Manual for the Management of Surface Water

Sustainable Forest Management Series

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Department of Environment and Conservation
Our environment, our future

Department of Environment and Conservation

17 Dick Perry Av, Western Precinct

Technology Park

Kensington

Western Australia 6151

Telephone (08) 9334 0300

Facsimile (08) 9334 0498

Website: www.dec.wa.gov.au

email: forest-info@dec.wa.gov.au

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1. Framework for this manual

1.1. Purpose

The purpose of this document (Manual for the Management of Surface Water) is to provide guidance for the protection of soil and water values affected by timber harvesting and associated activities in native forest. This manual prescribes a proactive approach to the management of soil and water values as required by the *Forest Management Plan 2004-2013* (FMP).

1.2. Scope

This manual applies to State forest, timber reserve and freehold land that contains indigenous vegetation and which is held in the name of the CALM Act Executive body. It covers the geographic area of the Swan, South West and Warren regions of the Department of Environment and Conservation, other than marine waters. This manual applies to timber harvesting and associated activities unless there is an authority that overrides the provisions of the CALM Act or the FMP. Timber harvesting means the cutting, felling and gathering of forest timber. Associated activities are those which are related directly to harvesting and includes pre-harvest activities such as the demarcation of boundaries, scrub rolling of understorey, treemarking, gravel pit establishment and the extraction of basic raw materials, and road construction and maintenance. Associated activities also include post-harvest activities such as the installation and maintenance of structures to manage surface water, seed collection, silvicultural burning, rehabilitation of extraction tracks, landings and gravel pits, silvicultural treatments including coppicing, notching and the mechanical removal of cull trees, seeding and planting for regeneration or rehabilitation.

The guidance provided in this manual is for use in the establishment and maintenance of structures to manage surface water. The main activities are prevention of erosion, waterlogging and turbidity associated with extraction tracks, landings, gravel pits and in-forest access tracks carrying relatively low volumes of traffic.

1.3. Context

This manual provides the detail for operational practices which meet requirements for the protection of soil and water prescribed in the FMP. In particular, this manual addresses guiding principle number 5 in relation to the conservation of soil values from SFM Guideline No. 5 *Soil and Water Conservation Guideline.* Collectively, this manual together with SFM Manual No. 1 *Manual of Procedures for the Management of Soil and Water Associated with Timber Harvesting in Native Forests*, and SFM Guideline No. 5 *Soil and Water Conservation Guideline* replace Appendix 6 of the FMP.

This document should be read in conjunction with:

- SFM Guideline No. 5 *Soil and Water Conservation Guideline* (which provides guiding principles, rationale and strategies);
- SFM Manual No. 1 *Manual of Procedures for the Management of Soil and Water Associated with Timber Harvesting in Native Forests* (which provides detail regarding operational practices); and
- SFM Technical Report No. 4 *Reference Material for the Conservation of Soil and Water Values* (which provides background information).

2. Legislative requirements

The legislative controls in relation to management of surface water in Western Australia are found in the relevant State and Commonwealth Acts and regulations. Table 1 below summarises the relevant legislation.

Table 1: Summary of State government legislation relevant to management of surface water.

