe installed under a road to safely transmit water from the upslope to the down-slope side. In forest management, culverts are mainly used where a road crosses a stream, or to safely transmit water from an upslope table drain under a road or track to a stable disposal point. Culverts are commonly made of concrete, steel or PVC.

Design

Culvert size should be selected based on a return interval appropriate to the road and catchment characteristics. The "Runoff tools" model (DEC SFM Form number 13) assists in estimating the size of the culvert pipe required and allows for the selection of an appropriate head on the pipe. The recommend fall of the culvert pipe is around 0.5% and up to 2.0%. Increasing the fall raises discharge velocity and above a fall of 2.0%, discharge velocity can create significant scouring and soil erosion. Where a culvert is used to channel a natural stream, the culvert should be installed as close as possible to the natural grade. Culverts should be firmly seated, and earth packed firmly up the side of the pipe during installation.

Culvert Inlets

The design, construction and finishing of culvert inlets is important to the on-going efficiency of the culvert. There are several design criteria for a successful culvert:

- The cut face opposite and downhill from the inlet should be hard faced to prevent scouring and be level with the running surface of the road to prevent overflowing;
- The face opposite the pipe (the cut batter) should be hard faced to prevent undercutting and slumping;
- The face around the pipe should be hard faced to prevent tunnelling and undercutting around the pipe and to prevent the road shoulder slumping over the pipe inlet;
- The inlet box should be designed to hold the appropriate volume of water and to supply sufficient hydraulic head to the pipe. It should be large enough to allow easy access for clearing and maintenance;
- Hard facing can be constructed using concrete bags, prefabricated concrete or local stone; and
- The inlet leading to the sump may be hard faced to prevent headward erosion of the table drain where this does not detract from the ability to conduct maintenance works such as sediment removal by backhoe. The floor of the culvert inlet should be at least 30 cm below the bottom of the pipe to allow ponding and sedimentation.

An example of a culvert inlet and sump is shown in Figure 17.

This culvert inlet face has been hard faced to prevent tunnelling and undercutting around and above the pipe and to prevent the road shoulder slumping over the pipe inlet.

The inlet sump is large enough to allow easy access for clearing and maintenance.

This installation could be improved by extending the hard facing below the bottom of the inlet pipe to prevent scouring and undercutting.

Figure 17: A culvert inlet and inlet sump.

Culvert Outlets

Where culvert outlets deliver water onto spill batters or unstable surfaces, the drop zone and spillway must be protected to prevent erosion. This can be achieved using a number of techniques including geotextile overlain with stone, concrete half pipes, corrugated iron or concrete sandbags.

Maintenance

Clearing of silt and debris from culvert inlets and outlets should to be undertaken regularly. Culverts should generally be maintained annually before the onset of winter rains, immediately after road grading maintenance is completed, and after the catchment feeding the culvert is harvested, thinned or burnt.

4.2.4 Non-trafficable structures for closed or rehabilitated roads or extraction tracks

Spreaders (also known as catch drains and previously known as erosion control barriers)

Spreaders are short, generally non-trafficable sections of bank, constructed on a grade across a channelled flow such as a closed extraction track, log gouge or shallow gully. The structures are used to divert water to a safe disposal area before it concentrates and causes erosion. Spreaders may be used with level sills at the discharge end.

In forest applications, these structures are sometimes referred to as "erosion control barriers". However, this term is misleading because the purpose of the structure is to move water rather than to act as a barrier to water movement. Ideally, spreaders should be constructed with a grade of 0.5% and discharge onto a stable, vegetated or protected surface. Spacings for spreaders according to slope and soil stability are shown in Schedule 19.

Using the recommended spacings in Schedule 19 as a guide, the placement of spreaders can be fine tuned to consider location as follows:

- Upslope of any significant curve in the extraction track or road to reduce the likelihood of the accumulated runoff increasing its erosive capacity as a result of the change of direction;

- Care should be taken to disperse the water away from the inside of a curve so that is not collected again on the next downhill section of the extraction track or road;
- Upslope of the entry point to any landing or road, to ensure that the water collected from the extraction track is not directed onto the landing or road. It is important to leave a sufficiently wide filter strip so that the water does no run back onto the landing or road and accumulate again;
- Above a stream reserve to spread flow before entering a stream or creek;
- Immediately prior to a soil/landform change where downhill soil represents an erosion risk; and
- On the upslope side of any obvious increase in gradient so that the water is dispersed before it has the opportunity to be accelerated by the change in gradient.

Figure 18 below illustrates the desired cross–section for spreaders. Dimensions will vary depending on track slope, machine type and soil type.

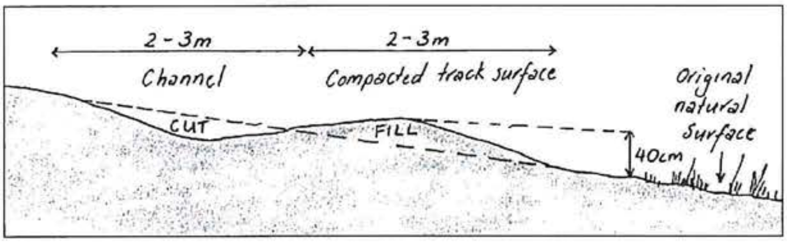


Figure 18: **Cross section through a spreader – the dimensions shorten with steeper slopes and hence the greater the height of the compacted bank.**

Figure 19:
A spreader must *not* act as a dam **this is likely to result in failure due to overflowing**

4.3 Drainage and protection of basic road types

Tracks and roads should be constructed using a method of safely removing runoff. Unless runoff is removed from the track surface, it may lead to deterioration of the surface and accumulation at critical points resulting in erosion or failure.

Roads are for vehicle transport and not for water transport

4.3.1 Crowned roads or tracks

Crowns are essentially constructed to keep the road surface dry. Crowns allow water falling onto the road to rapidly reach the table drains on each side, keeping the running surface unsaturated. This road design concentrates water in table drains and culvert outlets. Crowned roads are used where there are unstable or erodible fill slopes, on steep grades, where traffic volumes are high or slippery conditions are expected.

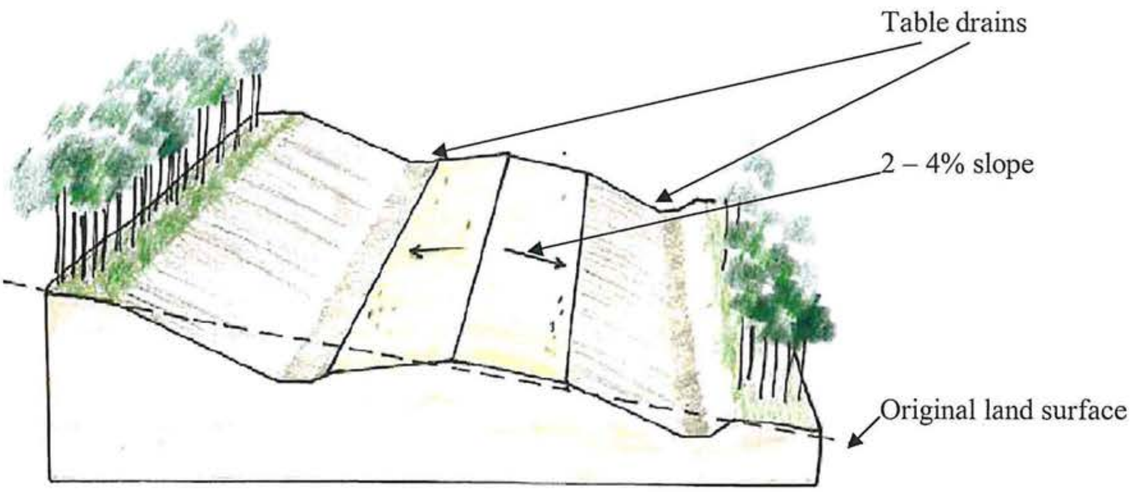


Figure 20: Cross-section of a crowned track

4.3.2 Cross-fall roads or tracks

On land with cross-fall, where a track is not to be crowned, the surface may either slope into the hillside or out from the hillside. These cross sections are called in-slope and out-slope respectively. The concept can be used on major access roads if safety and design speed criteria can be met, but is most often applied to minor access routes that have limited use and low design speeds.

In-slope

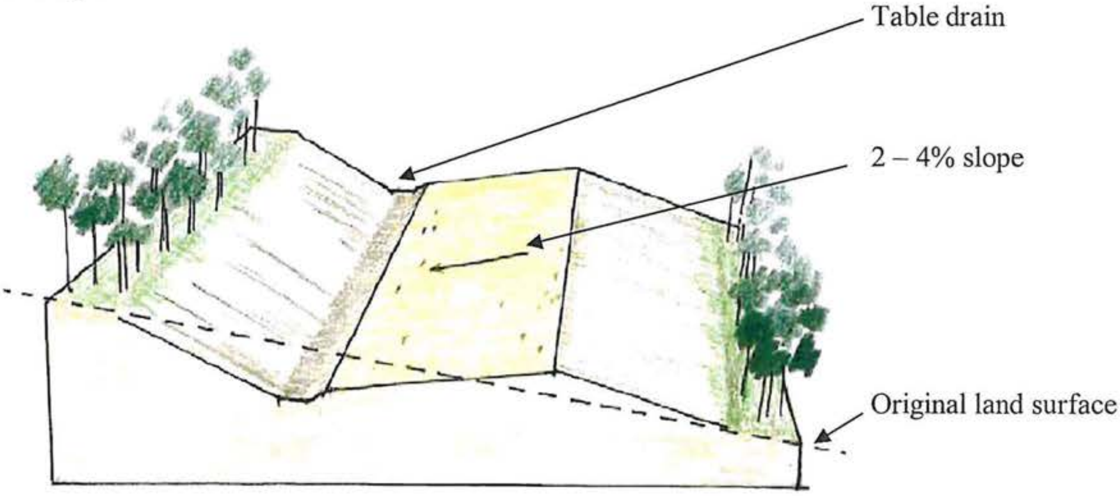


Figure 21: Cross-section of an in-slope track

In-slope tracks are constructed with a table drain to remove runoff from the track's surface. Water drains towards the cut slope and is collected in a table drain. Cross-road (or transverse) culverts are installed under the road to relieve the table drains at spacings recommended in Schedule 21 and dispersed downhill. In-slope tracks require more excavation and clearing than out-slope tracks, but are suitable when unstable or erodible fill slopes exist, on steep grades or when slippery conditions are expected. They are not suitable where table drains cannot be constructed or where table drains or culverts have a high probability of clogging.

Out-slope

Figure 22: Cross-section of an out-slope track

Out-slope tracks usually require less excavation and clearing than other road types. Road surface water runs directly off the side of the road. This negates the requirement for constructing table drains and culverts. Out-slope tracks are constructed with rolling dips to remove water at spacings recommended in Schedule 20. Rolling dips assist in the removal of runoff from the track's surface and any vehicle ruts. Discharge from rolling dips is dispersed downhill. Out-slope tracks are useful in rocky or well drained soils, where maintenance of table drains is not practical, where there are stable fill slopes and on temporary or spur roads that are less than 8% grade. Out-slope roads are not suitable on steep grades, for high traffic volumes, where there are unstable fill slopes or where slippery conditions are expected.

4.4 Choosing, installing and maintaining the appropriate structures

4.4.1 Planning and design phase

Ideally, all drainage or surface water management structures require a degree of planning and design. This involves:

1. Determining what disturbance events need to be considered;
2. Choosing the most appropriate structure; and
3. Applying appropriate design criteria.

4.4.1.1 Determine what disturbance events need to be considered

Forest condition can change considerably with natural or management events such as wildfire, prescribed fire and timber harvesting. When planning and designing surface water management, it is important to anticipate changes in the forest condition over the service life of the structures. For example, if it is known that a silvicultural burn will be undertaken after harvesting, the decreased ground cover after the burn should be factored into the prediction of peak surface flows. If a downstream area is known to be sensitive to, or have economic consequences resulting from failure, and the catchment area is carrying a high fuel load, it may be important to set design criteria based on post-wildfire catchment conditions. In some cases it may be necessary to decide whether structures are required or likely to be effective (Figure 23 below).

This area of karri forest has been recently thinned. There is a large amount of litter and brushing covering the extraction track. There are no deep tyre ruts or log-gouges to divert runoff. Slope is not excessive and the track slopes naturally to the right of picture. Water generally follows natural overland flow paths.

No erosion control structures are required in this area

This extraction track has been bared of vegetation and contains log gouges that will act as channels for surface water flow. Levelling of the log gouges and installation of spreaders to divert surface water flow to stable areas is required.

Figure 23: Comparison of the need for erosion control on extraction tracks.

4.4.1.2 Choose the appropriate structure

The appropriate structure will vary from site to site and may be related to factors such as the intended service life, follow-up activities in the catchment, the requirement for trafficability and available resources for inspection and maintenance.

- Rolling dips may be used instead of culverts where maintenance is costly or impractical;
- In-slope roads may be better than out-slope roads where design speed is important;

- Spreaders are effective and cheaper than rolling dips where vehicle access is not required; and
- Bridges may be more effective than culverts for large spans and high flows.

4.4.1.3 Apply appropriate design criteria

Surface water management structures should be designed for the anticipated service life and prevailing site conditions. The design criterion for a culvert depends on the type of protection required. For example, a temporary road may only be expected to have a service life of one or two years. The structures installed to drain and protect such a road may only be required to handle a "one in five" year storm event (Annual Exceedance Probability (AEP) 0.181). On the other hand, a strategic haul road carrying a high volume of traffic or crossing an environmentally sensitive area may be designed to handle a "one in fifty" year (AEP 0.020) or greater storm event. Design criteria relate to the cost of failure in terms of opportunity cost for lost access, cost of construction, the cost of repair, and environmental consequences of failure.

Notes on estimating peak rainfall events:

The Average Recurrence Interval (ARI) and the AEP are both measures of the rarity of a rainfall event (and the resulting flood or surface water flow). The ARI describes the time period that could be expected between exceedances of a given rainfall total. The AEP describes the probability that a given rainfall event will be exceeded in any one year. The terms "recurrence interval" and "return period" (associated with ARI) should be used with caution because the user may infer that the associated magnitude is only exceeded at regular intervals, and that they are referring to the elapsed time to the next exceedance. The AEP is an easier concept to grasp when expressing the rarity of a rainfall event. For example:

> "A rainfall event of 18mm/hour for 1 hour at Jarrahwood has a 0.632 (i.e.63%) probability of being equalled or exceeded in any one year"
>
> is a better way of describing an event with an ARI of one year.

Table 11: The relationship between ARI and AEP

ARI (Years)	AEP
1	0.632
2	0.393
5	0.181
10	0.095
20	0.049
50	0.020
100	0.010

With ARI expressed in years, the relationship is:

$$AEP = 1 - \exp\left(\frac{-1}{ARI}\right)$$

ARIs of greater than 10 years are very closely approximated by the reciprocal of the AEP

Source: Adapted from Bureau of Meteorology, (2003)

Models for estimating peak flow

An important design criterion for surface water management is peak flow runoff. This is the maximum flow that could be expected through a watercourse and is usually stated with an ARI or AEP. Peak flow depends on factors such as catchment size, slope, stream length and structure, slope, soil type and vegetation cover. Two commonly used methods for estimating peak flow are the Flood index method and the Rational method. These methods are both available on DEC SFM form 013 "runoff tools".

Flood index method - With this method, flood frequency data from catchments within a region are analysed. Relationships are developed between flood frequency data and catchment characteristics. Specific formulae are then developed incorporating these relationships and characteristics such as catchment area, average annual rainfall, and percentage of catchment cleared and slope. The formulae can be used to predict runoff peak flows for a single ARI. Runoff peak flows can then be calculated for other ARIs by multiplying the predicted peak flow by frequency factors for other required ARIs. The formulae are derived from a limited range of data and characteristics. For the jarrah and karri forest in south-western Australia, the limit of catchment size for best accuracy is around 1000 to 2000 km^2. Catchments with areas greater than this will be outside the parameters for prediction of runoff and the use of the Flood Index method may lead to errors in predicted runoff peak flows.

Rational method - The Rational method is a probabilistic or statistical method used in estimating design floods. It uses average rainfall intensity for an ARI to estimate peak flow for the same selected ARI, and a runoff coefficient represented by the ratio of peak flow and rainfall rate for a selected duration for the same ARI from frequency analysis of flood peaks and rainfalls. The method calculates the peak flow rate for an ARI by multiplying average rainfall intensity for the design ARI and duration, by a coefficient of runoff for the design ARI and by the area of catchment.

To use this method the "time of concentration" for the catchment is calculated. This is the time taken form the start of rainfall until all of the catchment is simultaneously contributing to flow at the outlet. The time of concentration is used as the typical response time of flood runoff. Rainfall intensities are calculated for the time of concentration and the design ARI using maps of rainfall intensities for storms of 1, 12, and 72 hours durations for 2 year and 50 year ARI which are contained in *Australian Rainfall and Runoff: A Guide to Flood Estimation,* Institution of Engineers, Australia (1987). The coefficient of runoff is then calculated and multiplied by the appropriate frequency factor. This is used with the design rainfall intensity and catchment area in the rational equation to calculate the design discharge in cubic metres per second. In forested areas of the south-west of Western Australia, this method is likely to be more accurate than the Flood index method, but is still only appropriate for areas up to approximately two thousand square kilometres.

Note: Models relating to risk and return interval are developed based on average or general conditions and it is always a good idea to supplement this information with available local knowledge regarding site conditions or the historic performance of different structures.

The "runoff tools" model (DEC SFM form number 013) is recommended for use in designing surface water management structures up to a catchment size of 1000 to 2000 km^2. For larger catchments or where high environmental or safety requirements exist, forest managers are advised to seek professional engineering advice.

The classification of soils based on engineering properties is necessary when planning and installing conservation and erosion control structures. For example, a less stable soil type such as dispersive clay will not be able to handle the same volume and velocity of water as a well structured clay or gravelly soil. In such a case, a grade of 0.3 to 0.5% may be more appropriate than a grade of 1%, and structures to shed water may be required at closer spacing. The Unified

Soil Classification System (USCS) is the standard for classifying soils by engineering properties in Australia and can be used to rate the stability of a soil.

It is a good idea to document and record structure selection and design criteria. These may then be used as a permanent record to assist future reviews of the cost and effectiveness of surface water management.

Further information regarding data on Australian rainfall and runoff can by found in *Australian Rainfall and Runoff: A Guide to Flood Estimation,* Institution of Engineers, Australia (1987). Information regarding best practice principles and guidelines for floodplain management can be found in *Floodplain management in Australia; best practice principles and guidelines,* CSIRO (2000).

4.4.2 Installation phase

Installation of structures is most effective where:

- Design criteria are adequately documented and communicated;
- The required works are accurately planned, pegged or otherwise demarcated;
- Appropriate equipment is used for the job;
- Operators are trained or experienced regarding machine capability and construction techniques; and
- Works are periodically checked against design criteria or benchmarks.

Once practiced, pegging out the location and dimensions of structures can be a very quick and effective way to ensure correct design criteria are achieved. It is also a very good way to "get your eye in" and develop an ability to read the land more intuitively. When this occurs, checking becomes second nature and may be required less frequently.

Digital slope display.

Peg marks planned alignment of structure at the require level.

A long straight object helps to accurately set the level. Move this until the desired slope is achieved and then peg the location.

Figure 24: Pegging out the grade of a structure is quick and easy

Choice of machinery

A range of earthmoving equipment is traditionally used for forest management. The choice of machinery is generally governed by a combination of effectiveness, efficiency, availability and cost. It is important that clear standards are set for machine operators regarding the standards and technical specifications of work required. This enables appropriate machines to be allocated, and improves the ability to monitor or audit results. Some of the strengths and limitations of machines commonly used in forest management are summarised in Figure 25 at the end of this section.