Title of Act or Regulation	Relevance of legislation	Responsible agency
Conservation and Land Management Act *(CALM Act)*	Regulations under the CALM Act pertaining to the control and eradication of forest diseases require authorisation for the taking of a potential carrier into a risk area or the movement of a potential carrier within a risk area. 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 land within the FMP area that is managed in accordance with an approved management plan.	Department of Environment and Conservation
Country Areas Water Supply Act (1947) (CAWS Act)	This Act together with the ***Metropolitan Water Supply, Sewerage and Drainage Act (1909)*** and associated by-laws are used to proclaim Public Drinking Water Source Areas (PDWSA). These may be referred to as water reserves, catchment areas or underground water pollution control areas. All operations in PDWSA are required to comply with Department of Water (previously Water and Rivers Commission) Statewide Policy No.2 *Pesticide use in Public Drinking Water Source Areas*.	Department of Water
Environmental Protection Act (1986) *(EP Act)*	Relates to the prevention, control and abatement of pollution and environmental harm. It is to ensure the conservation, preservation, protection, enhancement and management of the environment, and may relate to any contamination caused by hydrocarbons from machinery and pesticides from treatment of jarrah stands and weeds on firebreaks.	Department of Environment and Conservation
Forest Products Act (2000) *(FP Act)*	Clearing of vegetation maintained, or established and maintained, under the FP Act, or under a production contract or road contract, is exempt from the EP Act clearing permit requirements.	Forests Products Commission
Metropolitan Water Supply, Sewerage and Drainage Act (1909) (MWSSD Act)	This Act and the CAWS Act and their associated by-laws are used to proclaim Public Drinking Water Source Areas (PDWSA). These may be referred to as water reserves, catchment areas or underground water pollution control areas. There are also requirements that relate to the use of pesticides in PDWSA. All operations in PDWSA are required to comply with Department of Water (previously Water and Rivers Commission) Statewide Policy No.2 *Pesticide use in Public Drinking Water Source Areas*.	Department of Water
Rights in Water and Irrigation Act (1914) *(RIWI Act)*	Makes provision for the regulation, management, use and protection of water resources, to provide for irrigation schemes and related purposes. This Act has proclaimed Groundwater Management Areas and Surface Water Management Areas. This Act covers water courses and wetlands together with their beds and banks. Activities that could lead to interference, obstruction or destruction of the water resources within the proclaimed areas may need to obtain approval from the Department of Water before commencing.	Department of Water
Soil and Land Conservation Act (1945)	Provides for the conservation of soil and land resources. It includes the mitigation of the effects of erosion, salinity and flooding. This Act covers crown land. The Commissioner may advise a Government department or public authority in regard to the care or use of Crown lands which have lead to land degradation.	Department of Agriculture and Food
Waterways Act (1976)	Provides for defined management areas. There are a number of specific controls that may require approval from the relevant management authority. These involve any activities that put mud, earth, gravel, litter or other matter into any waters or use design drainage that discharges directly or indirectly into any waters.	Department of Water

3 Roles and responsibilities

On DEC managed lands, it is the responsibility of the proponent for any disturbance activity to undertake operations according to DEC standards. Disturbance activities include the removal of vegetation and the construction and upgrading of roads and the installation of structures to manage surface water. Table 2 below summarises the primary roles and responsibilities associated with activities aimed to manage surface water.

Table 2: Roles and responsibilities associated with management of surface water.

Activity	Standards or approvals	Responsibility
Authorisation	Disturbance operations must not commence without an approved Pre-operational Planning Disturbance Checklist.	DEC to approve Pre-operational Planning Disturbance Checklist
Safety	Design, installation and maintenance of structures to manage surface water must consider the safety of operational staff and other forest users. A Traffic Management Plan must be used to protect road users during works.	Proponent
Hygiene	A Hygiene Management Plan (HMP) may apply to the area. The movement of soil and water may be restricted under the HMP or other operational controls.	DEC to approve HMP
Demarcation	All demarcation is to comply with the DEC SFM Standard *Forest Management Tapes and Marking Standard.*	Proponent
Removal or modification of vegetation	*Outside of road corridor* including clearing of surrounding overstorey trees or understorey vegetation or machine movement outside the high point of the road batters.	DEC to approve Pre-operational Planning Disturbance Checklist
	Within road corridor between the high point of the batters on an established road alignment. Works including removal of tree and understorey regrowth from the road surface and batters, grading of the road, patching of the road surface, and resurfacing and maintenance of car parks where there is no additional clearing of surrounding overstorey trees or understorey vegetation or machine movement outside the high point of the road batter.	Proponent
Movement of heavy vehicles	Movement of heavy vehicles off-road and off landing requires approval during moist soil conditions.	DEC to approve strategic and feller's block level plans
Construction or upgrading of roads or tracks	The construction of new roads or upgrading of roads or tracks may not occur without authorisation from DEC.	DEC to approve Road Plan.
Construction of a new river or stream crossing	The creation of new river or stream crossings is generally discouraged unless failure to undertake the work may lead to environmental degradation or significant economic, social or safety impacts as described in SFM Guideline No. 4. *Guidelines for the Protection of the Values of Informal Reserves and Fauna Habitat Zones*.	DEC to approve Road Plan
Closure of a road	Temporary closures require a Traffic Management Plan. Roads should not be permanently closed without the authorisation of DEC.	DEC to approve prior to closure occurring.