4.4.3 Maintenance phase

Every surface water management structure has a design life and maintenance requirement. Short term structures such as spreaders on regenerating extraction tracks may not require maintenance (in the absence of extreme storm or fire events) if they are appropriately placed and constructed. On the other hand, the effective working of structures such as culverts may require inspection on at least an annual basis.

It is important to understand the maintenance requirements of your surface water management structures and program maintenance into the annual works program. Remember that structures such as culverts are only as effective as the annual maintenance program. In circumstances where the resources for annual maintenance may not be available, consider constructing low-maintenance structures for road drainage such as rolling dips. Surveillance for maintenance requirements should be increased:

- Before the onset of the wet season;
- When the opportunity cost of failure is high; and
- Following events likely to generate increased runoff such as harvesting or fire.

The maintenance of roads is an essential and costly activity in forest areas. Correct road design and maintenance practices can significantly reduce the cost and effectiveness of this activity.

This road (near Pemberton) was winter graded and rolled just prior to this photograph being taken. Multiple windrows are apparent; one windrow from construction and three from road maintenance.

The windrow to the right of the left hand guide post is diverting water flows from entering a culvert and safely exiting the road. The water subsequently runs some distance along the road causing damage to the road surface.

Figure 25: Windrows from road construction and maintenance should be avoided

Road maintenance should be undertaken when the surface is moist, incorporating all road surface material. The final windrow from grading should be feathered to the road shoulder, leaving no windrow. In the case pictured above, the money saved on maintenance may be exceeded by repair costs in the future.

Figure 26: Types of Machinery – Strengths and limitations

Machinery	Strengths	Limitations
Wheel loader 	Very good at carrying and loading materials such as soil, gravel, logs and construction materials. Can travel between jobs without requiring a float on the road.	Bucket attachments available for earthwork, but the blade cannot be tilted. Top heavy nature makes work in very steep country difficult. Not ideal in wet and boggy conditions.
Bulldozer 	Excellent performance in steep country. Good in wet conditions due to tracks spreading ground pressure. Can turn within own length. Good for heavy work at a fire, road cutting, and shifting large volumes of dirt – usually has rippers for cutting dirt, batters and deep ripping.	Heavy footprint due to tracks which also shift and carry more dirt around. Requires a float to move significant distance (<1km). Not licensed for the road.
Grader 	Ideal for road work, drainage work and contour banks. Good for cutting batters and drains. Relatively fast to move between sites. Total blade control.	Large clear area required to manoeuvre. Harder to operate in confined spaces.
Tracked Excavator 	Good where work required in a narrow corridor of disturbance. Lighter footprint of tracks (designed to carry not push like a dozer). Can carry things. Reach up to 10 m (good for working near streams and sensitive areas).	Machine needs to be floated site to site. Not licensed for road use/transport. Slower than a dozer for some jobs.
Tracked Bobcat 	Very manoeuvrable – ideal for confined spaces like building sites and forest tracks and trails. Easy to transport. Relatively inexpensive to operate.	Not appropriate for large or heavy jobs.
Skidder 	Usually readily available in forest operations. Can drive at a reasonable speed from site to site. Quick to push dirt, move logs or make firebreaks. Good for "opening up" bush (for other vehicles to follow). Go anywhere – no terrain worries, climbing, power etc. Relatively light footprint, reasonable turning circle.	Poor visibility of blade from cab. No tilt ram - angle of cut is fixed. Not designed to shift dirt with precision.

OPERATIONAL REQUIREMENTS

5 Timber Harvesting

5.1 Planning for timber harvesting

5.1.1 Summary of mandatory planning actions for timber harvesting

A summary of mandatory planning actions to be implemented for timber harvesting is shown in Table 12 below.

Table 12: Mandatory actions for the planning phase of timber harvesting

Topic	Action	Responsibility
Legislation	Requirements of legislation, policies, DEC and FPC guidelines, manuals and other regulatory documents are to be met.	DEC, FPC
Identify areas to be protected	Prepare an operations base plan identifying areas to be protected including formal reserves, informal reserves and fauna habitat zones.	FPC
Environmental risk assessment	Determine whether the area (or adjoining area) is likely to contain caves, steep slopes, erodible soils or other fragile areas. Determine appropriate management response to the risks and values via the Pre-Operations Checklist.	FPC
Identify whether specific water protection is required	Includes reservoir, reservoir protection zone, Public Drinking Water Supply Areas, a harnessed catchment, a Gazetted catchment, a Department of Water Significant Waterway/Wetland	FPC
Identify whether salt risk measures apply	Apply criteria in Schedule 18.	FPC, DEC
Existing Roads	Ensure that roads have been constructed, maintained or upgraded to handle the traffic load and surface water flows expected during the harvest period (Schedules 19-22).	FPC
New roads	Ensure that new roads are authorised by the land manager (DEC).	FPC, DEC
Moist soil risk periods	Harvest planning should encompass the requirements for all risk periods during which it is anticipated that a particular feller's block could be active. Ensure that operations are planned to be carried out in accordance with allowable activities for risk periods based on Trafficability Index$_{SDI}$. (Schedules 1-3). If the area is intended to be accessed in the Medium to High (post transitional) or High risk periods, prepare and submit a formal request via the two-stage approvals process (Schedules 3 and 4).	FPC
Extraction network	Plan the layout of extraction tracks prior to commencement of extraction, including field demarcation and the preparation of a sketch map. Maximise the use of old extraction tracks and do not duplicate extraction tracks.	FPC
Notification	Contact the land manager (DEC) before commencing harvesting.	FPC

Further explanation for some of these requirements is provided below. The details and technical specifications to follow are found in the Schedules and Appendices in Sections 11 and 12.

5.1.2 Defining acceptable soil moisture conditions for the off-road operation of heavy vehicles – Trafficability Index $_{SDI}$

Trafficability Index $_{SDI}$ (TI_{SDI}) is an indirect estimate of soil moisture. Lower values of TI_{SDI} indicate higher soil moisture and greater risk of soil damage. When TI_{SDI} reaches zero, soils are likely to be saturated. Permissible management activities for timber harvesting in native forest vary according to four levels of risk. The risk thresholds are determined by TI_{SDI} and change with the wetting or drying phases of the year and according to soil type (Schedule 1).

Figure 27: The relationship between risk period, soil moisture, trafficability and management requirements. As soil becomes wetter, increased planning, approval and monitoring is required.

Risk Period	Soil Moisture	Trafficability Index (TI_{SDI})	Management requirements
Low	Dry	2000	
Medium	↓	↓	Increasing Planning Approval & Monitoring Requirements
Medium to High (Transitional)			↓
Medium to High (Post Transitional)			
High	Wet (Saturated)	0	

The Trafficability Index calculations are based on the method described by Mount (1972) for the "Soil Dryness Index", as adapted by the Bureau of Meteorology for conditions in south - western Australia. Calculations are based on rainfall and temperature data supplied daily by the Bureau of Meteorology for a set of automatic weather stations.

5.1.3 Mandatory management requirements associated with the risk levels for soil damage

Permissible management activities for timber harvesting in native forest vary according to the levels of risk described above. Some management requirements apply over all risk periods such as the requirement for harvest planning, coupe diary entries, observation of soil disturbance limits and the requirements of legislation, policy and guidelines (Schedule 3).

During the Medium to high risk period, significantly increased planning, monitoring and approvals are required. Operators should also plan and obtain approval for special treatments and strategies to protect soil.

During the High risk period, the use of heavy vehicles off-road or off-landing is not allowed, except in the case of first thinning of young (less than 35-year-old) regrowth karri forest, subject to written approval. The loading and haulage of stockpiled logs on landings is also permissible, subject to written approval.

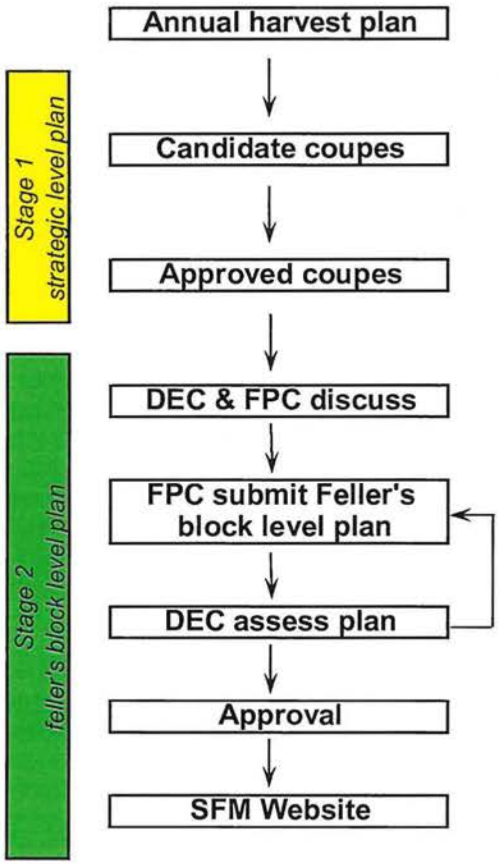
Details of planning and authorisation to operate according to the various risk levels for soil damage are contained in Schedules 2 – 4.

5.1.4 Mandatory planning requirements for operating under moist soil conditions - two stage approval process

During the wettest part of the year special planning and approval is required in order to conduct timber harvesting activities. A schematic diagram of the process is shown in Figure 28 below, and a full description of requirements is shown in Schedules 3 and 4. In summary, the process requires that areas to be harvested during the wettest part of the year are to be identified early in the harvesting year and additional information for these areas is to be provided and approved as part of a two-stage approval process.

The first stage is called the strategic level and the second stage is called the feller's block level. The strategic level plan is required to demonstrate the suitability of candidate coupes in terms of landforms, soils, topography, site, rainfall zone, dieback management and access that make the harvest area suitable for operations in moist soil conditions. The plan should indicate why the chosen coupes are the most suitable out of all the coupes on the Annual Harvest Plan.

The aim of the feller's block level plan is to demonstrate how consideration of the physical features of the proposed harvest area, combined with operational tactics makes it suitable for operations in moist soil conditions. The feller's block level plan is required to provide detail on the feller's blocks to be harvested including planned layout of extraction tracks, the preparation of a map and identification of roads, landings and the type and extent of any special treatments to protect soil, for example cording, matting, brushing or avoidance of susceptible areas.



Stage 1

To be eligible, coupes must be on the current annual harvest plan.

FPC Identify the coupes most likely to sustain harvest operations during moist soil conditions.

DECs Director of SFM provides feedback and assists with refining the candidate coupes list.

FPC provides a formal proposal as a consolidated request for all Regions.

The proposal to DECs Director of SFM must include maps and supporting information to demonstrate suitability of candidate areas in terms of landforms, soils, topography, site, rainfall zone, dieback management and access.

Director of SFM provides a written response listing approved coupes & any specific conditions.

NOTE: Approval at stage 1 does not entitle access for M-h & H risk periods.

Stage 2

FPC check that feller's blocks for 2nd stage proposal have a current Pre-Operations Checklist signed by the DEC Regional Manager and a current hygiene management plan.

Local DEC & FPC officers discuss issues in advance of submission of the feller's block level plan.

Plan to include layout of extraction tracks, map identifying type and extent of any special treatments to protect soil, evidence that the use of old extraction tracks is maximised, details of provisions to prevent soil mixing on landings and any issues that could not be addressed because of the unavailability of information during stage 1.

DEC assess and respond in writing within 5 working days (copy by email is acceptable), and will either:

- Identify actions that must be completed before approval can be reconsidered;
- Identify additional information that must be provided before approval can be reconsidered;
- Identify issues which must be resolved before approval can be reconsidered; or
- Approve the operation and clearly identify any conditions of this approval.

Once approved, the DEC approval, FPC proposal and attachments to the FPC proposal will be made available to DEC and FPC officers on DECs SFM website.

Disputes will be urgently referred to the Director of SFM for resolution

Figure 28: Summary of two stage approvals process for access during the Medium to high (post transitional stage) and High risk periods.

5.2 Implementation of timber harvesting

5.2.1 Summary of mandatory implementation actions for timber harvesting

A summary of mandatory actions for the implementation of timber harvesting is shown in Table 13 below.

Table 13 Mandatory actions for the implementation of timber harvesting

Topic	Action	Responsibility
Approval	Do not commence operation until approval is given by the land manager (DEC).	FPC
Compliance with conditions of authorisation	Ensure compliance with conditions of the Pre-Operations Checklist authorisation, together with other approvals such as the feller's block level authorisation (Schedule 4).	FPC
Notification	Notify land manager active, completed and dormant feller's blocks each Monday (Schedule 14).	FPC
Soil disturbance limits	Manage operation within the soil disturbance limits of Schedules 6-8 If limits exceeded or likely to be exceeded – cease operations and notify DEC. If an operation ceases due to the likelihood of exceeding soil disturbance limits then it cannot recommence until FPC has satisfied DEC that the operation will not exceed the soil disturbance limits.	FPC
Demarcation	Demarcate all boundaries to the harvest area (such as stream zones and other informal reserves). Manage the harvest operation to be contained within the demarcated work area. Demarcate the layout of the extraction track network on the ground prior to commencing extraction.	FPC
Allowable activities in relation to risk period	Ensure that operations are carried out in accordance with allowable activities for risk periods based on Trafficability Index$_{SDI}$. (Schedules 1-3).	FPC, DEC
Moist soil protection measures	Apply protective soil treatments such as cording, matting and brushing in accordance with approvals and before disturbance occurs.	FPC
Rain	Extraction is to cease while it is raining.	FPC
Surface water management	Install surface water management structures according to Schedules 19-22 on all roads, completed and dormant feller's blocks.	FPC
Rehabilitation	Identify, map and rehabilitate all areas of severe or very severe soil damage according to (Schedules 24 and 25). Undertake rehabilitation work as soon as is reasonable and practicable after the completion of harvest operations. Observe TI$_{SDI}$ limits for rehabilitation earthworks (Schedule 24). Where roads constructed by FPC and used for harvesting are considered not to be of benefit to DEC, then FPC will be responsible for the rehabilitation of these roads.	FPC
Waste management during harvest operations	Control waste and pollution in accordance with Appendix 1.	FPC and Contractors

5.2.2 Tracks and the importance of minimising trafficked areas

Tracks created during timber harvesting are the site of the most intensive traffic and usually the greatest soil disturbance, particularly soil compaction and in some cases rutting. Both the harvesting and the extraction phase may create tracks.

Key objectives of operational management are to:

1. Use previous disturbance such as old roads and landings where possible;
2. Concentrate machine movement onto as few tracks as possible; and
3. Minimise machine traffic off the tracks.

These actions reduce the area of the harvest cell that is disturbed. To achieve this:

- Plan the track layout prior to harvest;
- Both the pattern of harvesting tracks (where machine harvesting is used) and the extraction track layout should be considered so that the overall area of tracks is minimised;
- Use old extraction tracks or landings from the previous harvest where practical;
- Do not duplicate tracks;
- Do not have parallel tracks or multiple extraction tracks heading to the same area;
- Do not have separate harvest tracks and extraction tracks leading to the same area;
- Do not have a extraction track going around both sides of a tree;
- Do not "criss-cross" extraction tracks;
- Minimise the width of extraction tracks. The extraction track should be no wider than the wheel tracks of the vehicle;
- Avoid the use of machine harvesting where possible under moist soil conditions or in stands with an unsuitable structure;
- Minimise the width of harvest tracks (where machine harvesting is used). This is achieved by using a harvest machine of the minimum size necessary and with the careful operation of the machine; and
- Keep landings as small as possible and only one landing should be allocated to each feller's block or sub-coupe.

In short, plan the layout and manage the development of the harvest and extraction track pattern.

Schedule 3 requires that "Duplicate, parallel and criss-crossing extraction tracks are not constructed unless under exceptional circumstances". For the purpose of addressing this clause the "exceptional circumstances" will be:

1. In urgent circumstances for the purposes of gaining access to harvesting personnel for medical treatment or rescue, without consultation with DEC; or
2. To avoid unforeseen hazards and soil conditions that are atypical of the remainder of the feller's block, for example where a small localised bog hole is avoided in a generally dry area or where the shape of infected and clean areas requires more than the normal amount of tracks to maintain hygiene. This should only occur following consultation and approval by DEC (these instances should be recorded in the coupe diary).

5.2.3 Moist soil protection measures

Treatments such as cording, brushing and matting must be installed according to approval from DEC and prior to the onset of soil damage occurring. Treatments must not be applied as a remedial action after damage has occurred.

Where cording, matting or brushing is used as a treatment to minimise soil disturbance on landings or extraction tracks, the following key points are to be observed:

- Material is to be used as a preventative measure and applied before soil disturbance occurs.
- Under no circumstances are woodchips or bark matting to be applied to bare soil either for use on the landing, the extraction tracks, or for stockpiling for subsequent use.
- The material must be satisfactorily removed or prepared for silvicultural burning by either:
    1. Recovery and removal for re-use;
    2. Recovery and removal for disposal at an approved site;
    3. Heaping and burning on site; or
    4. Heaping and preparation for burning in accordance with burn security requirements.
- Prior to commencement of the ripping phase of rehabilitation, all bark, cording, matting or brushing must be burnt or removed from the landing or extraction track to the required standard (Schedule 24).

5.2.4 Stockpiling of topsoil on landings

For landings on deep loam soils or duplex soils which are operated on in the medium to high risk period, the topsoil must be removed, to a maximum of 100 mm depth, and neatly stockpiled to one side to avoid mixing with subsoil horizons. This topsoil must be protected and not mixed or covered with harvesting debris. During the rehabilitation phase, the topsoil is spread evenly back over the landing. Operations that are to extend into the Medium to high risk period must have topsoil stockpiled as the landing is established and prior to the commencement of extraction and loading. Topsoil stockpiling is not required where a landing is corded and matted as long as the cording and matting is laid at the establishment phase of the landing and prior to the commencement of any extraction and loading.

The practice of topsoil stockpiling is recommended for all other landings, with the exception of those with extensive sheet laterite or concreted layers.

5.3 Monitoring of timber harvesting

5.3.1 Summary of mandatory monitoring actions for timber harvesting

A summary mandatory actions for the monitoring of timber harvesting is shown in Table 14 below.

Table 14: Mandatory actions for the monitoring of timber harvesting

Topic	Action	Responsibility
Notification	Notify land manager (DEC) of active, completed and dormant feller's blocks each Monday (Schedule 14). Notify FPC prior to entering active harvesting work site.	FPC DEC
Coupe diary	Maintain a coupe diary.	FPC
Surveillance	Conduct surveillance according to risk period (Schedule 12). Verify, through surveillance that the conditions of authorisation are being complied with.	DEC & FPC
Rutting and erosion	Conduct rutting and erosion survey according to risk period (Schedule 12).	DEC & FPC
Transect survey	Conduct transect survey according to risk period (Schedule 12).	DEC & FPC
Provision of monitoring information	Send all survey results to DEC (weekly). Provide surveillance records and coupe diary if requested. Send all DEC and FPC monitoring results to Forest Policy and Practices Branch at the end of each month.	FPC FPC DEC
Key Performance Indicator 21	Report the level of soil damage by risk category resulting from timber harvesting annually. Measurement must be by transect survey.	DEC

5.3.2 Notification

FPC is to notify DEC of active, completed and dormant feller's blocks each Monday. DEC is to notify FPC prior to entering an active feller's block.

5.3.3 Coupe Diary

A coupe diary must be maintained by FPC Coupe OIC. Information to be record in the coupe diary includes:

- A record of each day that each feller's block was operated in;
- Machinery that was used;
- Date of completion of each phase of the harvesting for each feller's block;
- Any decisions to cease harvesting and the reasons for cessation particularly those related to soils;
- Decisions made regarding issues of compliance (date and time of stoppages);
- Records of discussions and agreement between FPC and DEC staff;
- Record of action taken in response to breaches or non-compliance;
- Health and safety issues associated with the coupe;
- Instructions issued to FPC contractors;
- Coupe data such as rainfall records; and
- Date and time and type of monitoring undertaken.