4. Planning for the management of surface water

Background

Management of surface water is the process of managing the overland flow of water in such a way as to protect resources and environmental values. Where structures to manage surface water are not installed or incorrectly constructed, the potential on-site impacts are minor sheet and rill erosion from surface flows, gully and major erosion of soils, ponding and water-logging. Potential off-site impacts are deposition, flooding and reduced water quality through turbidity, contamination or sedimentation of rivers, streams, wetlands and water supplies.

Planning is the first stage in management of surface water, and involves consideration of the protection requirements of a site and then choosing appropriate structures to manage surface water based on consideration of safety, environmental, operational and economic factors. The design criteria for construction and maintenance are an outcome from the planning stage. Design criteria are a clear set of specifications that need to be met for structures to manage surface water to be correctly built and to function effectively. In planning for management of surface water it is also important to recognise when to seek specialist engineering advice.

4.1. Choosing appropriate structures

Objectives

- Protect on-site and off-site values.
- Define objectives for the management of surface water.
- Incorporate local and operational considerations into planning.

Operational controls

1. Consider and address the on-site and off-site values to be protected including safety, environmental, operational and economic values.
2. Define the outcomes to be achieved, for example:
   - to reduce erosion by slowing and spreading flow;
   - to maintain effective drainage by removing water; and
   - to reduce contamination by capturing suspended sediment.

   Examples illustrating structures used to achieve different outcomes are shown in Table 3 below.
3. Consider local and operational factors including those described in Table 4 below. These factors influence the design criteria for structures (Section 4.3) and are reflected in the specifications contained in Appendices 3-6.

Table 3: Examples of the structures to manage surface water used to achieve a range of outcomes.

Outcome to be achieved	Risks addressed or values protected	Type of structure
Maintain drainage on a landing or gravel pit.	Extend seasonal operating window. Protect revegetation from waterlogging. Prevent disease introduction.	Spreaders to shed water up-slope of the area. Appropriate grade of ripping or mounding used for rehabilitation.
Maintain safe operating conditions and drainage on road surface.	Prevent rill and gully erosion. Maintain a dry running surface.	Choice of appropriate road type and use of table drains, mitre drains, rolling dips and culverts.
Facilitate rehabilitation of a closed road or track.	Prevent erosion and waterlogging by removing channelled water flow from track surface.	Non-trafficable spreader.
Prevent erosion of road surface from overflow of up-slope table drain.	Maintain safe operation and reduce costs due to maintenance and repair.	Relief culvert.
Protect a river or stream from contamination by ash and silt from an up-slope area recently burnt.	Prevent loss of nutrients and organic matter from land surface. Prevent contamination of water supplies or aquatic ecosystem.	Sediment fence.
Prevent a major culvert from becoming blocked or failing due to accumulated sediment.	Safe operation of road infrastructure. Protection of aquatic ecosystem. Facilitate cost effective maintenance.	Gabion.
Remove suspended sediment from turbid flows associated with road drainage.	Protect the quality of water for aquatic ecosystems or human consumption.	Silt trap or settlement pond.
Protect an extraction track during temporary closure.	Reduce erosion and turbid flow.	Non-trafficable spreader.
Maintain hygiene at a wash down point.	Prevent infested water draining from the wash-down area into non infested areas.	Appropriate road surface and contouring for drainage, ramps for separation of vehicle from road surface, sump or sediment pond to capture sediment, drained to a suitable outlet.
Protect a disease free area from introduction of pathogens via surface water from an infested area.	Prevent water draining from infested area into non infested area.	Spreader, table drain, culvert and settlement pond.