5.3.4 Monitoring of soil disturbance

Type of monitoring

Monitoring of soil disturbance occurs at two levels – surveillance and formal survey.

- **Surveillance** is a rapid method of appraisal and is used to provide a quick check on the condition of a feller's block prior to start-up in the morning. Surveillance relies on visually assessing key indicators of site condition in relation to the conditions of approval to operate. Surveillance may be used as a trigger to determine whether more formal survey methods are required and can be used to modify management in a pro-active manner.
- **Formal survey** is a more comprehensive method of assessment which includes the measurement of specific criteria in order to check their status in relation to allowable limits. Formal survey is used by FPC to manage operations with allowable limits of soil disturbance. Formal survey is used by DEC after completion of harvesting and extraction operations to audit the performance of FPC against allowable limits. The survey of rutting and erosion and transect survey of visible soil disturbance are both formal surveys.

Description of monitoring techniques and standard forms for monitoring soil disturbance are provided in SFM Manual No. 1.

Frequency of monitoring

The frequency of monitoring required by DEC and FPC varies with the type of operation and risk period. Details of requirements are provided in Schedules 12 and 13.

Responsibilities for data collection and provision of information

Monitoring of soil disturbance by officers of the Forest Products Commission is the responsibility of the FPC Authorised Officer (Coupe OIC). The data collected by these officers is to be copied to DEC's Regional Leader of SFM as identified in Schedule 14. The information will be used to facilitate the review of implementation of the provisions of the FMP.

Monitoring of soil disturbance by officers of DEC is the responsibility of DEC's Regional Leaders for SFM located in the Swan, South West and Warren Regions. The data collected by these officers and that provided by FPC is to be collated by the Regional Leader for SFM and copied to Forest Policy and Practices Branch to facilitate review and continuous improvement in forest management practices.

Assessment criteria

Visual soil disturbance types prescribed in Schedules 5 are to be used as the basis for rating soil disturbance. The ratings vary according to the severity of disturbance from undisturbed (D0) to Very Severely Disturbed (D4). On extraction tracks, default disturbance categories apply (SFM Manual No. 1) unless there is clear evidence supporting another disturbance rating. The total disturbance percentages for each type in a feller's block together with the size of the landing and presence of rutting and erosion are to be assessed against the allowable limits prescribed in Schedules 6 – 8.

Further detail of surveillance and survey technique, together with standard forms for conducting monitoring may be found in DEC SFM Manual No. 1.

5.4 Review of timber harvesting

Table15 Mandatory actions for the review of timber harvesting

Topic	Action	Responsibility
Effectiveness of soil protection measures	DEC, in consultation with FPC and the Conservation Commission will continue to review the effectiveness of the system and the soil protection measures will be revised if appropriate to achieve the objective.	DEC, FPC, CC
Soil damage levels	If soil damage exceeds prescribed maximum levels, investigate the cause and report it to the Conservation Commission and to the Minister for the Environment.	DEC

6 Public Drinking Water Supply Areas (PDWSAs)

6.1 Mandatory planning actions in public drinking water supply areas

Table 16 Summary of mandatory planning actions in PDWSAs

Topic	Action	Responsibility
Identification of PDWSAs	Ensure that all planning for forest management takes into account the location of PDWSAs.	All planners and managers
Fire Management	Liaise with DoW to ensure that where required, site specific actions relating to water quality protection are incorporated into prescribed burn prescriptions and wildfire operations.	FMS
Notification and communication	Ensure that planned forest management activities occurring on PDWSAs are communicated to DoW.	DEC, FPC, proponents

6.1.1 Identification and description of PDWSAs

Public Drinking Water Supply Areas (PDWSAs) include all underground water pollution control areas, catchment areas and water reserves constituted under the *Metropolitan Water Supply, Sewerage and Drainage Act (1909)* (MWSSD Act) and the *Country Areas Water Supply Act (1947)* (CAWS Act).

Defining PDWSAs

DoW is primarily responsible for defining, proclaiming and protecting the PDWSAs. A full list of currently gazetted areas is available in the Department's Water Quality Protection Note 75 *Gazetted Public Drinking Water Source Areas.* These areas are shown on DoW Internet site www.water.wa.gov.au, (select *Maps, atlases and data > Geographic data atlas > Environment > Public Drinking Water Source Areas*). PDWSAs are generally defined by the topography of surface water catchments or the recharge areas and capture zones of the well fields for groundwater sources. These areas are proclaimed (gazetted) as Water Reserves, Catchment Areas or Underground Water Pollution Control Areas under the MWSSD Act, or as Water Reserves or Catchment Areas under the CAWS Act.

Public Drinking Water Source Area and the Water Protection By-laws

Proclaiming a metropolitan or country Public Drinking Water Source Area triggers the statutory application of the respective water source protection by-laws to the PDWSA. The objective of the by-laws is to prevent deterioration of the water quality, control development and regulate the transient activities of the public in surface water catchments. Surface water requires greater protection from human activities in and around the water such as the contamination of the surface water with human wastes and disease causing pathogens.

The *Metropolitan Water Supply and Sewerage Drainage By-laws 1981* currently apply to:

- Six Perth metropolitan Underground Water Pollution Control Areas e.g. Gnangara; and
- Fifteen surface catchment areas e.g. Canning Catchment Area.

The *Country Areas Water Supply By-laws (1957)* apply to about 120 surface water catchment areas and groundwater reserves. There are two main water supply schemes supplied by CAWS surface catchments. These are the Goldfields and Agricultural Supply Scheme, which is supplied from Mundaring weir (which is also supplemented by the Integrated Water Supply Scheme), and the Great Southern Towns Water Supply Scheme which is supplied from the Harris Reservoir.

Details on the location of specific PDWSAs are available in the relevant Land Use and Water Management Strategy, Drinking Water Source Protection Plans or by reference to DoW web site. The water protection by-laws are currently being reviewed to provide more consistent and updated legislative controls in PDWSA.

6.1.2 Priority Classification Areas and Protection Zones

In Public Drinking Water Source Areas there are three levels of water quality protection called priority classification areas and two types of protection zones.

- **Priority 1 (P1)** source protection areas are defined to ensure there is no degradation of the water resource. They cover land normally owned by the State where the provision of the highest quality drinking water is the prime land use value. P1 areas are managed with the principle of risk avoidance.
- **Priority 2 (P2)** source protection areas are defined to ensure that there is no increase in risk of pollution to the water source. P2 areas are declared over land where low intensity development (such as rural) already exists. Protection of public water supply sources is a high priority in these areas. P2 areas are managed in accordance with the principle of risk minimisation and some development is allowed under specific guidelines.
- **Priority 3 (P3)** source protection areas are defined to limit the risk of pollution to the water source. P3 areas are declared over land where water supply sources need to co-exist with other land uses such as residential, commercial and light industrial developments. Protection of P3 areas is achieved through management guidelines rather than restrictions on land use. If the water source does become contaminated, then water supplies may need to be treated or an alternative water source found.
- **Wellhead and Reservoir Protection Zones -** in addition to the three Priority Classification Areas, specific protection zones are defined to protect drinking water sources from contamination in the immediate vicinity of water extraction facilities. Within these zones by-laws may prohibit, restrict or approve defined land uses and activities to prevent water source contamination or pollution. Special conditions, such as restrictions on storage and use of chemicals, may apply within these zones. The legislation is currently being reviewed to simplify and enhance the protection of public drinking water sources.
  - *Wellhead protection zones (WHPZ)* are used to protect underground sources of drinking water. They are circular (unless information is available to determine a different shape), with a radius of 500 metres in P1 areas, and 300 metres in P2 and P3 areas. WHPZ do not extend outside PDWSA boundaries.
  - *Reservoir protection zones (or 'prohibited zones' as they are called in the by-laws)* consist of a statutory buffer of up to two kilometres as shown in the relevant drinking water source protection plan, and include the reservoir water-body. The reservoir protection zones (RPZ) apply over Crown land and prohibit public access to prevent contamination (physical, chemical and biological) of the source water. RPZ do not extend outside PDWSA boundaries.

Special protection measures apply in WHPZ and RPZ (prohibited zones) as described in the by-laws under the MWSSD Act and the CAWS Act.

6.1.3 Activities within PDWSAs

Activities within a PDWSA are regulated according to risk and impact. Some of the activities that potentially relate to forest management include chemical storage, surface water management, waste management, pesticide, herbicide or fertiliser application (see mandatory actions in 6.2 below).

6.2 Implementation of forest management in PDWSAs

Table 17 Summary of Mandatory actions for the implementation of forest management in PDWSAs

Topic	Action	Responsibility
Stream zones	Conduct operations in a manner that has regard to the provisions for stream zones in accordance with Schedule 17 and with the Guidelines for the Management of Informal Reserves.	DEC, FPC, DoW Proponents
Use of herbicides, pesticides and chemicals	Use of pesticides to be in accordance with Appendix 3 (DOH's PSC 88 "*Use of herbicides in water catchment areas*"). Use of herbicides to be in accordance with Appendix 2 (Extract from DoW's Statewide Policy No. 2 Pesticide use in PDWSAs). Use of chemicals to be subject to arrangements with DoW.	DEC, FPC, Proponents
Prevention of turbidity	Manage surface water in accordance with schedules 19 – 22. Use of roads adjacent to reservoirs shall be subject to arrangements between DoW and FPC. Winter harvesting adjacent to reservoirs shall be subject to arrangements between DoW and FPC.	DEC, FPC, DoW, Proponents
Track closure	Close and rehabilitate unnecessary roads and tracks according to schedules 23 and 24 following timber harvesting to reduce public access and potential erosion problems.	DEC, FPC
Fire Management	Liaise with Water Corporation rangers regarding fire operations. Inspect catchment areas following fire to assess the need for turbidity mitigation works. Rehabilitate emergency firebreaks as soon as possible according to Schedules 23 and 24. Use suppressants and retardants in accordance with DEC Fire Operations Guideline 76.	DEC, DOW and WC
Gravel pits	Do not establish unauthorised gravel pits within a RPZ. Ensure that gravel extraction occurs in accordance with DEC advisory note r. Close and rehabilitate gravel pits that are not required for forest management operations or road maintenance according to schedules 23 and 24.	DEC, FPC, Contractors
Infrastructure maintenance - power lines, pipelines and roads	Ensure that maintenance workers are aware of water quality protection objectives and that adherence to water quality protection is a condition of approval for access within PDWSAs. For information on drinking water protection requirements, contact DoW's Water Source Protection Branch in Perth: Ph: 6364 6700 or fax: 6364 6516.	DEC, DoW, WC
Harvest restrictions	No harvesting operations, including roadworks may take place within 500 m of the high water mark of any reservoir without prior notification to the relevant Water Corporation office.	FPC
Waste management during harvest operations	Control pollution in accordance with Appendix 1. Ablutions shall not occur within 100 m of water reservoir or tributary streams and any human or animal waste will be buried to a minimum depth of 15 cm. Portable chemical toilets may be required if harvesting is within the RPZ.	FPC and contractors
Abstraction of	Where water is abstracted from the environment, ensure that statutory	All users

water	approvals and licenses are obtained from DoW in proclaimed areas or DEC in other areas of State forest and timber reserve.	

6.3 Monitoring requirements in PDWSAs

Table 18: Summary of mandatory monitoring actions in PDWSAs

Topic	Action	Responsibility
Compliance with mandatory actions	Monitor to ensure compliance with the mandatory actions in 6.2 above.	FPC, DEC, DOC, WC, Proponents
Record soil damage	Record the location of damaged soil so that it can be rehabilitated.	All
Monitor rehabilitatio n	Monitor the success of rehabilitation and conduct follow-up work if required.	All
Monitoring by forest management activity	Mandatory review requirements for the forest management activities outlined in Sections 5 and 7 will occur in PDWSAs.	All

6.4 Review of timber harvesting in water catchment areas

Table 19: Summary of mandatory review actions in PDWSAs

Topic	Action	Responsibility
Review of road network	Review the extent and condition of public access ways leading to public water catchment areas, with a view to considering whether the number of access ways ought to be reduced or their condition improved.	DEC, DOW, WC
Review by forest management activity	Apply the mandatory review requirements for timber harvesting and fire management as described in Sections 5 and 7 where these land management practices occur in PDWSAs.	All

7 Fire Management

7.1 Planning for Fire Management

7.1.1 Summary of mandatory planning actions for fire management

A summary mandatory planning action for fire management is shown in Table 20 below.

Table 20: Mandatory actions for the planning phase of fire management

Topic	Action	Responsibility
Legislation	Requirements of legislation, policies, guidelines, manuals and other regulatory documents are to be met.	DEC, others
Environmental care	Principles of environmental care must guide all preparedness, suppression, recovery and prescribed burning activities.	FMS
Identification of areas requiring protection or special management	Determine whether the fire management area is likely to contain drinking water source reservoirs, caves, steep slopes, erodible soils, rock outcrops or special formations, peat swamps, organic soils or other fragile or sensitive areas. Determine whether specific drinking water protection is required. Prescribe appropriate management response to the risk of damage.	FMS
Training and preparedness	Maintain a comprehensive set of standards, procedures and prescriptions relating to fire management activity supported by training for all personnel involved in fire management.	FMS

7.2 Implementation of fire management

7.2.1 Summary of mandatory implementation actions for fire management

A summary of mandatory actions for the implementation of fire management is shown in Table 21 below.

Table 21: Mandatory actions for the implementation of fire management

Topic	Action	Responsibility
Use of heavy machinery for burn preparation	Conduct operations involving the use of heavy machinery for burn preparation in a manner that has regard to the requirements of Schedule 16.	DEC FPC Other agencies
Minimisation of environmental harm	Where possible: • The containment of fires will be undertaken with due regard to minimising the disturbance of soil and vegetation; • When constructing mineral earth firelines, machine operators should attempt to remove the litter and leave the soil profile intact; • When constructing firelines, attempt to minimise disturbance by utilising natural openings in the vegetation; • Fireline that crosses streams and rivers should be rehabilitated immediately the crossing is no longer required; and • Modify construction standards in sensitive areas.	DEC
Use of foams and retardants	Refer to Fire Operations Guideline 76 – Use of suppressants and retardants. Only products that have been approved for use by the USDA Forest Service are to be used in DEC operations or applied to DEC managed lands. Wherever possible: • Foams and retardants are not to be applied within 100 m of any standing water body or wetland; • Foams and retardants are not to be mixed within 200 m of any water body or wetland; and • All aerial retardant applications should utilise gum-thickened retardants, which provide the best accuracy, effectiveness and reduce the likelihood of drift.	DEC
Rehabilitation of damaged soil	Refer to Fire Management Guideline G2 Fireline Stabilisation and Rehabilitation. Where firelines are constructed or other soil damage occurs during suppression operations, the damage must be subsequently rehabilitated according to Schedules 23 and 24 to minimise the threat of soil erosion by: • Identifying and mapping damaged soil; and • Undertaking rehabilitation work as soon as is reasonable and practicable after the completion of the operation.	DEC
Prevention of turbid water flows	As part of the post-burn recovery plan inspect, install and maintain surface water management structures such as culverts, sediment traps, spreaders and cross-road drainage (Schedules 19-22).	DEC
Waste management	Control waste and pollution during the course of operations. Remove all waste or spillage from the fire ground and associated areas.	All

7.2.2 Protection of firefighters and the public

The protection of soil and water values is a key requirement in the management of fire. However, fire-fighter and public safety is the first priority in every fire management activity. At times, action may be taken for the protection of firefighters or the public that impact on soil and water values. Where this occurs, the threats to these values must be identified and rehabilitation conducted after the event.

7.2.3 Fireline construction principles for the minimisation of environmental harm

During fire suppression operations, it is important that potential long-term environmental damage is minimised. In some cases the inappropriate use of machines during fire suppression operations can result in greater environmental damage than if the fire was allowed to continue to burn. All personnel concerned with the construction of firelines must remain sensitive to the damage that can be caused through the inappropriate use of machinery. Remember that even during fire control operations most long-term environmental damage can be avoided or minimised if the fireline is appropriately located and constructed.

When constructing mineral earth firelines, the aim of machinery operators should be to remove the litter and leave the soil profile intact.

Selecting routes for fireline construction

Make maximum use of natural or existing barriers. It must be remembered that it is pointless to construct a fireline if a suitable barrier already exists.

In determining the width and construction of tracks consider:

- Whether environmental considerations are important. For example, machine work may be unacceptable in highly sensitive areas and there is a general requirement for lines to be constructed in such a manner as to allow rehabilitation with minimal work at a later date;
- Modify construction standards in sensitive areas; and
- When constructing turnarounds attempt to minimise disturbance by utilising natural openings in the vegetation.

Topographical and vegetation factors to consider when selecting a route for construction of a fireline

Where possible the following areas should be avoided during fireline construction - particularly with machinery:

- Steep country;
- Swamps, boggy ground and sand dunes;
- Excessively rough ground e.g. rocky outcrops, breakaways;
- River and stream crossings; and
- Heavy forest types and fuels.

Steep Country

Consider:

- Working straight up and down to minimise catchment area;
- Potential for erosion to occur at a later date and the cost of remedial action;
- Establishing cut-off or mitre drains when establishing turnarounds and passing bays;
- Constructing drains as required by mounding dirt rather than digging; and
- Problems associated with side cutting: time consuming, expensive and the potential to collect water.

Swamps, Boggy Ground and Sandy Areas

Construction of firelines in these areas should be avoided if possible because the cost of rehabilitation may often outweigh the advantages of fire suppression. However, occasionally machines will be required to track through swamps or other areas of boggy ground. Dozers and wheeled loaders will often encounter serious difficulties in wet or boggy ground. Generally smaller to medium size dozers are best suited to this type of work especially if fitted with extra wide or swamp tracks.

River and Stream Crossings

River and stream crossings should be avoided wherever possible. However, it will on occasions be necessary to construct firelines that traverse creeks or rivers. This may require a machine to cross or ford a creek or river. Some points to consider include:

- Never cross a river or major creek if it is avoidable. Construct the fireline at a suitable position either side of the river and construct a rake trail or hoseline to the riverbank to contain the fire;
- Never attempt a water crossing until permission has been gained from your direct supervisor;
- Both banks should have gentle slopes for ease of entrance and exit;
- Where possible employ two machines for safety; and
- Where possible, use fallen logs to fill crossings that have steep banks to elevate the fill level and remove when the fire is safe.

Exclude Areas of Heavy Fuel Concentration

Locate fireline in the areas of lowest fuel if possible. This will make the tasks of fireline construction and mop-up much easier.

Note:	Further information can be obtained by reading Fireline Construction with Machines DEC Learner's Guide Module 2.35.

7.2.4 Use of suppressants and retardants

Retardants can be applied in situations where the construction of mineral earth control lines may be unacceptable for environmental reasons. Only products that have been approved for use by the USDA Forest Service are to be used in DEC operations or applied to DEC managed lands.

Guidelines for the use of foams and retardants are contained in Fire Operational Guideline (FOG) 72 – Use of suppressants and retardants:

- Foams and retardants are not to be applied within 100 m of any standing water body or wetland;
- Foams and retardants are not to be mixed within 200 m of any water body or wetland; and
- All aerial retardant applications should utilise gum-thickened retardants, which provide the best accuracy and effectiveness and reduce the likelihood of drift.

Exceptions:

- When alternative line construction tactics are not available it is acceptable to anchor the foam or retardant application to the waterway using the most accurate method of delivery (e.g. helicopter);
- When life or property is threatened and the use of retardant or foam can be reasonably expected to alleviate the threat; and
- When potential damage to natural resources outweighs possible loss of aquatic life, the incident controller may approve a deviation from these guidelines.

Note:	Further information can be obtained by reading DEC Fire Operational Guideline 76.