Table 4: Local and operational factors to consider in planning for management of surface water

Local and operational factors	Consideration
Disturbances	Fire modifies vegetation, initially reducing interception and the transpiration of water. After fire, the land surface may initially be less stable and generate higher volumes of surface water containing ash and silt. The effect of high intensity bushfire is considerably greater than the effect of low intensity prescribed burning. The initial rains after a fire are the period of highest risk.
	The removal of vegetation reduces interception and transpiration which can lead to the generation of increased surface water.
	Soil profile disturbance such as the removal or mixing of soil layers reduces the stability of soil and can lead to increased generation of turbid surface water.
	Soil compaction is usually caused by the movement of heavy vehicles. Compaction reduces the infiltration of water and can lead to increased generation of surface water. The risk is higher where compaction leads to depressed tracks or channels which accumulate surface flow.
Natural or inherent landform and soil features	Steeper slopes require a greater degree of protection due to the increased velocity and volume of flows generated.
	Unstable soils require modified construction techniques or closer spacing of structures.
	Poorly draining soil types require larger or more closely spaced structures to deal with generation of greater surface flow.
Safety	Plan for all likely users of the road or forest.
	Incorporate safety considerations into the choice of materials use for construction.
	Incorporate safety into construction techniques and practices.
	Consider safety implications from the potential failure of structures.
Hygiene	Evaluate the potential introduction of disease or pathogens.
	Evaluate the potential for introduction of weeds.
Contamination	Evaluate potential contamination of land or water supplies.
Access	Consider expected vehicle configuration and load requirements.
	Evaluate the need for trafficable vs. non-trafficable structures.
Cost	Consider the natural and infrastructure values to be protected and potential consequences of failure.
	Consider the cost of different materials and construction techniques.
	Consider the availability of labour to undertake maintenance requirements.
	Incorporate anticipated service life into consideration of cost.

Some examples of how these factors influence choice of structure are:

- rolling dips may be used instead of culverts where maintenance is costly or impractical;
- cross-fall roads may be preferred to crowned roads where usage is low and design speed is not important;
- non-trafficable 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.

4.2. Environmental considerations

Objective

Address the relevant environmental risks when planning for management of surface water.

Operational controls

1. Determine whether there are any legislative controls relevant to the site such as Public Drinking Water Source Areas. Ensure that control options address the relevant legislative requirements.
2. Ensure that the disposal of water will not cause waterlogging or salinisation elsewhere.
3. Determine and address whether the control option or disposal option have a detrimental effect on the water quality of rivers, streams, wetlands and water supplies.
4. Ensure that implementation of the control option does not introduce nutrients or other contaminants such as pesticides into rivers, streams or wetlands.
5. Ensure that the disposal of water will not create additional disturbance or erosion through excess flow or by other means.
6. If construction and operation may affect the movement of native animals within the area, address the risks or seek advice regarding the need for specific design criteria.
7. Ensure that pathogens or pest plants that may be introduced due to the construction, operation or maintenance of the control option are addressed.
8. Determine whether the area potentially has acid sulphate soils that require investigation and management.
9. Address potential for unpleasant odours or unsightly visual impact.

4.3. Setting design criteria

Objectives

- Clearly specify design criteria for structures to manage surface water prior to commencement.
- Incorporate risk assessment into the development of design criteria.

Operational controls

(1) Specify design criteria for the structures to manage surface water which may include:

- the volume of water to be handled, often related to a calculated exceedence probability;
- physical dimensions;
- materials to be used;
- the grade of structures;
- the spacing of structures;
- the construction technique, possibly specifying the type of machinery to be used;
- maintenance requirements; and
- life expectancy.

(2) Use risk assessment when developing design criteria.

Risk assessment has been incorporated into design criteria in the tables in Appendices 3 - 6. These tables apply to the everyday application of commonly used structures and are generally regarded as best practice. For structures such as culverts on river and stream crossings, design criteria should be individually determined by considering factors such as catchment size, shape and condition as well as the frequency or severity of rainfall event that is to be handled. This type of planning is particularly important where the consequences of failure have significant safety, environmental or financial implications.

Estimating and describing rainfall events

The Average Recurrence Interval (ARI) and the annual exceedence probability (AEP) are both measures of the rarity of a rainfall event and the resulting flood or surface water flow. Tables 5 and 6 below describe and compare the use of these two expressions.

Table 5: Expressions for describing the rarity of rainfall events.

Expression	Meaning
Average Recurrence Interval	Describes the time period that could be expected between exceedances of a given rainfall total.
Annual Exceedence Probability	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 an untrained 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 interval between exceedances is not predictable. The AEP is recommended as a safer and 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 per cent) 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 6: 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)

A temporary track or shunt may only be expected to have a service life of one or two years. The structures installed to drain and protect such an access way may only be required to handle a "one in five" year storm event (AEP 0.181). 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. Recommended return intervals for culverts on river and stream crossings are given in Appendix 6.

Models for estimating peak flow

An important design criterion for management of surface water is peak flow.

Peak flow runoff is the maximum flow that could be expected through a drainage point and is usually stated for a given ARI or AEP.

Peak flow runoff depends on catchment factors such as its area, slope, stream length, soil type and vegetation cover. Two commonly used methods for estimating peak flow runoff are the Flood index method and the Rational method. These are both available as a spreadsheet calculator in DEC SFM Form 017 *Tools for the Management of Surface Water*.

Flood index method

For 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 peak flows for a single ARI. 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 25 square kilometres. Catchments with areas greater than this will be outside the parameters for prediction of surface water flow and the use of the Flood Index method may lead to errors in predicted 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 surface water 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 from 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 surface water. 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 hundred and fifty 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 *Tools for the Management of Surface Water* (DEC SFM Form 017) allows users to estimate peak flow using the flood index and rational methods.

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, 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).

Classification of soil type

The classification of soils based on engineering properties is necessary when planning and installing structures to manage surface water. 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 per cent may be more appropriate than a grade of 1 per cent, and structures to shed water may be required at closer spacing. The Unified Soil Classification System (Harding & Zierholz, 1990) is the standard for classifying soils by engineering properties in Australia and can be used to rate the stability of a soil.

DEC guidance documents recognise two main soil types – lateritic gravels, and all other soils. The lateritic gravels are generally stable, well drained and generate less surface water flow than other soil types.

The grade of structures

Almost all structures to manage surface water that are designed to gently move water are constructed on a grade of about 0.5 per cent. 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 grade may be as low as 0.3 per cent and still work efficiently, but can only be increased on exceptionally stable soil types and short structures up to around 1 per cent (1 in 100 or approximately ½ of one degree). Although a number of traditional forest applications measure grade in degrees, the industry standard unit for measurement of slope or fall is per cent. Comparative values for measurement of grade (gradient, grade and angle) are shown in Appendix 1.

4.4. Recognising when to seek engineering or environmental advice

The guidance provided in this manual is for use in structures to manage surface water for forested areas in the south-west of Western Australia. The prediction of surface water flow and the determination of structure dimensions and capacity from that prediction should be limited to catchment areas less than 25 km^2 for the Flood Index Method and 250 km^2 for the Rational Method. For larger catchments, where there are unusual site conditions or where single or a series of culverts, greater than 1.05 m diameter, are used to replace bridges it may be appropriate to seek advice from a qualified engineer.

When it is necessary to build structures within river or stream reserves, it may be necessary to seek advice regarding design and construction techniques that have minimal impact on the aquatic ecosystem.