7.2.5 Recovery Plans

Purpose

The purpose of a recovery plan is to ensure the environmental, social and economical impacts of a Fire are minimised by ensuring:

- Clear achievable recovery objectives are established for key values;
- All key recovery actions are identified; and
- Appropriate recovery actions are detailed, required resources estimated and implementation responsibilities are assigned.

Key implementation objectives relating to soil and water management include:

- Identification and rehabilitation of damaged soil;
- Control of soil erosion; and
- Measures to minimise turbid water flows.

7.3 Monitoring of fire management

7.3.1 Summary of mandatory monitoring actions for fire management

A summary of mandatory actions for the monitoring of fire management is shown in Table 22 below.

Table 22: Mandatory actions for the monitoring of fire management

Topic	Action	Responsibility
Record soil damage.	Record the location of damaged soil so that it can be rehabilitated as part of the fire recovery plan.	DEC
Burn preparation soil disturbance monitoring	Conduct monitoring or surveillance according to Schedule 16 for burn preparation conducted during moist soil conditions.	DEC
Monitor the success of rehabilitation on disturbed areas	Inspect rehabilitated areas to ensure that they are protected adequately, clean culverts etc.	DEC

7.4 Review of fire management

7.4.1 Summary of mandatory review actions for fire management

A summary of mandatory actions for the review of fire management is shown in Table 23 below.

Table 23: Mandatory actions for the review of fire management

Topic	Action	Responsibility
Monitoring and audit	The achievement of fire management objectives contained in DECs prescribed burning programs and in area management plans will be subject to periodic audit by the Conservation Commission.	CC

8 Glossary

Annual Exceedence Probability	The probability that a given rainfall total accumulated over a given duration will be exceeded in any one year.
Average Recurrence Interval	The average, or expected, value of the periods between exceedances of a given rainfall total accumulated over a given duration.
Biodiversity	The number or variety of species in an environment or ecosystem.
Block	A named administrative subdivision of the forest, varying in size from about 3,000 to 8,000 hectares.
Brushing	A dense thick layer of small diameter log, branch and woody understorey material that is randomly laid to form an interlocked mat and distribute vehicle load over a wide area.
Catch drain	See "**Spreader**".
Cell	See "**feller's block**".
Clay	A soil texture class consisting primarily of fine grained minerals less than 0.002 mm in diameter, which is generally plastic at appropriate water contents and will harden when dried.
Compression	Packing resulting from a vertical force from wheels or tracks
Coupe	An area of forest that is planned for timber harvesting as a single unit. It may contain more than one silvicultural objective, such as a number of discrete gaps or clearfells or a combination of both.
Cording/corduroy	Corduroy, or cording, is round or split log material that is closely and continuously laid at right angles to the direction of the extraction tracks, or placed on landings, to distribute the machine load over a large area and reduce soil compaction, mixing, and rutting.
Disturbance	Any range of conditions affecting the condition of a natural area. Disturbance may be natural (e.g. fire) or human induced (e.g. timber harvesting).
Drizzle[1]	Fairly uniform precipitation composed exclusively of fine drops of water (diameter less than 0.5 mm) very close to one another. The drops appear almost to float, thus making visible even slight movement of the air. Drizzle is associated with the following cloud types; stratocumulus, and stratus.
Erosion	The wearing away of the land surface by rain, running water, wind, ice, gravity, or other natural or anthropogenic agents.
Eutrophication	Artificially high nutrient levels in a stream or water body.
Extraction track	A track along which logs are pulled or carried from the felling point at the stump to a landing or point of loading.
Feeder extraction track	A second or higher order extraction track that leads onto a primary extraction track.
Feller's block	The area of harvest supplying timber to an individual landing. The term "cell" may also be used to describe this management unit of harvesting.
Flood index method	A method of estimating peak flow (floods) for a given ARI based on flood frequency data from catchments based on relationships between observed flood frequency data and catchment characteristics. The peak flow is used to design surface water management structures for a given ARI.
Forwarder	A self-propelled machine, usually self-loading, that is used to extract logs by carrying them completely off the ground, usually in a bunker behind the cabin.
Forwarder landing	A cleared area, generally along the edge of a road or track, where logs are stored prior to transport. These will generally be based on an adapted road network with widened "pull-off" areas to allow trucks and trailers to be parked and loaded. There may be significant areas of moderate soil disturbance but only small areas of severe soil damage.

Forwarder track	A track along which a forwarder carries logs, completely off the ground, from the felling point to a landing or point of loading.
Free water	Free water is defined as any puddles or overland flow anywhere in the feller's block, but in particular on the extraction track.
Gouge	See "**Log gouge**".
Gully erosion	The removal of soil in large channels called gullies. Gullies are often defined as being more than 30 cm deep and can incise up to several metres into the soil. They are typically steep sided and have branches. Gully formation occurs as a result of runoff or a combination of runoff and seepage.
Habitat	The set of conditions required for a population to effectively survive
Headward erosion	Gully or rill enlargement in an upstream direction due to incision by concentrated runoff and the formation of a waterfall and splash pool. The action of water at the waterfall and splash pool will lead to undercutting and slumping of the gully head. This type of erosion is commonly associated with roadside table drains and culverts. It is an indicator of potential rapid escalation of damage, and should be addressed promptly.
High rainfall zone	Areas receiving greater than 1100 mm of mean annual rainfall.
In-slope (roads or tracks)	Cross-fall roads or tracks constructed with a grade sloping in towards the cut (uphill) section. Runoff from the track surface drains towards the cut slope and is collected in a table drain.
Intermediate rainfall zone	Areas receiving between 900 and 1100 mm of mean annual rainfall.
Inter-rill erosion	See **Sheet erosion.**
Landing	A cleared area in the forest to which logs are yarded or skidded for loading on to trucks for transport. The landing is considered to be the area where there is repeated machine movement and/or severe soil disturbance resulting from the movement or stockpiling of logs.
Level sill	A level outlet section of a soil conservation structure (in the form of a reversed bank), which spreads water flowing from the structure thereby preventing erosion.
Litter layer	The surface layer of the forest floor that is not in an advanced stage of decomposition, usually consisting of freshly fallen leaves, needles, twigs, stems, bark and fruit.
Log gouge	A furrow or depression in the soil caused by the action of dragging logs during extraction. Where they occur, they are generally found running down the centre of the extraction track.
Log storage area	A cleared area adjacent to a landing that is not subjected to repeated machine movement, or severe soil disturbance from log movement, or stockpiling. Generally associated with operations of forwarders or static loaders.
Lower plastic limit	The moisture content when soil changes from being brittle to plastic and is the minimum moisture content at which the soil can be moulded. It is also the maximum moisture content at which the soil is friable. In most soils it is at or near the upper limit of water storage (field capacity). Puddling begins to occur at the lower plastic limit.
Low rainfall zone	Areas receiving less than 900 mm mean annual rainfall.
Mass movement	Includes slumps, earth flows, soil creep and landslides. Mass movement is a form of erosion where water is often involved but the primary agent of movement is gravity. It is most common in high rainfall areas on steep slopes with gradients in excess of around 27 per cent (15°), that have been cleared or had significant amounts of vegetation removed.
Matting	Material such as bark or wood chips that is used to cover an extraction track or landing, whether by itself or in addition to cording, to reduce soil disturbance, improve trafficability or reduce unevenness of cording to improve operator comfort.

Mitre Drain	A drain to conduct runoff from table drains to a disposal area away from a road.

Monitoring	Regular assessment of a management program and of the resources being managed, checking that desired outcomes are achieved, and adjusting the plan where necessary.
Mounding	Heaping of the soil. This is caused by the movement and deposition of soil onto the ground, or by the upward movement of the soil due to pressure applied to the adjacent ground.
Out-slope (roads and tracks)	Roads or tracks which slope to the natural downhill (out-slope) side. Out-slope roads usually require less excavation and clearing than other road types. Water on the road surface runs directly off the side of the road and negates the requirement for constructing table drains and culverts.
Parent material	The unconsolidated or less chemically weathered mineral material from which the soil horizons are developed by pedogenic processes. For the purpose of DEC assessment of soil disturbance, parent material is also considered as soil material at a depth greater than 50 cm below ground level.
Peak Flow	The maximum flow through a watercourse which will recur with a stated ARI or AEP. The maximum flow for a given frequency may be based on measured data, calculated using statistical analysis of peak flow data, or calculated using hydrologic analysis techniques. Projected peak flows are used in the design of culverts, bridges, and dam spillways.
Pedogenic process	A pedogenic process is any chemical or physical process that contributes to the formation of soil through the break-down or combination of minerals and mineral material.
Primary extraction track	The main extraction track that leads into a landing.
Puddling	The combination of water and repeated mechanical disturbance of soil, often as a slurry or under saturated conditions. Puddling breaks down natural soil aggregates and realigns soil particles, generally resulting in dramatically poorer aeration and drainage and exacerbating the effects of compaction.
Rain[1]	Precipitation of liquid water particles, either in the form of drops of more than 0.5 mm in diameter, or of widely scattered smaller drops. May be distinguished from drizzle by the fact that drops are scattered. Rain is associated with the following cloud types; altostratus, nimbostratus, stratocumulus, cumulus and cumulonimbus. Rain does not include drizzle or intermittent light showers. It does include persistent light showers, intermittent medium or heavy showers or more intense forms of precipitation.
Rational method	The Rational method is a probabilistic or statistical method used in estimating peak flow (floods) for a given ARI in order to design surface water management structures.
Rill erosion	The removal of soil by runoff in numerous small channels (rills) which are commonly around 5 to 10 mm deep (but may be much greater). Rills typically form on cultivated or disturbed soils. Sandy soils are particularly prone to rill erosion.
Ripping	Mechanical penetration and shattering of soil, generally beneath the topsoil, for the purpose of breaking up compacted soil to facilitate penetration of plant roots and water. Ripping is usually undertaken using a winged-tyne mounted on the rear of a bulldozer.
Rolling dip	A trafficable dip excavated on a grade and with gentle side slopes to divert water off a track or road. Spoil is runoff downhill from the dip on gentler slopes or incorporated into side slopes of downhill bund.
Rut	A rut is a depression in the soil surface initially caused by the passage of machine tyres or tracks over the soil surface. Rut development may also involve the processes of soil removal, mixing and puddling.

Scalping	Removal of a layer of soil. Typically caused by scraping of the soil surface.

Scarification	Loosening of the soil surface to assist germination and establishment of seedlings.
Sheet erosion	(Or inter-rill erosion) is the removal of a uniform layer of soil by raindrop splash and/or runoff. No perceptible channels are formed and soil particles are either transported to rills, gullies and streams or moved further down-slope where they are liable to be displaced by subsequent erosion.
Soil compaction	The process by which soil particles are rearranged, resulting in a decrease in void space and causing closer contact with one another, thereby increasing bulk density. Soil compaction can result from applied loads, vibration or pressure from harvesting or site preparation equipment. Compaction can cause decreased tree growth, increased water runoff and erosion.
Soil damage	An undesirable level of soil disturbance.
Soil disturbance	Any range of events affecting the condition of the soil in an area. Soil disturbance may be natural (e.g. fire) or human induced (e.g. timber harvesting) and may be beneficial (e.g. facilitating establishment of seedlings) or detrimental (e.g. causing compaction).
Soil profile disturbance	The mixing and/or removal of soil layers which may be caused by machine activity or the movement of logs.
Soil disturbance categories	**Undisturbed** – characterised by an intact litter layer. **Lightly disturbed** – characterised by the litter layer being disturbed or a light disturbance to the topsoil. **Moderately disturbed** – characterised by the topsoil mixed with subsoil or the topsoil partially removed. **Severely disturbed** – characterised by the topsoil completely removed and subsoil exposed or the topsoil mixed with subsoil, or the subsoil disturbed, or subsoil mixed with parent material or soil at greater than 50 cm depth, or the subsoil partially removed. **Very severely disturbed** – disturbance that involves parent material or soil layers that are greater than 50 cm below the soil surface (excluding caprock), or meets any of the definitions of very severe soil disturbance in Appendix 3.
Soil mixing	A type of soil profile disturbance which occurs when soil horizons such as the topsoil and subsoil are mixed.
Soil strength	A measure of the capacity of a soil mass to withstand stresses without giving way to those stresses by rupturing (failing suddenly and quickly) or becoming deformed (failing gradually by compression). Soil strength is measured in megapascals (MPa) which indicate penetration resistance.
Spreader	(Sometime called catch drain). A short section of bank constructed on a grade and diverting channeled flow of closed tracks, shallow gullies or gully fill. Structures are used to divert water to a safe disposal area. Often used with level sills at the discharge end.
Streambank erosion	The removal of soil from the banks of streams by the action of water or sediment flowing in the stream. It is usually most severe on outside bends during high flows as this is where energy is most concentrated.
Subsoil	The layer of soil below the topsoil, which is lacking in organic matter. It is typically a lighter colour than the topsoil and may also have a higher clay content, or be a clay layer.
Surface water management	The process of managing runoff in such a way as to protect the environment and resources.
Table drain	A side drain of a road constructed adjacent and parallel to the road's shoulders.
Thinning	A felling made in an immature stand usually for the purpose of improving the growth of trees that remain and encouraging regeneration

	without permanently breaking the canopy. Thinning can also have other purposes such as water production.
Timber harvesting	The cutting, felling, and gathering of forest timber undertaken as part of a planned sequence of silvicultural activities including the regeneration of the forest.
Topsoil	The uppermost layer of soil beneath the litter that is darkened by the organic matter which has been incorporated into the soil and contains the majority of fine roots.
Trafficability Index$_{SDI}$ (TI$_{SDI}$)	A predictor of the deficiency of soil moisture in a hypothetical soil profile having 200 mm capacity. The predictor uses rainfall input, runoff, evaporation and transpiration by plants. The measure is zero when soils are at field capacity and 2000 when completely dry.
Trigger values	The concentrations (or loads) of the key performance indicators measured for the ecosystem, below which there exists a low risk that adverse biological (ecological) effects will occur. They indicate a risk of impact if exceeded and should 'trigger' some action, either further ecosystem specific investigations or implementation of management/remedial actions.
Traverse culvert	A culvert installed under a road or track to relieve flow in uphill table drains.
Tunnel erosion	(Or tunnelling) occurs where sub-surface soil is less stable than the topsoil and removed by erosion while the topsoil remains intact (until the tunnel collapses and a gully is formed). Field and laboratory tests are available to detect the presence of unstable subsoil.
Turbidity	Discoloration of water due to suspended solids, dissolved solids, chemicals, algae etc.
Upper plastic limit	(Or liquid limit) is the moisture content at which the soil changes from a plastic solid to a viscous liquid.
Wind erosion	A type of erosion in which soil is detached and transported from the land surface by the action of wind.

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10 SCHEDULES

Schedule 1 Soil management risk periods in relation to Trafficability Index (TI_{SDI}) and other factors.

TI_{SDI} value	Pre-trans & transitional (1 Mar-31 Aug)	Post-transitional (1 Mar-31 Aug)		Spring / Summer (1 Sep-28 Feb)	
	All soils	UGS soils	Non-UGS soils	UGS soils	Non-UGS soils
TI=0	MH	H-	H	H-	H
0<TI≤50	MH	MH	H-	MH	H-
50<TI≤250	M	MH	H-	MH	H-
250<TI≤500	M	M	M	M	M
500<TI≤750	L	L	L	M	M
TI>750	L	L	L	L	L

UGS = Upland gravels and sands (excluding the Blackwood Plateau)[1]
L = Low risk period
M = Medium risk period
MH = Medium to high risk period
H = High risk period
H– = High risk period if it is raining or free water is present, or Medium to high risk period if it is not raining and no free water is present

[1] Soil types (upland gravels and sands, other soils) are as described by Rab et al. 2005. The custodian of the map of soil types to be used for this purpose is the Forest Management Branch of the Department of Environment and Conservation. Blackwood Plateau is as described by Mattiske and Havel 1998. Refer to point 4 on page 2.

Values of TI_{SDI} are calculated and published daily and can be found on the DEC intranet page http://calmweb.calm.wa.gov.au/drb/sfm/fmb/sti_estimates.htm. The values at this site are to be used by all DEC and FPC officers implementing management and monitoring requirements in relation to TI_{SDI}. Further details on applying the Trafficability Index $_{SDI}$ system are provided in Schedules 2 and 3. It is a mandatory requirement for timber harvesting to operate using this system.

Schedule 2 Defining acceptable soil moisture conditions for the off-road operation of heavy vehicles

The Trafficability Index SDI (TI SDI) is a measure of soil moisture that is indicative of the capacity of the soil to cope with traffic from heavy vehicles and is used to set thresholds to define risk levels for soil damage. The TI SDI thresholds in relation to risk periods are summarised in Schedule 1 and described below.

The TI SDI to be used to determine the risk level will be that estimated for the location of the harvesting operation by DEC using the TI SDI system.

The Director of SFM or a delegated officer will have the authority to set more specific TI SDI thresholds and the Conservation Commission will be notified when this occurs.

The mapped soil types described by Rab et al. (2005) and Blackwood Plateau as described by Mattiske and Havel (1998) will be used as the primary determinant of soil type and associated risk period for the Medium to high (post transitional stage) and High risk periods. Where FPC presents information, to DEC's satisfaction, that demonstrates that an alternative interpretation of soil type is appropriate, then this alternative may be used.

- Low risk is when soils are relatively dry. The TI SDI is greater than 500 in autumn or winter or greater than 750 in spring or summer;
- Medium risk is when soils may be moist enough that soil damage could occur, depending on the specific soil, management and vehicle factors. The TI SDI is:
  - □ Less than or equal to 500 and greater than 50 in the wetting up phase of the year (autumn or winter – pre-transitional (see below)); or
  - □ Less than or equal to 500 and greater than 250 in the wet season after the transitional stage of the Medium to high risk period (see below) has been passed through; or
  - □ Greater than 250 and less than or equal to 750 in the drying out phase of the year (spring or summer);
- Medium to high risk is when soils are moist or wet and soil damage is likely in parts of most working areas unless intensive management action is taken to avoid such damage and attention to soil type, topography and position in the landscape is given. This period has two stages:
  - □ *Medium to high risk period - Transitional stage*

    A transitional stage in the wetting up phase of the year (autumn or winter) in the Medium to high risk period is recognised to account for the observed over-estimation of the risk of soil damage using TI SDI. The over-estimation was recognised in the 2004 soil damage risk periods but inadequate allowance was made for it.

    The transitional stage commences from the first day that the TI SDI has fallen to 50 or below in the wetting up phase of the year (autumn or winter). In the circumstance where the transitional stage has been initiated, but due to subsequent drying conditions the TI SDI rises above 50 before it has fallen to 0, the transitional stage will be cancelled. A new transitional stage will commence from the first day that TI SDI falls to 50 or below following rain. The transitional stage will apply up to the time when either:

    - o An additional 50 mm of rain has occurred at the relevant harvest location;
    - o Rutting, caused by a failure of soil strength, has been initiated at the level described as significant in Schedule 8;

  - Other soil disturbance that threatens the allowable limits has occurred; or
  - The harvesting operation ceased because of concerns about soil disturbance, with the exception of precautionary cessation because of impending wet weather or other circumstances.

- □ *Medium to high risk period - Post transitional stage*

  The Medium to high risk period (post transitional stage) occurs in autumn and winter after limits for the Medium to high risk period (transitional stage) have been exceeded, and in spring and summer, and is dependent on soil type.

  - For upland gravels and sand, excluding the Blackwood Plateau, the Medium to high risk period (post transitional stage) is when the TI $_{SDI}$ is:
    - 0 and it is not raining and free water is not present; or
    - Greater than 0 and less than or equal to 250;
  - For all other soil types, including all of the Blackwood Plateau, the Medium to high risk period (post transitional stage) is when the TI $_{SDI}$ is:
    - Greater than 0 and less than or equal to 250, and it is not raining and free water is not present;

- High risk is when soils are wet and soil damage is likely in parts of most feller's blocks for operations that involve off-road use of heavy vehicles. The High risk period occurs after the Medium to High risk period (transitional stage) has ceased, and is dependent on soil type:

  - □ For upland gravels and sand, excluding the Blackwood Plateau, the High risk period is when the TI $_{SDI}$ is 0, and it is raining or free water is present;
  - □ For **all other soil types**, including all of the Blackwood Plateau, the High risk period is when the TI $_{SDI}$ is:
    - 0; or
    - Less than or equal to 250, and it is raining or free water is present.