5. Implementation of management of surface water

Background

To implement management of surface water, the required structures must be built to achieve the design criteria that have been set. Construction must be undertaken in a manner that minimises adverse affects on the surrounding area. Many structures require maintenance so they continue to function effectively. Records of performance should be kept to facilitate continual improvement.

5.1. Construction to achieve design criteria

Objectives

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

Operational controls

1. Ensure that structures to manage surface water are installed and maintained by appropriately trained staff or contractors.
2. Provide design criteria to operators who are responsible for the construction of structures to manage surface water.
3. For large structures or in sensitive areas demarcate the location and dimensions of structures. Figure 1 below shows a method to accurately demarcate the grade of a structure.
4. For the routine construction of small structures, suitably trained operators may be provided with the recommended specifications in Appendices 3 – 6.
5. Use machinery according to 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 to enable appropriate machines to be allocated. Two important considerations are the type of machine and the size of the machine. After a harvesting operation, it may be more cost effective and efficient to move larger equipment on to the next harvest coupe and use a smaller and more specialised or manoeuvrable machine to install structures to manage surface water. Criteria used for the choice of machines includes turning circle, ground pressure, visibility and the ability to tilt the blade or implement used for construction. Some of the strengths and limitations of machines commonly used in forest management are summarised in Appendix 2.
6. A shovel is possibly the most efficient and effective tool for management of surface water. After the construction or maintenance of roads and structures to manage surface water, a small amount of shovel work is a good way to clear the inlets, outlets and remove berms that channel water away from the desired flow path.
7. After construction check that design criteria have been achieved prior to completion of works for the management of surface water. Communicate the success, or required changes with construction staff or contractors. Where physical dimensions for structures to manage surface water made of earth are specified, these are after compaction and settling have occurred. Check that structures are built larger than the desired final dimensions to allow for settling and compaction to occur.

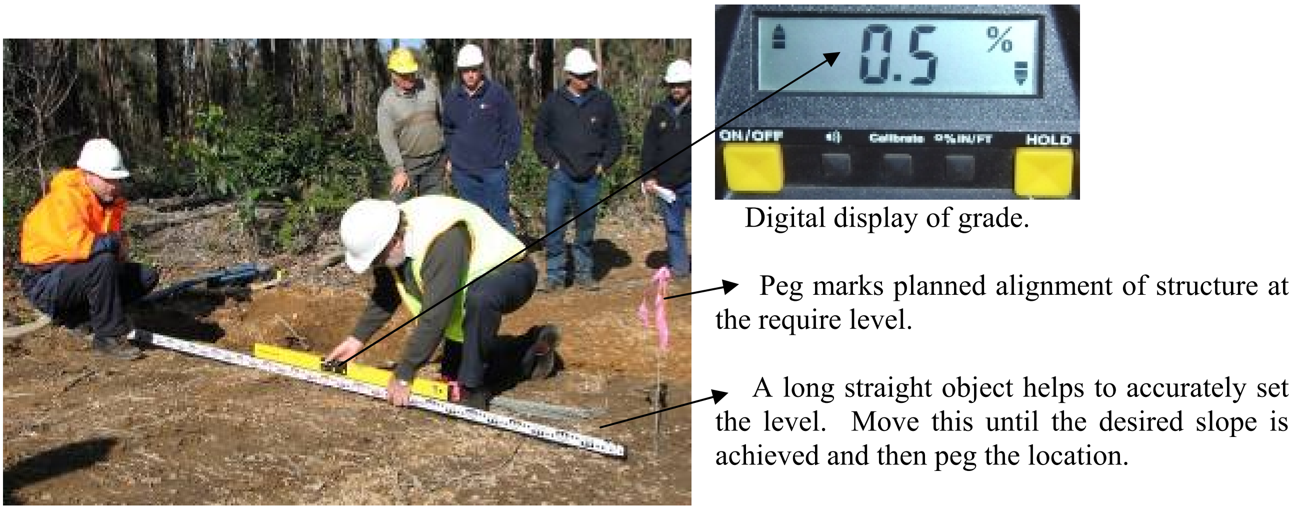


Figure 1: Demonstration of how to peg out the grade of a structure.