Schedule 3 Management requirements associated with the risk levels for soil damage

All risk periods

Management requirements under all risk periods are:

- Requirements of legislation, policies, DEC and FPC guidelines, manuals and other regulatory documents are to be met;
- The soil disturbance limits of Schedules 6 - 8 apply;
- A coupe diary is to be maintained by the Forest Products Commission and is to record information on actions taken by FPC to commence or manage harvesting activities. Issues to consider recording in the coupe diary include a record of each day that each feller's block was operated in, machinery that was used, date of completion of each phase of the harvesting for each feller's block, any decisions to cease harvesting and the reasons for cessation particularly those related to soils, decisions made regarding issues of compliance (date and time of stoppages), records of discussions and agreement between FPC and DEC staff, record of action taken in response to breaches or non-compliance, health and safety issues associated with the coupe, instructions issued to FPC contractors, coupe data such as rainfall records, and date and time and type of monitoring undertaken;
- Off-road and off-landing use of heavy vehicles is to cease when free water is present; and
- Harvest planning should encompass the requirements for all risk periods during which it is anticipated that a particular feller's block could be active.

See Glossary for definitions of free water. For the purposes of ceasing the use of heavy vehicles where a particular extraction track in a feller's block has puddles of free water present then measures should be taken to drain the puddles. This does not by itself exclude the use of another extraction track in another part of the feller's block.

Additional management requirements within the risk periods are:

Low risk period

Low risk is when soils are relatively dry. The TI_{SDI} is greater than 500 in autumn or winter or greater than 750 in spring or summer.

The off-road and off-landing use of heavy vehicles is permissible subject to the following conditions:

- Planning and implementation of management techniques that will enable the area to be harvested without exceeding the soil disturbance limits;
  - □ The layout of extraction tracks is planned prior to extraction, including demarcation and the preparation of a sketch map;
  - □ The use of old extraction tracks is maximised; and
  - □ Duplicate, parallel and criss-crossing extraction tracks are not constructed unless under exceptional circumstances as specified in Section 5.2.2 of this Guideline;
- The Forest Products Commission is to monitor soil disturbance in each feller's block, as outlined in Schedules 11 and 12;

- Surveillance in each feller's block is to be undertaken by the Forest Products Commission, as specified in Schedule 12. Copies of the records of surveillance are to be available for inspection by DEC;
- If surveillance indicates that a soil disturbance threshold may be exceeded if the operation continues then a long transect survey of visible soil disturbance and / or a survey of rutting and erosion in the feller's block is to be undertaken by the Forest Products Commission, and a copy of the results of that survey is to be provided to the Department;
- The Forest Products Commission is to undertake a long transect survey of visible soil disturbance, as specified in Schedule 12, and provide a copy of the results of those surveys to the Department;
- If surveillance, the long transect survey of visible soil disturbance or the survey of rutting and erosion indicates that a soil disturbance threshold is likely to be exceeded if the operation continues then the operation in the feller's block is to cease and the Department is to be notified;
- If an operation ceases due to the likelihood of exceeding soil disturbance limits then it cannot recommence until the Forest Products Commission has satisfied the Department that the operation will not exceed the soil disturbance limits;
- If a significant rainfall event (TI_{SDI} reduced by 400) occurs then conditions as specified in Schedules 9-11 are to be applied; and
- The Department will monitor soil disturbance and provision of information from the Forest Products Commission, as specified in Schedules 13 and 15.

The management requirements following significant rainfall in the low risk period are described in Schedule 10. Where forecast predictions indicate a high likelihood of a significant rainfall event, such as in advance of cyclonic or strong frontal developments, surface water management structures should be installed in active coupes to reduce the impact of erosion according to Schedules 19-22.

Medium risk period

Medium risk is when soils may be moist enough that soil damage could occur, depending on the specific soil, management and vehicle factors. The TI_{SDI} is:

- Less than or equal to 500 and greater than 50 in the wetting up phase of the year (autumn or winter – pre-transitional (see below)); or
- Less than or equal to 500 and greater than 250 in the wet season after the transitional stage of the Medium - high risk period (see below) has been passed through; or
- Greater than 250 and less than or equal to 750 in the drying out phase of the year (spring or summer);

The off-road and off-landing use of heavy vehicles is permissible subject to the following conditions:

- Planning and implementation of management techniques that will enable the area to be harvested without exceeding the soil disturbance limits:
- The layout of extraction tracks is planned prior to extraction, including demarcation and the preparation of a sketch map;

- The use of old extraction tracks is maximised; and
- Duplicate, parallel and criss-crossing extraction tracks are not constructed unless under exceptional circumstances as specified in section 5.2.2 of this Guideline;
- The Forest Products Commission is to monitor soil disturbance in each feller's block, as outlined in Schedule 12;
- Surveillance in each feller's block is to be undertaken by the Forest Products Commission, as specified in Schedule 12. Copies of the records of surveillance are to be available for inspection by DEC;
- If surveillance indicates that a soil disturbance threshold may be exceeded if the operation continues then a long transect survey of visible soil disturbance and / or a survey of rutting and erosion in the feller's block is to be undertaken by the Forest Products Commission, and a copy of the results of that survey is to be provided to the Department as specified in Schedule 14;
- The Forest Products Commission is to undertake a long transect survey of visible soil disturbance, as specified in Schedule 12, and provide a copy of the results of those surveys to the Department as specified in Schedule 14;
- If surveillance, the long transect survey of visible soil disturbance or the survey of rutting and erosion indicates that a soil disturbance threshold is likely to be exceeded if the operation continues then the operation in the feller's block is to cease and the Department is to be notified as specified in Schedule 14;
- If an operation ceases due to the likelihood of exceeding soil disturbance limits, with the exception of precautionary cessation because of impending wet weather or other circumstances, then it cannot recommence until the TI_{SDI} is greater than 750; and
- The Department will monitor soil disturbance and provision of information from the Forest Products Commission, as specified in Schedules 13 and 15.

Medium to high risk period

Medium to high risk is when soils are moist or wet and soil damage is likely in parts of most working areas unless intensive management action is taken to avoid such damage and attention to soil type, topography and position in the landscape is given. This period has two stages; Medium to high risk period - Transitional stage and medium to high risk period - Post transitional stage.

Rehabilitated bauxite pits are not to be harvested in either stage of the medium to high risk period.

The off-road and off-landing use of heavy vehicles is permissible on the basis described below:

Medium to high risk period - Transitional stage

The transitional stage commences from the first day that the TI_{SDI} has fallen to 50 or below in the wetting up phase of the year (autumn or winter). In the circumstance where the transitional stage has been initiated, but due to subsequent drying conditions the TI_{SDI} rises above 50 before it has fallen to 0, the transitional stage will be cancelled. A new transitional stage will commence from the first day that TI_{SDI} falls to 50 or below following rain. The transitional stage will apply up to the time when either:

- An additional 50 mm of rain has occurred at the relevant harvest location;

- Rutting, caused by a failure of soil strength, has been initiated at the level described as significant in Schedule 8;
- Other soil disturbance that threatens the allowable limits has occurred; or
- The harvesting operation ceased because of concerns about soil disturbance, with the exception of precautionary cessation because of impending wet weather or other circumstances

During the transitional period the off-road or off-landing use of heavy vehicles is permissible subject to the following conditions, which have the objective of minimising soil damage, monitoring soil disturbance and improving the definition of this transitional period:

- Planning and implementation of management techniques that will enable the area to be harvested without exceeding the soil disturbance limits:
  - □ The layout of extraction tracks has been planned prior to extraction, including demarcation and the preparation of a sketch map;
  - □ The use of old extraction tracks has been maximised; and
  - □ Duplicate, parallel and criss-crossing extraction tracks are not constructed unless under exceptional circumstances as specified in Section 5.2.2 of this Guideline;
- The Forest Products Commission is to monitor soil disturbance in each feller's block, as outlined in Schedule 12;
- Surveillance in each feller's block is to be undertaken by the Forest Products Commission, as specified in Schedule 12. Copies of the records of surveillance are to be available for inspection by DEC;
- If surveillance indicates that a soil disturbance threshold may be exceeded if the operation continues then a long transect survey of visible soil disturbance and / or a survey of rutting and erosion in the feller's block is to be undertaken by the Forest Products Commission, as specified in Schedule 12, and a copy of the results of that survey is to be provided to the Department as specified in Schedule 14;
- The Forest Products Commission is to undertake a long transect survey of visible soil disturbance and a survey of rutting and erosion, as specified in Schedule 12, and provide a copy of the results of those surveys to the Department as specified in Schedule 14;
- If surveillance, the long transect survey of visible soil disturbance or the survey of rutting and erosion indicates that a soil disturbance threshold is likely to be exceeded if the operation continues then the operation in the feller's block is to cease and the Department is to be notified as specified in Schedule 14;
- If an operation ceases due to the likelihood of exceeding soil disturbance limits, with the exception of precautionary cessation because of impending wet weather or other circumstances, then it cannot recommence until the TI_{SDI} is greater than 750;
- The Department will monitor soil disturbance and provision of information from the Forest Products Commission, as specified in Schedules 13 and 15; and
- Rainfall information can be based on either:
  - □ Bureau of Meteorology or DEC rainfall data at an appropriate weather station, which may be extrapolated to the desired location using the TI_{SDI} system; or
  - □ A rain gauge appropriately located near to the area where heavy vehicle activity is planned and rainfall measured by the Forest Products Commission, preferably on a daily basis, but on a maximum interval of 3 days. FPC to document the quantity of rain,

record the decision in the coupe diary, and inform DEC of the decision. FPC to use rain gauge readings and calculate TI_{SDI} and thus risk period and permissible activities during the remainder of time the feller's block remains open. Records are to be provided to DEC Regional Leader for SFM on a weekly basis.

Medium to high risk period - Post transitional stage

The Medium to high risk period (post transitional stage) occurs in autumn and winter after limits for the Medium to high risk period (transitional stage) have been exceeded, and in spring and summer, and is dependent on soil type.

- For upland gravels and sand, excluding the Blackwood Plateau*, the Medium to high risk period (post transitional stage) is when the TI_{SDI} is:
  - □ 0 and it is not raining and free water is not present; or
  - □ Greater than 0 and less than or equal to 250;
- For all other soil types, including all of the Blackwood Plateau*, the Medium to high risk period (post transitional stage) is when the TI_{SDI} is:
  - □ Greater than 0 and less than or equal to 250, and it is not raining and free water is not present;

* The mapped soil types described by Rab et al. (2005) and Blackwood Plateau as described by Mattiske and Havel (1998) will be used as the primary determinant of soil type and associated risk period for the Medium to high (post transitional stage) and High risk periods. Where FPC presents information, to DEC's satisfaction, that demonstrates that an alternative interpretation of soil type is appropriate, then this alternative may be used.

The off-road and off-landing use of heavy vehicles is permissible subject to the following conditions:

- Written approval is obtained in each stage of a two-stage approvals process:
  - □ Firstly, written approval is obtained from DEC's Director of Forests or a delegated officer as described in Section 5.1.4 and Schedule 4 of this Guideline. Approval will be considered subject to the provision of a strategic level plan that covers all candidate areas proposed to be accessed during this period in a particular calendar year, and demonstrates that candidate areas are the most suitable harvest areas on the annual harvest plan. This plan will be required to demonstrate the suitability of candidate areas in terms of:
    - o Landforms, soils, topography, site, rainfall zone, dieback management and access that make the harvest area suitable for operations in soil moisture conditions expected during the Medium to high risk period;
  - □ Secondly, written approval is obtained from DEC's Director of Sustainable Forest Management or a delegated officer as described in Section 5.1.4 and Schedule 4 of this Guideline. Approval will be considered subject to the provision of a feller's block level plan, that demonstrates the suitability of the feller's block in terms of the management techniques to be employed that will enable the area to be harvested without threatening the soil disturbance limits. This should include:
    - o Planned layout of extraction tracks, including the preparation of a map and identification of any special treatments to protect soil, for example cording, matting, brushing or avoidance of susceptible areas. For karri thinning

operations where this information cannot be provided together with other information for the feller's block level plan, then the location of landings or forwarder landings should be mapped and this provided prior to disturbance operations commencing. A map of the extraction tracks, including any special treatments to protect soil, used to feed each landing or forwarder landing should be provided at the completion of load out of each landing or forwarder landing;

  - The use of old extraction tracks is maximised;
  - Provisions to prevent soil mixing on landings; and
  - Any issues that because of the unavailability of information could not be addressed for the feller's block in the strategic level plan;

- Whilst for upland gravels and sand, excluding the Blackwood Plateau, the Medium to high risk period (post transitional stage) includes $TI_{SDI} = 0$, machine harvesting is not allowed when the TI_{SDI} is 0, except for first thinning of young (less than 35-year-old) regrowth karri forest. First thinning of young (less than 35-year-old) regrowth karri forest is allowable on the basis that it has a dense layer of litter and trash to serve as natural matting (i.e. is unburnt or has an understorey age >7 years old), is harvested using a harvester/forwarder operation that does not involve snigging, and that it is managed so that soil disturbance thresholds are not threatened;
- The Forest Products Commission is to monitor soil disturbance in each feller's block, as outlined in Schedule 12;
- Surveillance in each feller's block is to be undertaken by the Forest Products Commission, as specified in Schedule 12. Copies of the records of surveillance are to be available for inspection by DEC;
- If surveillance indicates that a soil disturbance threshold may be exceeded if the operation continues then a long transect survey of visible soil disturbance and / or a survey of rutting and erosion in the feller's block is to be undertaken by the Forest Products Commission, as specified in Schedule 12, and a copy of the results of that survey is to be provided to the Department as specified in Schedule 14;
- The Forest Products Commission is to undertake a long transect survey of visible soil disturbance and a survey of rutting and erosion, as specified in Schedule 12, and provide a copy of the results of those surveys to the Department as specified in Schedule 14;
- If surveillance, the long transect survey of visible soil disturbance or the survey of rutting and erosion indicates that a soil disturbance threshold is likely to be exceeded if the operation continues then the operation in the feller's block is to cease and the Department is to be notified as specified in Schedule 14;
- If an operation ceases due to the likelihood of exceeding soil disturbance limits, with the exception of precautionary cessation because of impending wet weather or other circumstances, then it cannot recommence until the TI_{SDI} is greater than 750;
- The Forest Products Commission is to undertake surveys of rutting and erosion for feller's blocks not certified as complete, as specified in Schedule 12, and provide a copy of the results of those surveys to the Department as specified in Schedule 14;
- The Department will monitor soil disturbance and provision of information from the Forest Products Commission, as specified in Schedules 13 and 15.
- The Forest Products Commission is to ensure that extraction tracks are demarcated in the field prior to extraction commencing;

- Duplicate, parallel and criss-crossing extraction tracks are not constructed unless under exceptional circumstances as specified in Section 5.2.2 of this Guideline; and
- The Forest Products Commission is to verify, through daily surveillance, that the provisions of the management plan are being complied with. Copies of the records of surveillance are to be available for inspection by DEC.

High risk period

High risk is when soils are wet and soil damage is likely in parts of most feller's blocks for operations that involve off-road use of heavy vehicles. The High risk period occurs after the Medium to high risk period (transitional stage) has ceased, and is dependent on soil type:

- For upland gravels and sand, excluding the Blackwood Plateau*, the High risk period is when the TI_{SDI} is:
  - □ 0 and it is raining or free water is present;
- For all other soil types, including all of the Blackwood Plateau*, the High risk period is when the TI_{SDI} is:
  - □ 0; or
  - □ Less than or equal to 250, and it is raining or free water is present.

* The mapped soil types described by Rab et al. (2005) and Blackwood Plateau as described by Mattiske and Havel (1998) will be used as the primary determinant of soil type and associated risk period for the Medium to high (post transitional stage) and High risk periods. Where FPC presents information, to DEC's satisfaction, that demonstrates that an alternative interpretation of soil type is appropriate, then this alternative may be used.

See Glossary for definitions of rain and free water.

- The Forest Products Commission is to undertake surveys of rutting and erosion for feller's blocks not certified as complete, as specified in Schedule 12, and provide a copy of the results of those surveys to the Department as specified in Schedule 14.

- Rehabilitated bauxite pits are not to be harvested in the High risk period.

- Use of heavy vehicles, off-road or off-landing, is not allowed, except for first thinning of young (less than 35-year-old) regrowth karri forest (see below).

First thinning of young regrowth karri forest

The first thinning of young (less than 35-year-old) regrowth karri forest is permissible subject to the following conditions:

- On the basis that it has a dense layer of litter and trash to serve as natural matting (i.e. is unburnt or has an understorey age >7 years old), is harvested using a harvester/forwarder operation that does not involve snigging, and that it is managed so that soil disturbance thresholds are not threatened;
- Written approval is obtained in each stage of a two-stage approvals process:

- ☐ Firstly, written approval is obtained from DEC's Director of Forests or a delegated officer as specified in Section 5.1.4 and Schedule 4 of this Guideline. Approval will be considered subject to the provision of a strategic level plan, that covers all candidate areas proposed to be accessed during this period in a particular calendar year, and demonstrates that candidate areas are the most suitable harvest areas on the annual harvest plan. This plan will be required to demonstrate the suitability of candidate areas in terms of:
  - o Landforms, soils, topography, site, rainfall zone, dieback management and access that make the harvest area suitable for operations in soil moisture conditions expected during the high risk period;
- ☐ Secondly, written approval is obtained from DEC's Director of Forests or a delegated officer as specified in Section 5.1.4 and Schedule 4 of this Guideline. Approval will be considered subject to the provision of a feller's block level plan, that demonstrates the suitability of the feller's block in terms of the management techniques to be employed that will enable the area to be harvested without threatening the soil disturbance limits. This should include:
  - o Planned layout of extraction tracks, including the preparation of a map and identification of any special treatments to protect soil, for example cording, matting, brushing or avoidance of susceptible areas. Where this information cannot be provided together with other information for the feller's block level plan, then the location of landings or forwarder landings should be mapped and this provided prior to disturbance operations commencing. A map of the extraction tracks, including any special treatments to protect soil, used to feed each landing or forwarder landing should be provided at the completion of load out of each landing or forwarder landing;
  - o The use of old extraction tracks is maximised;
  - o Provisions to prevent soil mixing on landings; and
  - o Any issues that because of the unavailability of information could not be addressed for the feller's block in the strategic level plan;
- Extraction is to cease while it is raining.
- The Forest Products Commission is to monitor soil disturbance in each feller's block, as outlined in Schedule 12;
- Surveillance in each feller's block is to be undertaken by the Forest Products Commission, as specified in Schedule 12. Copies of the records of surveillance are to be available for inspection by DEC;
- If surveillance indicates that a soil disturbance threshold may be exceeded if the operation continues then a long transect survey of visible soil disturbance and / or a survey of rutting and erosion in the feller's block is to be undertaken by the Forest Products Commission, as specified in Schedule 12, and a copy of the results of that survey is to be provided to the Department as specified in Schedule 14;
- The Forest Products Commission is to undertake a long transect survey of visible soil disturbance and a survey of rutting and erosion, as specified in Schedule 12, and provide a copy of the results of those surveys to the Department as specified in Schedule 14;
- If surveillance, the long transect survey of visible soil disturbance or the survey of rutting and erosion indicates that a soil disturbance threshold is likely to be exceeded if the operation continues then the operation in the feller's block is to cease and the Department is to be notified as specified in Schedule 14;

- If an operation ceases due to the likelihood of exceeding soil disturbance limits, with the exception of precautionary cessation because of impending wet weather or other circumstances, then it cannot recommence until the TI SDI is greater than 750;
- The Forest Products Commission is to verify, through daily surveillance, that the provisions of the management plan are being complied with. Copies of the records of surveillance are to be available for inspection by DEC; and
- The Department will monitor soil disturbance and provision of information from the Forest Products Commission, as specified in Schedules 13 and 15;

Loading and haulage of stockpiled logs on landings

The loading and haulage of stockpiled logs on landings is permissible, subject to:

- Written approval is obtained in each stage of a two-stage approvals process:
  - □ Firstly, written approval is obtained from DEC's Director of Forests or a delegated officer as specified in Section 5.1.4 and Schedule 4 of this Guideline. Approval will be considered subject to the provision of a strategic level plan, that covers all candidate areas proposed to be accessed during this period in a particular calendar year, and demonstrates that candidate areas are the most suitable harvest areas on the annual harvest plan. This plan will be required to demonstrate the suitability of candidate areas in terms of:
    - o Landforms, soils, topography, site, rainfall zone, dieback management and access that make the harvest area suitable for operations in soil moisture conditions expected during the high risk period;
  - □ Secondly, written approval is obtained from DEC's Director of Forests or a delegated officer as specified in Section 5.1.4 and Schedule 4 of this Guideline. Approval will be considered based on the provision of a plan that demonstrates that the landing and access route will be appropriately managed. This should include:
    - o How soil mixing on the landing will be avoided, for example the use of static boom loaders; and
    - o How dieback management is to be achieved, for example the use of hard-surfaced all-weather roads.
- The Forest Products Commission is to verify, through daily surveillance, that the provisions of the plan are being complied with. Copies of the records of surveillance are to be available for inspection by DEC.