5.2. Minimising unnecessary disturbance during the construction phase

Objectives

- Minimise the area that is disturbed adjacent to the structure being constructed.
- Minimise the time the disturbed areas are exposed without stabilisation or cover.
- Incorporate temporary controls where required to manage surface water and sediment during the construction phase.
- Avoid contamination or infestation of the construction site.

Operational controls

1. Develop design drawings that indicate the area of site disturbance, hygiene measures and any areas where disturbance is to be avoided or vegetation is to be retained.
2. Schedule high risk works for drier times of year.
3. Brief construction staff and provide them with maps and design drawings or demarcate areas on the ground to avoid accidental disturbance.
4. Where applicable, conserve and safely stockpile topsoil for later distribution.
5. Divert up-slope surface water around the works or site.
6. Rehabilitate disturbed areas progressively.
7. Develop and apply a maintenance program for both the temporary and permanent erosion and sediment control measures that have been adopted.

5.3. Monitoring performance

Objectives

- Monitoring is conducted at intervals appropriate to risks.
- Monitoring considers changes in site and forest characteristics over time.
- Monitoring is linked to maintenance schedules.
- Monitoring is used to continually improve practices.

Operational controls

1. Maintain records of design criteria used for management of surface water including date of installation, cost, materials and techniques used and records of checking that design criteria were achieved.
2. Maintain records of maintenance works conducted on structures to manage surface water.
3. Use surveillance to monitor the performance of structures to manage surface water. Focus on performance following high flow events or where safety requirements, assets or environmental values are high.
4. Investigate instances where structures have failed or performed below expectation.
5. Periodically review the recommended design criteria and maintenance schedules based on performance.

5.4. Maintenance

Objectives

- Maintain roads, tracks and structures to manage surface water so they continue to function effectively.
- Schedule maintenance according to risk.

Operational controls

1. Determine the maintenance requirements of structures to manage surface water in relation to design life and risks.
2. Develop an annual maintenance works program incorporating the maintenance requirements of structures to manage surface water.
3. Culverts are only effective if maintained. It is recommended that structures such as culverts require inspection and cleaning on at least an annual basis.
4. If they are appropriately located and constructed, short term structures such as spreaders on regenerating extraction tracks may not require scheduled maintenance and only require surveillance following storm or fire events.
5. In circumstances where the resources for annual maintenance may not be available, consider constructing low maintenance structures for road drainage such as rolling dips.
6. 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 surface water flow such as harvesting or fire.
7. 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 berm.
8. On minor unsealed roads and tracks water often accumulates and runs down the road edges (Figure 2). This type of flow often occurs in wheel ruts, where a berm of soil has built up or where the grader has left a windrow of gravel along the edge of the road. When allowed to accumulate, this flow can lead to major erosion and deposition events, decrease trafficability and increase maintenance costs. This water should be intercepted and diverted off the road. Small shovel built mitres can be installed at points where the water will be shed into table drains or a stable surface. The breaking of the berm to release contained water, and the installation of these mitres should be part of any inspection and maintenance of minor roads.