Timber harvesting in native forest that is a precursor to land clearing

- Where timber harvesting in native forest occurs as part of land clearing for bauxite mining, coal mining, extraction of basic raw materials, establishment of a permanent road, or any other form of clearing, then the restrictions on activity by heavy vehicles in the high and medium-high risk periods specified above will not necessarily apply. Activity by heavy vehicles during these risk periods will be addressed in the approvals for access to DEC-managed lands provided by the DEC Regional Manager. The DEC Regional Manager will assess such proposals based on a regard for the intent of the soil conservation measures and the objectives and authority of the subsequent clearing operation.

- The rationale for not applying the same restrictions on these activities as applies to operations not involving clearing is that the need to conserve the soil for biodiversity and productive capacity objectives is not as great where the site is to be permanently cleared, or where subsequent to timber harvesting, the soil is to disturbed to a greater extent than during the timber harvesting operation.

Timber harvesting in rehabilitated bauxite pits

- Rehabilitated bauxite pits are only to be harvested in Low and Medium risk periods.

Schedule 4 Mandatory planning requirements for operating under moist soil conditions - two stage approval process

Introduction

A two-stage process for the FPC to seek access to harvest cells during the Medium to high (post transitional stage) and High risk period is a mandatory requirement. The following Appendix explains issues regarding procedures, information management, and professional courtesy, between DEC and FPC in managing the two-stage approval process.

Stage 1 – Strategic level plan

The first stage is a strategic level plan and analysis of the suite of coupes available to the FPC within the current harvest year, to identify those most likely to be able to sustain harvest operations during the Medium to high (post transitional stage) risk period or High risk period.

Areas

Consideration can only be given to coupes, cells or feller's blocks that are on the Annual Harvest Plan for that particular year.

Process and timing

The first stage comprises a formal submission by FPC of candidate moist soil coupes, as a consolidated proposal for all Regions, to DEC's Director of SFM. The submission must incorporate all the required maps and supporting information and be submitted by the 15th April each year.

The DEC Director of SFM will provide a written response listing the approved coupes and any specific conditions to the FPC by 15th May each year.

As a precursor to the formal submission, it is recommended that the FPC prepare a draft list of candidate coupes that are on the Regional Indicative Harvest Plan and provide a copy to DEC's Director of SFM before the 15th of February each year. The draft list of candidate coupes will act as a "heads up" planning tool to facilitate the scheduling of any mapping, planning and field inspection required by the agencies in preparation for planning and approving moist soil coupes. The Director of SFM will only provide comments on the Regional Indicative Harvest Plan if necessary.

Issues to address

The strategic level plan will be required to demonstrate the suitability of candidate areas in terms of landforms, soils, topography, site, rainfall zone, dieback management and access that make the harvest area suitable for operations in soil moisture conditions expected during the Medium to high (post transitional stage) risk period or High risk period. Aspects suggested for inclusion in order to facilitate approval include % dieback impact categories, % slope, % landform groups, rainfall, priority and further comments such as the likely order of scheduling.

Stage 2 – Feller's block level plan

Introduction

The Director of SFM has delegated the authority to approve cell level harvesting in the Medium to high (post transitional stage) risk period and High risk period to the Regional Manager in the Swan, South West and Warren Regions. This is to ensure that the decisions are able to be based on the site-specific requirements of each individual area, and to make the administrative process as efficient as possible.

The objective for SFM staff is to ensure that the FPC harvesting proposal is assessed and processed in an appropriate and timely fashion. To ensure that this second stage of the approvals process does not unreasonably affect the ability of FPC to gain approval to access State forest and timber reserves for timber harvesting, the following guidance is provided.

Consideration of coupes may commence once the approval by the Director of SFM has been provided through approval of the strategic level plan. Ideally the information for the feller's block level plans should be presented as part of a consolidated package of areas for which access is sought, however this is not a specific requirement. Approval at stage 1, does not entitle the FPC to expect access to all feller's blocks within the coupe during the Medium to high (post transitional stage) risk period and High risk period. DEC will not be responsible for delays in access to harvest cells as a result of insufficient lead time to allow adequate consideration of the proposals. It is FPC's responsibility to ensure that the second stage applications are submitted to DEC in a timely way.

Areas

Consideration can only be given to coupes, cells or feller's blocks that:

- Are on the Annual Harvest Plan for that particular year;
- Have been approved in the first stage (strategic level plan) of the approvals process for access in the Medium to high (post transitional stage) risk period or High risk period;
- Have a current Pre-Operations Checklist signed by the Regional Manager; and
- Have a current hygiene management plan.

Process

DEC should liaise with FPC planners to prioritise planning work. DEC and FPC staff should meet to discuss and resolve harvest issues in advance of submission of the feller's block level plan.

Issues to address

The following issues need to be addressed in the FPC proposal for each feller's block level plan:

- Planned layout of extraction tracks, including the preparation of a map and identification of the type and extent of any special treatments to protect soil, for example cording, matting, brushing or avoidance of susceptible areas. For karri thinning operations where this information cannot be provided together with other information for the feller's block level plan, then the location of landings or forwarder landings should be mapped and this provided prior to disturbance operations commencing. A map of the extraction tracks, including any special treatments to protect soil, used to feed each landing or forwarder landing should be provided at the completion of load out of each landing or forwarder landing;

Evidence that the use of old extraction tracks is maximised;

Details of the type of the provisions to prevent soil mixing on landings; and

The final plan should outline the agreed resolutions to any issues that, because of the unavailability of information, could not be addressed for the feller's block in the strategic level plan.

DEC approvals

DEC staff should check the conditions of the approved Pre-Operations Checklist and the conditions on feller's blocks approved in the first stage (strategic level plan) of the approvals process for access in the Medium to high (post transitional stage) risk period or High risk period, to ensure that the proposed operation is compatible with all aspects and conditions of the higher level approvals for access.

The letter of approval from the Regional Manager to FPC is to reiterate the key aspects of the FPC proposal.

The letter of approval is to include the following minimum conditions:

The FPC will comply with agreed monitoring requirements as outlined in Schedules 11 and 12 of this Guideline and the Manual of Procedures for the Management of Soils Associated With Timber Harvesting in Native Forests;

The FPC will comply with all other requirements of the Medium to high (post transitional stage) risk period or High risk period, as set out in Schedules 2 and 3;

Surveillance is to be based on daily visits and direct observations by the FPC coupe OIC; and

The FPC coupe OIC is to notify the DEC Regional Leader for SFM:

Immediately prior to commencement of operations in the feller's block;

Each Monday morning when the feller's block is planned to be active for that week; and

On the day of completion of extraction of the feller's block.

Additionally, for feller's blocks not involving the first thinning of young karri regrowth forest, the letter of approval is to include:

No machine harvesting when TI=0.

For feller's blocks involving the first thinning of young karri regrowth forest, the letter of approval is to include:

Where layout of extraction tracks, including the preparation of a map and identification of the type and extent of any special treatments to protect soil, cannot be provided together with other information for the feller's block level plan, then the location of landings or forwarder landings should be mapped and this provided prior to disturbance operations commencing; and

A map of the extraction tracks, including any special treatments to protect soil, used to feed each landing or forwarder landing should be provided at the completion of load out of each landing or forwarder landing.

DEC staff responsible for assessing feller's block level plans for access in the Medium to high (post transitional stage) risk period or High risk period should ensure that they record the actions associated with the assessment and approval of the plans. It is recommended that DEC staff record the date submission received, the date of meeting, any interim advice provided to FPC and the date of response from DEC.

DEC approvals

DEC staff should respond in writing to the FPC (copy by email is acceptable) following receipt of the submission of the feller's block level plan. This response will either:

Identify actions that must be completed before approval can be reconsidered;

Identify additional information that must be provided before approval can be reconsidered;

Identify issues which must be resolved before approval can be reconsidered; or

Approve the operation and clearly identify any conditions of this approval.

Where issues are still to be resolved for a small number of feller's blocks within a coupe, conditional approval may be given for those feller's blocks that meet the required conditions.

Disputes

Where intractable issues are delaying the approval of the proposal of the feller's block level plan for access in the Medium to high (post transitional stage) risk period or High risk period then the feller's block level plan should be urgently referred to DEC's Director of SFM for consideration.

Schedule 5 Visual soil disturbance types.

Soil disturbance type	Code	Dominant soil layer	Level of mixing/removal
Undisturbed	D0	Litter	Litter layer intact.
Lightly disturbed	D1	Litter Topsoil Topsoil Topsoil	Litter layer broken/partially removed. Litter completely removed and topsoil exposed. Litter mixed with topsoil. Topsoil disturbed.
Moderately disturbed	D2	Topsoil Topsoil	Topsoil mixed with subsoil. Topsoil partially removed.
Severely disturbed	D3	Subsoil Subsoil Subsoil Subsoil Subsoil	Topsoil completely removed and subsoil exposed. Topsoil mixed with subsoil. Subsoil disturbed. Subsoil mixed with parent material or a soil layer below 50 cm. Subsoil partially removed.
Very severely disturbed	D4	Parent material or subsoil below 50 cm depth	Subsoil removed and deeper soil layer exposed, or subsoil mixed with parent material or soil layer below 50 cm. See categories of very severe disturbance in Schedule 8.

Schedule 6 Soil disturbance limits

<table>
<tr><th>Type of disturbance</th><th>Measure</th><th>Limit</th></tr>
<tr><td rowspan="7">Very severe soil disturbance

Visual soil disturbance - defined as the subsoil removed and parent material exposed or subsoil mixed with parent material.</td><td>For all areas other than landings, the percentage of the total area impacted.</td><td>0 per cent</td></tr>
<tr><td rowspan="4">For landings, the area of landings impacted as a percentage of the total harvest area.</td><td>1.5 per cent in jarrah</td></tr>
<tr><td>1 per cent in karri thinning</td></tr>
<tr><td>3.5 per cent in karri clearfall</td></tr>
<tr><td>No soil mixing to occur</td></tr>
<tr><td>For rutting, the depth and length of the rutting.</td><td>150mm maximum depth for gravel and sand soils, 300mm maximum depth for other soils; depths not to be exceeded over a cumulative length of 20 metres of extraction track for the feller's block.</td></tr>
<tr><td>Erosion</td><td>Erosion control measures installed as per Contractors Timber Harvesting Manual for South West Native Forests and only minor erosion occurs and is limited to between erosion control measures.</td></tr>
<tr><td rowspan="5">Severe soil disturbance*

Visual soil disturbance - defined as the topsoil completely removed and the subsoil exposed or the topsoil mixed with subsoil (B horizon), or the subsoil disturbed, or the subsoil mixed with parent material, or the subsoil partially removed.</td><td rowspan="4">For all areas other than landings the percentage of the total area impacted.</td><td>2 per cent in jarrah</td></tr>
<tr><td>1 per cent in karri thinning</td></tr>
<tr><td>1 per cent in karri pre-logging</td></tr>
<tr><td>2 per cent in karri clearfall (including pre-logging)</td></tr>
<tr><td>Landings, rutting and erosion.</td><td>As for the limits of the "very severe visible soil disturbance" category.</td></tr>
<tr><td rowspan="5">Moderate soil disturbance*

Visible soil disturbance - defined as the topsoil mixed with subsoil (A horizon) or the topsoil partially removed.</td><td rowspan="4">For all areas other than landings the percentage of the total area impacted.</td><td>8 per cent in jarrah</td></tr>
<tr><td>8 per cent in karri thinning</td></tr>
<tr><td>5 per cent in karri pre-logging</td></tr>
<tr><td>15 per cent in karri clearfall (including pre-logging)</td></tr>
<tr><td>Landings, rutting and erosion.</td><td>As for the limits for the "very severe visible soil disturbance" category.</td></tr>
</table>

* Allowable limits are inclusive of those for higher levels of soil disturbance i.e. 8 per cent of moderate soil disturbance in jarrah is to include any occurrence of severe or very severe soil disturbance.

The Director of Sustainable Forest Management or a delegate will have the authority to set more specific rutting depth thresholds for particular soil types, and the Conservation Commission will be notified when this occurs.

Schedule 7 Types of soil erosion and allowable limits

Type	Classification	Situation	Threshold	Action / consequence
Sheet erosion	Minor	All	<5mm	No action required if no perceptible channels are formed.
Rill erosion	Minor	In coupe	<20mm deep; and <10m in length; or <50m^2 in extent*.	No action.
		Extraction track	<50mm deep; and <10m in length; or <50m^2 extent*; and Contained within control structures.	At the upper limit if no structures in place these must be installed immediately.
	Minor– action required.	In coupe	<20mm deep; and <10m in length; or 50-100m^2 in extent*.	The range is the allowable circumstances where operations may continue (within that range) provided preventative action is taken. Install primary erosion control immediately. Monitor effectiveness daily. If erosion is stabilised in the presence of continued harvesting / extraction then the operation may continue; If erosion continues individual occurrence will be classed as "Very severe visible soil disturbance".
		Extraction track	<50mm deep; and 10-15m in length; or 50 - 100m^2 extent*; and Not contained within control structures.	The range is the allowable circumstances where operations may continue (within that range) provided preventative action is taken. Install primary erosion control immediately. Monitor effectiveness daily. If erosion is stabilised in the presence of continued harvesting / extraction then the operation may continue; If erosion continues or increases, cease harvesting / extraction.
	Major	In coupe	>20mm deep; and >10m in length; or >100m^2 in extent*.	Individual occurrence will be classed as "Very severe visible soil disturbance"
		Extraction track	>50mm deep; and >15m in length; or >100m^2 extent*; or Erosion has breached the erosion control barriers.	Individual occurrences will result in the cessation of harvesting / extraction.
		Roads, boundary tracks and table drains.	>100 deep	Rills associated with the roads, culverts and table drains must be maintained or repaired to prevent the problem from becoming worse. Severe cases that are not controlled may result in a need to stop either the harvesting or haulage operations.
Gully erosion	Major	In coupe / extraction tracks	>300mm deep	All gully erosion is consider major erosion and will be classed as "Very severe visible soil disturbance".
		Roads, boundary tracks and table drains.	>300mm deep	Erosion associated with the roads, culverts and table drains must be maintained or repaired to prevent the problem from becoming worse. Severe cases that are not controlled may result in a need to stop either the harvesting or haulage operations.
Deposition	Minor	All		Where deposition is the result of minor erosion.
	Major	All	A single deposition >30m^2 in extent or any deposition from major erosion	Deposition from any form of major erosion in the coupe or surrounding areas will be classed as "Very severe visible soil disturbance".
Turbid runoff	Minor	In coupe		Where turbid runoff is contained within the coupe, or within the filter strips.
	Major	In coupe		Where turbid runoff is not contained within the coupe, or within the filter strips, and reaches the watercourse

* Area criteria should not be applied if the depth and length criteria have been exceeded.

Schedule 8 Summary of very severe soil disturbance thresholds.

Type	Situation	Threshold
Rutting	Gravel and sand soils	A cumulative length of 20 metres of significant ruts on extraction tracks for an individual feller's block (Significant ruts are those with a maximum depth greater than or equal to 150mm which occur over a length greater than or equal to 5m).
	other soils	A cumulative length of 20 metres of significant ruts on extraction tracks for an individual feller's block (Significant ruts are those with a maximum depth greater than or equal to 300 mm which occur over a length greater than or equal to 5m).
Erosion	Rill erosion: in harvest cell (excluding extraction track)	>20mm deep; and >10m in length; or >100m^2 in extent.
	Rill erosion: extraction tracks	>50mm deep; and >15m in length; or >100m^2 extent; or Erosion has breached the erosion control barriers.
	Rill erosion: Roads, boundary tracks and table drains	>10 cm deep that are not controlled, repaired or maintained
	Gully erosion: In coupe / extraction tracks	>30 cm deep
	Gully erosion: Roads, boundary tracks and table drains.	>30 cm deep
Deposition		A single deposition >30m^2 in extent; or any deposition from major erosion.
Turbid runoff		Where turbid runoff is not contained within the coupe, or within the filter strips, and reaches the watercourse.
Scalping	Shallow scalping over an extensive area	Unauthorised removal of the topsoil over an area > 50 m^2
Hole from tree pulling or pushing		Repeated exposure of soil to a depth of >50 cm caused by unauthorised pulling or pushing of a tree e.g. > 10 x per fellers block.

Schedule 9 Rules for determining significant rainfall events at the feller's block and the requirements for management.

Did the rainfall event occur at the coupe?	Basis of determination	Action
Yes	Can use weather station if appropriate or be based on rain gauge in the feller's block or field inspection of the feller's block.	Apply the requirements for significant rainfall events outlined in Schedules 10 and 11.
Unsure	FPC / DEC staff to undertake field inspection, if no rain gauge is set up in the coupe.	Apply the requirements for significant rainfall events outlined in Schedules 10 and 11, unless the feller's block has been inspected by a DEC SFM officer who recommends continuation of the operation.
No	Confirm via on-site rain gauge.	Do not apply the requirements for significant rainfall events outlined in Schedules 10 and 11. Continue to operate as is required for the low risk period. FPC to document the quantity of rain, record the decision in the coupe diary, and inform DEC of the decision. FPC to use daily rain gauge readings and calculate TI_{SDI} and thus risk period and permissible activities during the remainder of time the feller's block remains open. Records are to be provided to DEC Regional Leader for SFM on a weekly basis.

Where forecast predictions indicate a high likelihood of a significant rainfall event such as in advance of cyclonic or strong frontal developments, erosion control barriers should be installed in active coupes to reduce the impact of erosion.

Schedule 10 Management requirements following significant rainfall in the low risk period.

TI_{SDI} after being reduced by 400	Risk Category after being reduced by 400	Management requirements
<500 in the wetting up phase of the year or <750 in the drying out phase of the year	Medium, Medium-High or High	Apply appropriate risk criteria until the TI_{SDI} rises above the threshold for the Low risk period, or for a minimum of 3 days, whichever is the greater. See Schedule 11 for monitoring requirements.
>500 in the wetting up phase of the year or >750 in the drying out phase of the year	Low	Stop extraction whilst free water is present. See Schedule 11 for monitoring requirements.

Rainfall patterns may be quite variable in space during the summer and autumn period and a rain gauge at the site of harvesting may assist in determining if a significant rainfall event occurred at the feller's block as opposed to at a weather station used for calculating TI_{SDI}. The following rule set is to be used to determine if a significant rainfall event has occurred at the feller's block and the requirements for management.

Schedule 11 Monitoring requirements following significant rainfall events in the low risk period

Risk category after being reduced by at least 400	Monitoring requirements
Low	Monitoring as is required for the Medium risk period for at least 3 days. Discontinue after 3 days if no issues are apparent. Transect survey of visible soil disturbance is required if other monitoring indicates that it is necessary (i.e. threshold is likely to be exceeded), otherwise a transect survey is not required.
Medium	Monitor as is required for the Medium risk period until the Low risk period is entered, or for a minimum of 3 days, whichever is the greater
Medium-High	Monitor as is required for the Medium-High risk period
High	Monitor as is required for the High risk period

Schedule 12 Soil disturbance monitoring required to be undertaken by FPC for each feller's block (except where stated otherwise).

Type of Monitoring	Risk period						
	Low	Medium	Medium - high		High		
			Transitional	Not transitional	Karri thinning	Where loading out is approved	Coupes not certified as complete, including karri thinning
Surveillance	Weekly[1]. Daily for the first two (2) days following a significant rainfall event[2]	Weekly[1]	Daily	Daily[3]	Daily[3]	Daily[3]	
Survey of rutting and erosion	If triggered by surveillance	If triggered by surveillance	Weekly[1] or if triggered by surveillance	Weekly[1] or if triggered by surveillance. Fortnightly in coupes not certified as completed[4]	Weekly[1] or if triggered by surveillance.		Fortnightly in coupes not certified as completed[4]
Transect survey of visible soil disturbance - long	Monthly per coupe or if triggered by surveillance	Monthly per coupe or if triggered by surveillance	Weekly[1,5,6] or if triggered by surveillance	Weekly[1,5,6] or if triggered by surveillance	Weekly[1,6] or if triggered by surveillance		

[1] Weekly is considered to be five active days of use of heavy vehicles in the feller's block. If a week comprises a combination of risk periods, the monitoring requirements of the higher risk period will apply.

[2] A significant rainfall event is when the TI_{SDI} falls by 400.

[3] This surveillance is to be based on daily visits and direct observations by the FPC coupe OIC.

[4] Certification of completion is based on the FPC104.

[5] In harvest operations where removed log volumes are low and numerous feller's blocks may be completed in a week, a long transect survey will be completed on a least one completed feller's block per coupe per week. The results of the survey will then form the basis of any decision to continue, modify or cease harvest operations at the coupe level.

[6] For karri thinning, if weekly transect surveys of soil disturbance show levels of disturbance are less than half of the allowable thresholds then surveys at two-weekly intervals may be appropriate i.e. ten active days of use of heavy vehicles in the feller's block.

Schedule 13 Soil disturbance monitoring to be undertaken by DEC.

Type of Monitoring	Risk period: Low	Risk period: Medium	Risk period: M-h (Transitional)	Risk period: M-h (Post transitional stage)	Risk period: High
Surveillance (including verification of plan to access in Medium-high or High risk periods)	One feller's block for each contractor per District per month	One feller's block for each contractor per District per month	One feller's block for each contractor per District per fortnight	Weekly for each feller's block	Weekly for each feller's block
Survey of rutting and erosion	If triggered by surveillance	If triggered by surveillance	If triggered by surveillance	One feller's block for each contractor per District per week	One feller's block for each contractor per District per week
Long transect survey of visible soil disturbance	One completed[1] feller's block per District per month	One completed[1] feller's block per District per month	One completed[1] feller's block per District per week	One completed[1] feller's block per District per week	One completed[1] feller's block per District per week
FPC reporting requirements[2]	Weekly[2]	Weekly[2]	Weekly[2]	Weekly[2]	Weekly[2]

1 The feller's block needs to have been operated during the specified risk period. Certification of completion is based on the FPC104.

2 Weekly = 5 active days.

Schedule 14 Communication and reporting required to be undertaken by FPC in relation to management of soil disturbance.

Stage of operation	Issue	Action by FPC and when
Commencement	Commencement of operations in the feller's block or loading out from landing stockpiles.	Notify DEC Regional Leader for SFM for each feller's block / landing on each Monday morning prior to commencement of operations in the feller's block or loading out from landing stockpiles i.e. the notification to cover the period from the Tuesday to the subsequent Monday.
Ongoing operation	Notification on ongoing operations.	Notify DEC Regional Leader for SFM of all feller's blocks / landings intended for continued operation on each Monday morning.
Surveillance	Surveillance of feller's blocks.	Provide copies to, or access by, DEC to surveillance records if requested.
Survey of rutting / erosion	Survey of rutting / erosion.	Provide copies to DEC Regional Leader for SFM each Monday morning (in Low / Medium risk periods, only if available).
Transect survey	Transect survey results.	Provide copies to DEC Regional Leader for SFM on 1st Monday of month in Low / Medium risk periods. Provide copies to DEC Regional Leader for SFM each Monday morning in Medium – high and High risk periods.
Cessation	Cessation related to soil management.	Notify DEC Regional Leader for SFM on the day of cessation.
Completion	Completion of extraction in the feller's block or loading out from landing stockpiles.	Notify DEC Regional Leader for SFM each Monday morning for the day of completion of extraction of the feller's block, or completion of landing. Also provide a copy of FPC104's.

Schedule 15 Communication required to be undertaken by DEC in relation to management of soil disturbance.

Stage of operation	Issue	When	Action by DEC
Commencement	Notification of commencement.	Ongoing	Formally write to FPC for all instances where DEC has not been advised.
Ongoing operation	Notification of continuing operations	Monday pm	Remind FPC if notification has not been provided.
	Follow-up regarding failure to notify of continuing operations	Tuesday am	Formally write to FPC re failure to notify of continuing operations.
Surveillance	Monitor surveillance by FPC of feller's blocks	Occasional	Remind FPC of surveillance requirements.
	Follow-up regarding failure by FPC to undertake surveillance.	Occasional	Formally write to FPC regarding failure to undertake required surveillance.
Survey of rutting / erosion	Monitor survey of rutting / erosion by FPC.	Monday pm	Remind FPC of requirement for surveys and notification to DEC.
	Follow-up regarding failure to notify or undertake surveys.	Tuesday am	Formally write to FPC for each feller's block regarding failure to undertake required surveys and/or notification to DEC.
Transect survey	Monitor transect surveys by FPC	Monday pm	Remind FPC of requirement for surveys and notification to DEC.
	Follow-up regarding failure to notify or undertake surveys.	Tuesday am	Formally write to FPC for each feller's block regarding failure to undertake required surveys and/or notification to DEC.
Cessation	Notification of cessation related to soil management.	Ongoing	Formally write to FPC for all instances where DEC has not been advised.
Completion	Notification of completion.	Monday pm	Remind FPC if notification has not been provided.
		Tuesday am	Formally write to FPC regarding failure to notify of completion.

Schedule 16 Allowable soil moisture conditions and soil damage assessment requirements and for burn preparation

Activity	Comment	Operational Guidelines		Soil Damage Assessment
		Soil Type	Allowable Risk period or TI_{SDI}	
Roads and Tracks				
Selection of new permanent access track using a wheeled loader or bulldozer.	• Heavy machines not permitted off alignment in the medium to High or High risk periods. • The requirements of SFM Advisory Note No. 2 – "Blade-up Access on State Forest and Timber Reserves" are to be used in all areas for road selection. • Activity should cease if rutting or erosion occurs as a result of machine traffic during selection. • Report occurrences of rutting to Regional Leader SFM. • A "Survey of rutting and erosion"[1] must be completed if rutting occurs.	All soils	Low or Medium risk period.	Surveillance required at completion to assess the level of disturbance off the final alignment. Long transect survey of visible soil disturbance if required.
Selection of a new temporary access track using a wheeled loader or bulldozer.	• Heavy machines not permitted off alignment in the Medium to High or High risk periods. • The requirements of SFM Advisory Note No. 2 – "Blade-up Access on State Forest and Timber Reserves" are to be used in all areas for road selection. • Exposed soil associated with understorey root balls will not be assessed as soil disturbance. • Exposed soil associated with root balls from pushed trees will be assessed as soil disturbance, using FMP limits. • Activity should cease if rutting or erosion occurs as a result of machine traffic during selection. • Report occurrences of rutting to Regional Leader SFM. • A "Survey of rutting and erosion" must be completed if rutting occurs. • Track must be rehabilitated, when it is no longer required.	All soils	Low or Medium risk period.	Surveillance required at completion to assess the level of disturbance off the final alignment. Follow-up with a Long transect survey of visible soil disturbance if required.
Rehabilitatio n of	• Deep ripping (to 500mm depth) while subsoil is dry	All	Low or Medium	Surveillance required at

Activity	Comment	Operational Guidelines		Soil Damage Assessment
		Soil Type	Allowable Risk period or TI_{SDI}	
temporary access tracks.	(preferably in the wetting up phase of the year) will be required along the full length of the final alignment, and in any areas disturbed as part of selection where a visual damage assessment indicates that the soil has been more than moderately disturbed. • Surface scarification to be completed for all areas, while the surface is moist, but not wet.		risk period.	completion to assess the level of disturbance prior to rehabilitation.
General maintenance of existing hard surface roads from table drain to table drain.	• Within scope of work defined as "General Road Maintenance".	All	At any time	Not required.
General maintenance of un-surfaced forest tracks from table drain to table drain.	• Within scope of work defined as "General Road Maintenance".	All	At any time	Not required.
Installation of new pipes on existing roads.	• Do not install these during winter unless required for emergency situations.	All	Low or Medium risk period.	Not required.
Vegetation Management				
Vegetation control between a table drain and the extent of the previous road building disturbance (road shoulders).	• Within scope of work defined as "General Road Maintenance". • Exposed soil associated with understorey root balls will not be assessed as soil disturbance. • Exposed soil associated with root balls from pushed trees will be assessed as soil disturbance, using FMP limits.	All	At any time	Surveillance at completion to assess the level of assessable disturbance. Follow-up with a Long transect survey of visible soil disturbance[3] if required.
Scrub modification of vegetation for a distance of up to 140 meters in depth from	• Heavy machines not permitted off alignment in High risk period. • Two-stage approval required for heavy vehicles off-road in Medium to High risk period. The first stage is approval as	Upland gravel and sands; or karri loams with a dense layer of natural	TI_{SDI} >50 if 2nd stage approval is granted.	Daily surveillance; Survey of rutting and erosion (if triggered). Follow-up with a Long transect survey of visible

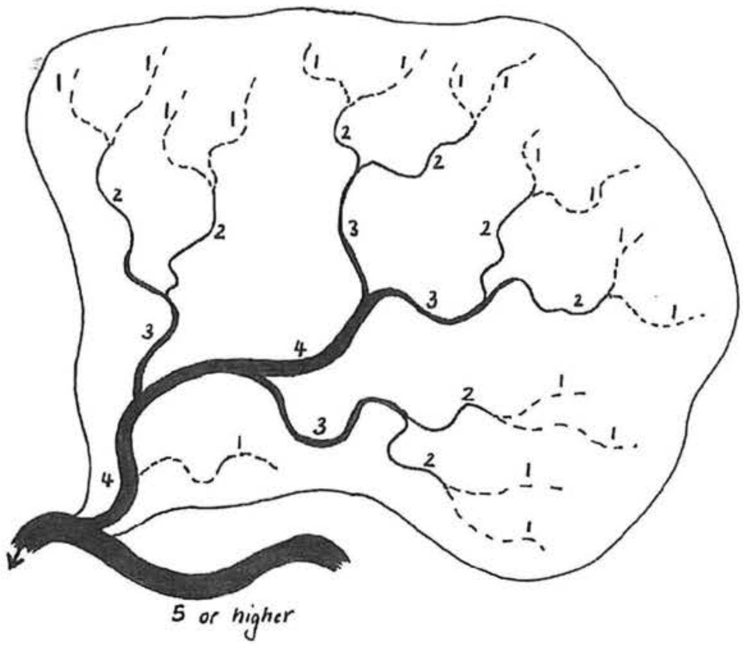
Activity	Comment	Operational Guidelines		Soil Damage Assessment
		Soil Type	Allowable Risk period or TI_{SDI}	
the top of the road batter, using a wheeled loader or bulldozer.	part of the Current Season burn programme, and the second stage will be approval by the Regional Manager or delegated Regional SFM Officer.	matting (i.e. is unburnt or has an understorey age >7 years old)		soil disturbance if required.
	• Activity should cease if rutting or erosion occurs as a result of machine traffic during selection. • Report occurrences of rutting to Regional Leader SFM. • A "Survey of rutting and erosion"[1] must be completed if rutting occurs. • Exposed soil associated with understorey root balls will not be assessed as soil disturbance.	Other soils	Low or Medium risk period.	Surveillance at completion to assess the level of assessable disturbance; Survey of rutting and erosion (if triggered). Follow-up with a Long transect survey of visible soil disturbance if required.
Tree removal for safety or burn security (machine pushing of trees by using a wheeled loader or bulldozer).	• No limit if hand falling only. • Heavy machines not permitted off alignment in High risk period. • Two-stage approval required for heavy vehicles off-road in Medium to High risk period. The first stage is approval as part of the Current Season burn programme, and the second stage will be approval by the Regional Manager or delegated Regional SFM Officer.	Upland gravel and sands; or karri loams with a dense layer of natural matting (i.e. is unburnt or has an understorey age >7 years old)	TI_{SDI} >50 if 2nd stage approval is granted.	Daily surveillance; Survey of rutting and erosion (if triggered). Follow-up with a Long transect survey of visible soil disturbance if required.
	• Activity should cease if rutting or erosion occurs as a result of machine traffic during selection. • Report occurrences of rutting to Regional Leader SFM. • A "Survey of rutting and erosion" must be completed if rutting occurs. • Exposed soil associated with root balls of trees is to be considered as soil disturbance, and FMP limits will apply.	Other soils	Low or Medium risk period.	Surveillance at completion; Survey of rutting and erosion (if triggered). Follow-up with a Long transect survey of visible soil disturbance if required.

Schedule 17 River and stream reserve requirements in State forest and timber reserves

River and stream reserves are an informal reserve type prescribed for the purposes of

- Providing forest undisturbed by timber harvesting
- Protecting water quality
- Protecting aesthetic and social values, and
- Protecting productive capacity, soil values and carbon pools.

Stream order	Reserve requirement
First, second and third	A 60 metre wide corridor with all boundaries being at least 20 metres from the bank of the stream
Fourth	A 150 metre wide corridor, with all boundaries being at least 50 metres from the bank of the stream
Fifth or higher	A 400 metre wide corridor, with all boundaries being at least 100 metres from the bank of the stream



Classification system for width and importance of streams varies from one for minor streams to five or higher for major streams or rivers

Schedule 18 Key requirements for managing salt risk

Activity	Requirement	Responsibility
Coupe planning	Determine high salt risk catchments and prepare regional indicative timber harvesting plans that allow for phased harvesting to meet additional stream buffers and basal area requirements	DEC
Harvesting second order catchments in intermediate and low rainfall zones	When harvesting in any second order catchments in the intermediate rainfall zone (900-1,100 mm/year) and low rainfall zone (less than 900 mm/year), at least 30 per cent of the area is to be retained at a basal area greater than $15m^2$/hectare for a period of 15 years after harvesting the remainder of the catchment *.	FPC
Thinning in intermediate rainfall zone	In thinning in the intermediate rainfall zone, keep final basal area to greater than or equal to $15m^2$ per hectare.	FPC
High Salt Risk catchments	For high salt risk second order catchments in the intermediate rainfall zone, retain additional river and stream buffers and locate areas temporarily reserved during phased logging operations.	FPC

* *Area retained may include areas not cut in current cutting cycle as well as informal reserves and Fauna Habitat Zones.*

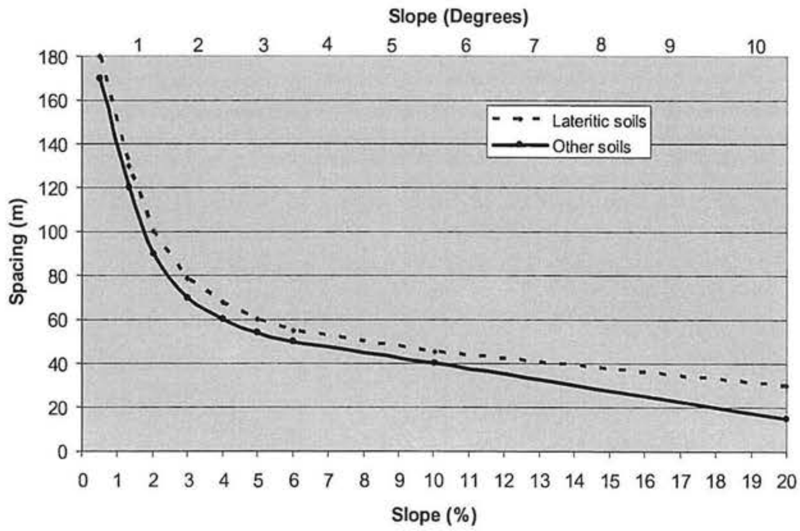
Schedule 19 Suggested placement and maximum spacings for spreaders (catch drain) for extraction tracks protection and rehabilitation.

Placement (key positions)			
Above stream and creek crossing to spread flows entering stream or creek			
At bend where water would pond on uphill side of road			
Immediately prior to a soil/landform change where downhill soil represents an erosion risk – outlet must be stable			
Spacing (no greater than)			
Slope of track (%)	**Slope of track (°)**	**Suggested maximum spacing (m) subject to soil erosion risk**	
		Lateritic gravel soil	**All other soils**
0.5 - 1	0° 17' - 0° 34'	180 - 130	120 - 90
1 - 2	0° 34' - 1° 09'	130 - 100	90 - 60
2 - 3	1° 09' - 1° 43'	100 - 80	60 - 50
3 - 4	1° 43' - 2° 17'	80 - 70	50 - 40
4 - 5	2° 17' - 2° 52'	70 - 60	40 - 36
5 - 6	2° 52' - 3° 26'	60 - 55	36 - 32
6 - 10	3° 26' - 5° 43'	55 - 45	32 - 25
10 - 20	5° 43' - 11° 19'	45 - 30	25 - 15

Notes: Maximum spacing can be reduced where soils are identified as less stable. Constructed on a grade of 0.3 – 0.5%.

Specifications for Size of Spreaders			
Size		Grade	Water Dispersal
Height	Width		
40 cm	120 to 320 cm *	0.3 – 0.5%°	Water directed from extraction track into nearby vegetation or trash that can slow the movement of water.

* Width 120 – 320 cm depending on construction technique, source of material and level of compaction.



Schedule 20 Suggested placement and maximum spacings for rolling dips on tracks and firebreaks

Placement (key positions)			
Above stream and creek crossings to spread flows entering stream or creek			
At bends where water would pond on uphill side of road			
Immediately prior to a soil/landform change where downhill soil represents an erosion risk – outlet must be stable			
Spacing (no greater than)			
Slope of track (%)	**Slope of track (°)**	**Suggested maximum spacing (m) subject to soil erosion risk**	
		Lateritic gravel soil	**All other soils**
0.5 - 1	0° 17' - 0° 34'	180 - 130	170 - 120
1 - 2	0° 34' - 1° 09'	130 - 100	120 - 90
2 - 3	1° 09' - 1° 43'	100 - 80	90 - 70
3 - 4	1° 43' - 2° 17'	80 - 70	70 - 60
4 - 5	2° 17' - 2° 52'	70 - 60	60 - 55
5 - 6	2° 52' - 3° 26'	60 - 55	55 - 50
6 - 10	3° 26' - 5° 43'	55 - 45	50 - 40

Notes: Maximum spacing can be reduced where soils are identified as less stable. Constructed on a grade of 0.3 – 0.5%.

Schedule 21 Suggested placement and maximum spacings for traverse (cross road) culverts

Placement (key positions)			
At stream and creek crossings			
Above stream and creek crossings to spread flows entering stream or creek			
At bends where water would pond on uphill side of road			
Immediately prior to a soil/landform change where downhill soil represents an erosion risk – outlet must be stable			
Spacing (no greater than)			
At mitre drain spacings where up slope table drain cannot be emptied by mitre drain installation			
Slope of road (%)	**Slope of road (°)**	**Suggested maximum spacing (m) subject to soil erosion risk**	
		Low	**High**
< 4	< 2° 17'	250 - 150	150 -120
4 - 5	2° 17' – 2° 52'	150 - 120	120 - 90
5 -10	2° 52' – 5° 43'	120 - 95	90 - 70
10 -15	5° 43' – 8° 32'	95 - 65	70 -35
15 - 20	8° 32' – 11° 19'	65 - 50	< 35

Notes: Where used to empty a table drain, minimum diameter for a traverse culvert is 300mm. Predict runoff and calculate culvert diameter at stream crossings.

Schedule 22 Suggested maximum spacing for mitre drains

Slope of road (%)	Slope of road (°)	Maximum spacing (m) subject to soil erosion risk	
		Low	**High**
< 4	< 2° 17'	250 - 150	150 -120
4 - 5	2° 17' – 2° 52'	150 - 120	120 - 90
5 -10	2° 52' – 5° 43'	120 - 95	90 - 70
10 -15	5° 43' – 8° 32'	95 - 65	70 -35
15 - 20	8° 32' – 11° 19'	65 - 50	< 35

Notes: Assess soil using USCS to determine erosion risk. Constructed on a grade of 0.3 – 0.5%.

Schedule 23 Rehabilitation requirements

Disturbance type	Rehabilitation requirement
Gravel pit	Re-establish contours, rip, scarify, replace topsoil, cross-rip, seed, plant and fertilise.
Landings	Burn, Rip, replace topsoil (where required), scarify (where required), seed, plant and fertilise
All primary extraction tracks	Level, rip and scarify
All areas that have significant ruts	Level, rip and scarify
All areas of severe or very severe soil disturbance	Level, rip and scarify
Secondary extraction tracks that have been used during the Medium to high risk period	Level and scarify
Tertiary extraction tracks that have been corded and used during the Medium - high risk period	Level and scarify
Primary and secondary extraction tracks that have been corded and used during any risk period	Level, rip and scarify
Cording or matting material	Remove or burn
Firebreaks no longer required	Level all firebreaks, rip and scarify compacted firebreaks or those trafficked during M-h or H risk period.
Roads retained for "Management Access Only" (A) Frequently used	Close with gates or block by (1) logs greater than 1m diameter, (2) earth bund 1m high and faced with rock greater than 300 mm diameter, or (3) rocks greater that 1m in diameter. Ensure that arrangements are in place for the ongoing inspection, maintenance, and protection of pipes or bridges on these alignments. Ensure DEC's corporate database is updated to reflect any change in road inventory or point items e.g. road signs
Roads retained for "Management Access Only" (B) Infrequently used	As above plus rip, and scarify the first 100m of the road to promote understorey regeneration to screen the alignment
Temporary access no longer required	Remove road hardware, reclaim BRM (if required), rip (if required), scarify, seed, plant and fertilise.
Roads for permanent closure	Remove road hardware, block the alignment at each junction or crossing with an open road as for management access above, reclaim BRM (if required), reshape the road alignment and drainage features to the natural contour, rip, respread stockpiled topsoil along the alignment (where this is available), scarify, seed, plant and fertilise. Update DEC's corporate database to reflect any change in road inventory or point items e.g. road signs.

All areas:

For more details refer to SFM advisory notes 1, x and r

- Rubbish must be removed,
- Erosion control and drainage measures must be installed,
- Activities must be in accordance with an approved Hygiene Management Plan.

Exceptions

- Extraction tracks with a concreted laterite or heavy rock base or where only low volumes of log material (<15t/ha) have been extracted, may not need to be ripped or scarified as part of the rehabilitation process.
- In karri thinnings with a heavy litter or trash layer ripping of extraction tracks may not be required.

Schedule 24 Rehabilitation standards

Activity	Comment	Risk period for earthworks	Success criteria
Log and debris preparation for Landings and gravel pits	Bark, log offcuts and cording and matting material (if present) removed, or lifted and heaped in preparation for burning; Wherever possible, stacks are to be no closer than 10m from any crop or habitat trees or other vegetation marked for retention.	All	Heaps of bark or other material are to be substantially free of soil.
Log and debris cleanup		All	For corded or matted extraction tracks and landings - cording and matting material has burnt away or is removed so that 80 per cent of sample points fall on bare soil. Bark residue from landings is burnt on the landing or spread back in the harvest area. Ash from the burnt debris is evenly spread over the landing or gravel pit.
Blading of extraction tracks		Low or Medium	Surface levelled to prevent water accumulation and channelling.
Ripping of extraction tracks, roads, gravel pits and landings	Ripping of roads and extraction tracks should not increase the amount or severity of damage to crop, habitat, other trees or significant secondary storey species. The ripping tyne should be lifted every 20m for a distance of 1m to reduce the potential for soil erosion in the rip line. Ripping should preferably be done with a winged tyne	Low or Medium in wetting up phase of year	Rip lines on landings and gravel pits aligned within 3^0 of the natural contour; Rip lines 1 m apart. Ripping does not result in mixing of the topsoil and subsoil layers; An 8 mm rod can be pushed by hand to a depth of at least 0.5m at 80 per cent of test points for landings and extraction tracks and 0.8m for roads and gravel pits. An 8mm rod can be pushed by hand to a depth of 200mm over 60 per cent of the remainder of the landing, extraction track , gravel pit or road.
Topsoil replacement (where required)	Where possible, manage stockpiled topsoil to be used within one year. Store topsoil in windrows less than 2 m high.	Low or Medium	Spread the stockpiled topsoil evenly over the landing, road or gravel pit. Do not cultivate deeper than the layer of replaced topsoil.
Scarification of landings, roads, gravel	Following ripping (and replacement of topsoil if required) scarify the soil surface to a	Low or Medium	Clods of compacted soil are less than 100mm in diameter. Scarification has not resulted in avoidable mixing of the topsoil

pits and extraction tracks	minimum depth of 100mm and a maximum of 200mm at approximately 250mm centres May be carried out with any suitable implement that will achieve success criteria.		and subsoil layers An 8mm rod can be pushed by hand to a depth of 100mm over 80 per cent of test points on the landing, extraction track, gravel pit or road
Fertiliser	Where fresh topsoil is not available, fertilise with 400 kg/ha of granulated fertilizer with elemental per cent: N – 17.5, P – 20.0, S – 1.2 (or an equivalent rate of an approved fertiliser)		Fertiliser spread evenly over the area
	When fresh topsoil is available to spread over the area, fertilise with 250 kg/ha of granulated fertilizer (with N – 16.1%, P – 9.1%, K – 0%, S – 14.3%) or an equivalent rate of an approved fertiliser		Fertiliser spread evenly over the area

Other comments:

For more details, refer to SFM Advisory Notes 1, x and r.

- Rehabilitation operations must not result in major erosion, deposition or ponding,
- All rehabilitation earthworks must be carried out in a way that is consistent with the requirements of the Hygiene Management Plan for the area.
- Exceptions to these limits are subject to approval on a case-by-case basis by the Regional Manager of DEC.
- Rehabilitated areas will be monitored for regeneration success and seedling survival during the summer following rehabilitation.
- Where a rehabilitation survey indicates that the required regeneration requirements have not been achieved, the area will have infill planting, reseeding or replanting carried out until the area is successfully rehabilitated.

To check ripping depth use minimum of 20 points across each landing, 20 points per ha of gravel pit and a sample every 5 – 10m along extraction tracks and roads.
To check removal of woodchips use a minimum of 20 points across the landing

11 APPENDICES

Appendix 1 Management of pollution in harvest operations
Extract from FPC Timber Harvesting Contractors Manual South West Native Forest section 4.3.3)

BACKGROUND
Pollution is considered to be any off site material that has the potential to contaminate soil and/or water. This includes diesel, oil and lubricants (hydrocarbons) either discharged or spilt during harvesting activities and litter left on site. These are referred to as "contaminants" in the Operational Controls. In water catchment areas, pollution includes human waste (covered in Section 4.2.1 – Water Reservoirs).

GOALS
1. No contamination of water and soil with chemicals or hydrocarbons.
2. No on or off site pollution that can be attributed to operational areas.

OPERATIONAL CONTROLS

1. A contractor is expected to have his/her work area in a tidy and orderly condition at all times, particularly when leaving the area. If a subsequent clean-up is required the work will be done at the contractor's expense.

2. A contractor shall dispose of all litter, food scraps, refuse, unserviceable equipment or machinery, or other debris resulting from his/her operations in the forest areas at such place and in such manner and time as FPC Authorised Officer shall direct.

3. The discharge of used engine oil onto the ground in any forest area is not permitted. If a subsequent clean-up is required the work will be done at the contractor's expense.

4. Fuelling of vehicles and machinery and replacement of hydraulic oils, on site, will be completed within a contained area that is relatively impervious. A 'contained area' means that if a spill occurs, it cannot flow more than a metre in any one direction from the point of the original spill. 'Relatively impervious' means that the spill cannot soak into the soil more than 50 cm before the spill can be contained. To estimate this the following examples are supplied;

> <u>Example 1</u> If a vehicle is being filled and the nozzle falls out of the vehicle, how much diesel is likely to be split on the ground. If it is hand pumped and a maximum of 5 litres will be spilt on clay soil, and be cleaned up immediately, it is unlikely to soak into the soil more than 50 cm. However, if the soil is sandy it will move through the profile before it can be cleaned up. Consequently, on sandy soil the operator would need to ensure there is material underneath the area of fuelling such as black plastic or crushed lime to ensure a potential spill will not cause more than 50 cm of contamination.

> Example 2. If a fuel trailer containing diesel does not have a hand nozzle with an "automatic off" (if there is no pressure on the nozzle handle, it will close) then there is the potential for a spill caused by the nozzle falling onto the ground and draining a significant quantity of fuel. If the nozzle is left without the automatic off, then the fuel trailer will need to be bunded and the area underneath the tank made impervious. A simpler solution, however, is to remove the risk and have an automatic off switch on the nozzle (as required by the Dangerous Goods Act if greater than 1000L of diesel is stored)

Any spillage of oil, diesel or lubricants greater than 5 litres must be reported to the FPC Authorised Officer (who will prepare an EMS incident report).

CONTAINED SPILLS

1. A 'contained spillage' is one that is not running off site from the original spillage location. If there is a contained, spill of 5 litres or more of oil, diesel or lubricants concentrated in one location, the spill must be cleaned up immediately. If this is not possible the spill must be cleaned up by the end of the working day. The area of contaminated soil will need to be dug up and placed in an impervious, sealable container for removal

2. The contaminated soil may be stored on site in an impervious and sealable container (for later disposal off site) or preferably, contaminated soil shall be moved from the site at the end of the day. Disposal of contaminated material must be in accordance with EPA regulations. Contaminated soil must NOT BE BURIED.

3. Some spills, particular hydraulic oil under pressure, may be spread over a large area and there may be no one area with more than 5 litres of oil. These spills will need to be reported to the FPC Authorised Officer, but removal of contaminated soil (with less than 5 litres in one location) will not be required, even though the total volume of oil could be 20 litres or more.

4. Spills that are classed as "Emergencies" need to comply with the relevant plan.

UNCONTAINED SPILLS

1. An uncontained spill is one that moves off site from the original spill area. This may be a rapid or slow process. Methods to contain the spill must be employed immediately.

2. All uncontained spills need to be reported to the FPC Authorised Officer in charge of the harvesting operation.

3. Containment can be achieved by mounding soil, using absorbent material such as 'Oil Soke' or sand. Cleanup of contaminated soil or absorbent material needs to occur as per 'contained spills' once the spill is controlled.

4. Table drains need to be immediately blocked if contaminants are spilled into them and uncontained. Absorbent material is also acceptable to use if it contains the movement of contaminants. Contaminated soil, water and/or absorbent needs to be removed immediately from table drains and any soaks it has entered.

5. Spills that are classed as "Emergencies" need to comply with the relevant plan.

Appendix 2 Pesticide use in Public Drinking Water Source Areas
(Extract from Department of Water Statewide Policy no 2)

Pesticide use in Public Drinking Water Source Areas

1. Pesticides should not be detected in sources used for drinking water.
2. All effective non-chemical methods of pest control and eradication shall be explored before considering the use of pesticides.
3. Pesticides that have not been authorised by the Department for use in Public Drinking Water Source Areas shall not be used in Public Drinking Water Source Areas.
4. Pesticides shall only be authorised for use in Public Drinking Water Source Areas where necessary and if they do not pose a risk to public health, have a low water contamination potential and are reasonably effective.
5. Except where the chemical treatment for nuisance pests is justified and approved by the Department, no application of pesticides shall be made within Wellhead Protection Zones, Reservoir Protection Zones and within 20 metres of water bodies. If expressed approval for application in these areas is sought, the Department may approve the use of a pesticide that is compatible with public health objectives and protection of drinking water when used in accordance with the label or specific permit from the National Registration Authority.
6. The Department will accept pesticide use within Public Drinking Water Source Areas where the use relates to the approved land use activities on the property and the pesticide, when applied according to the label or specific permit from the National Registration Authority, has a low water contamination potential, is prepared and stored in a way that is compatible with water quality objectives and does not pose a risk to public health
7. Where there is no alternative but to use pesticides, concentration and application rates shall be used strictly according to the label or the specific permit from the National Registration Authority.
8. When authorising ongoing pesticide use in Public Drinking Water Source Areas, the Department shall recognise the increased potential for the presence of authorised pesticides to occur in the source water and the need to monitor and take preventative action if detected.
9. Commercial manufacture, formulation or wholesale storage facilities for pesticides, including pesticide operator depots, shall not be located in Public Drinking Water Source Areas.
10. Retail storage facilities for pesticides is conditional in Priority 3 Public Drinking Water Source Areas.

Transportation of pesticides

11. Transport of pesticides in Public Drinking Water Source Areas should be avoided where possible.

Disposal of pesticides, equipment and containers

12. The rinse from any pesticide supply container, spent equipment, personal protective equipment and any other equipment that has been used from the mixing or application of pesticides should not be disposed of in Wellhead Protection Zones, Reservoir Protection Zones and within 50 metres of water bodies.
13. The rinse from any supply container, spent equipment, personal protective equipment and any other equipment that has been used for the mixing or application of pesticides, should be recovered where possible, and used as part of the make-up water for the next application.
14. All surplus pesticide concentrate and unused working solution should be removed from Public Drinking Water Source Areas for disposal in accordance with the Health (Pesticides) Regulations 1956.
15. All empty pesticide supply containers, spent equipment, personal protective equipment and any other equipment that has been used for the mixing or application of pesticides and cannot be used for further applications, should be disposed of outside Public Drinking Water Source Areas and in accordance with the Health (Pesticides) Regulations 1956.

Maintenance and cleaning of pesticide equipment

16. Equipment used for mixing, applying or storing pesticides should not be cleaned, washed down or left for permanently in Wellhead Protection Zones, Reservoir Protection Zones and within 50 metres of water bodies.
17. Pesticide application equipment should be tested and calibrated regularly to avoid over application and ensure proper working order.
18. The integrity of pesticide containers and secondary containment should be routinely checked and maintained.

Mixing and storage of pesticides

19. Pesticide formulation/concentrate shall not be mixed, diluted or stored within Wellhead Protection Zones, Reservoir Protection Zones, Priority 1 areas and within 50 metres of water bodies without prior approval of the Department.
20. The mixing of pesticides is allowed in Priority 2 and Priority 3 areas provided that sufficient controls are in place to capture any spill and avoid water contamination.
21. If the type, volume and storage facilities are compatible with water quality protection objectives, including appropriate containment, the storage of pesticides in Priority 2 and Priority 3 Public Drinking Water Source Areas is allowed.
22. Containers of pesticide concentrates, mixes or rinses should be stored in a secure, covered area that has sufficient measures in place to ensure any potential spillage is contained.

Monitoring and auditing

23. Monitoring for relevant pesticide residues in the source water should be undertaken where local usage suggests possible detection.
24. If a pesticide is detected at or above the limit of determination, steps should be taken to determine the source and prevent further contamination.

Clean up of contamination

25. A contingency plan should be implemented in the event of a spillage and if serious, include WESTPLANHAZMAT.

Policy review

26. This policy shall be reviewed five years from the date of publication.

Appendix 3 Use of Herbicides in Water catchment areas

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CIRCULAR NO: PSC 88

SUBJECT: USE OF HERBICIDES IN WATER CATCHMENT AREAS

Purpose

PSC 88 is for the purpose of protecting surface and ground water sources that are used as sources of water for human consumption from contamination by herbicides. The document is a best practice policy statement that applies to all government departments and their contractors.

Definitions

The term "Water Catchment Area" refers to:

(a) proclaimed public drinking water source areas (i.e. water reserves, catchment areas and underground water pollution control areas proclaimed under the *Country Areas Water Supply Act 1947* or *Metropolitan Water Supply, Sewerage and Drainage Act 1909*), and

(b) reserves vested for the purpose of water supply; and

(c) any other area that is designated by licensed water service providers and the Department of Water and confirmed by the Executive Director, Public Health

"Blanket Area Spraying" means the application of herbicide by boom sprayer, aircraft, misting machines, and like apparatus capable of treating a wide swath at one pass and these swaths being matched by continuous passes.

1. Other than with the expressed written approval of the Executive Director, Public Health, the only herbicides that may be used in water catchment areas are:

2,4-D	amitrole
fluazifop-p-butyl	glyphosate
hexazinone*	triclopyr

metsulfuron methyl - only when used for hand/spot spraying of weeds (eg blackberry and cape tulip)

*(hexazinone can affect native vegetation and therefore should be used with care or advice sought from the Department of Environment and Conservation where sensitive native plants are present.)

2. These herbicides may only be used when no other means are suitable for the control of weeds.

3. 2,4-D may only be used when the weeds are resistant to the other specified herbicides or when other chemicals are not sufficiently selective.

4. The specified herbicides may be used against declared plants and other undesired weeds on water catchments and water channels or in the vicinity of reservoirs provided timings, techniques and precautions ensure there is no spray drift or early run off from treated areas likely to contaminate reservoirs, rivers or streams. All applications must be under the supervision of a person experienced in the use of herbicides.

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5. Application is to be limited to injection techniques or direct spraying of individual weeds or clumps of weeds by apparatus producing a coarse or large droplet spray. Other than with the expressed written approval of the Executive Director, Public Health, blanket area spraying is not acceptable.
6. No mixing of the herbicide is to occur within 50 metres of reservoirs, rivers or streams. Except with the written permission of the Executive Director, Public Health, no application is to be made within 20 metres of reservoirs or rivers and streams when flowing. Application may be made within 20 metres of dry river and stream beds during the summer months.
7. Empty containers and all equipment to be removed from the catchment area before washing and disposal.
8. Other than with the expressed written approval of the Executive Director, Public Health, any unused herbicide is to be removed from the catchment area and no other herbicide except for immediate requirements is to be stored there.
9. Rates of application, safety directions and precautions on labels of the original container of the herbicide shall be strictly adhered to.
10. Records of the amounts and dates of use of herbicides on catchments are to be retained. They maybe required for investigation of incidents or complaints.

Dr M Stevens
Delegate of the
EXECUTIVE DIRECTOR, PUBLIC HEALTH
28 February 2007

Note:	Check the department of Health Website for updates at: http://www.health.wa.gov.au/home/