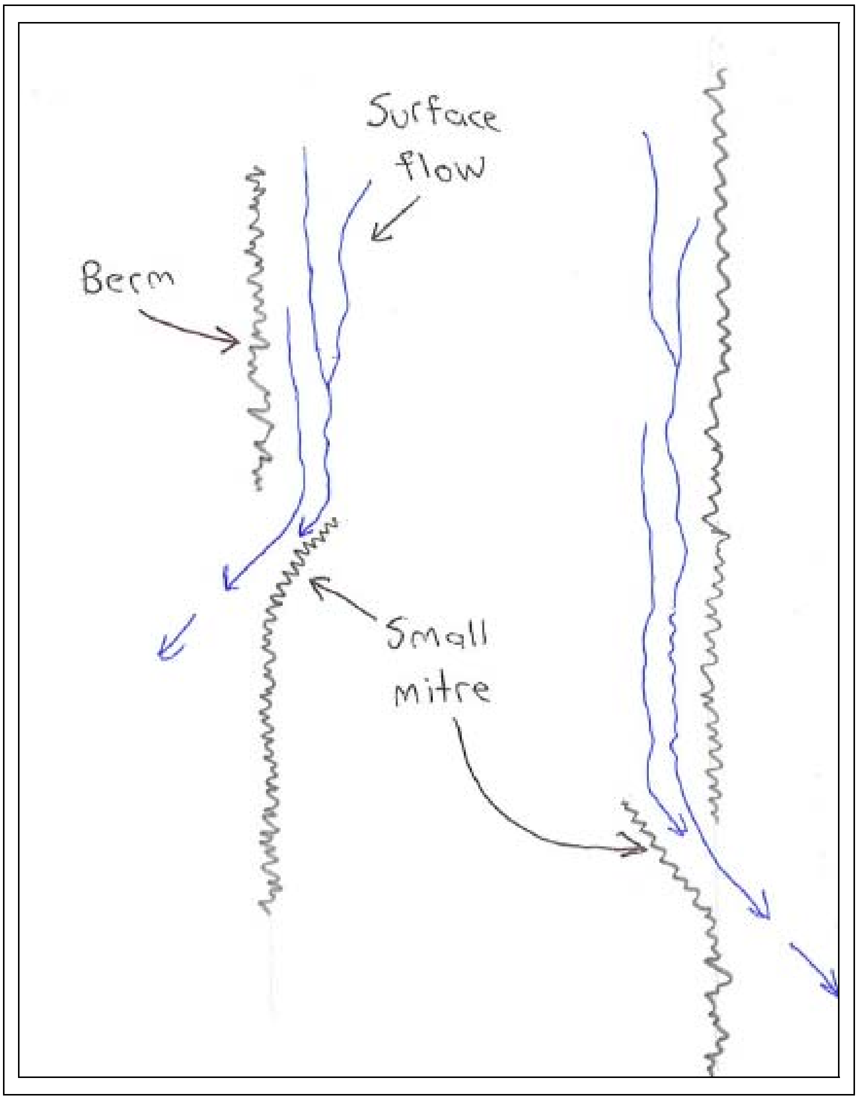


Figure 2: Diagram of the location of small shovel built mitres for road maintenance.

Rolling dip construction using bulldozer

Rolling dip construction using a bobcat

Non-trafficable spreader on a primary extraction track in a karri coupe.

Box culvert replacing a previous bridge on Crouch Road.

Inlet end of relief culvert on Crouch Road.

Outlet from a relief culvert on Crouch Road

Figure 3: **Structures to manage surface water.**

6. Spreaders

Background

A spreader is a short, generally non-trafficable section of bank, constructed on a grade across a channelled flow such as a closed extraction track, log gouge or shallow gully. The objective of a spreader is to divert the water contained in a channelled flow to a safe disposal area before it concentrates and causes erosion. Spreaders are also known as catch drains and have previously been referred to in DEC SFM guidance documents as erosion control barriers. The word barrier is no longer used because the purpose of the structure is to move water rather than to act as a barrier to water movement.

Objectives

- Spreaders have an outlet that moves water from the surface being protected into the surrounding vegetation.
- Water is discharged at regular intervals according to slope and soil stability.
- In rehabilitating areas, spreaders are constructed to dimensions that ensure they have sufficient capacity to handle flows generated by subsequent operations such as burning.
- Erosion or contamination is avoided when discharging drainage into the surrounding environment.

Operational controls

1. Use spreaders to protect closed tracks or firebreaks in the rehabilitation phase where vehicular access is no longer required. Spreaders may also be used for the protection of access ways that are temporarily closed. They are suitable up to a grade of 20 per cent.
2. Place spreaders where water can be diverted to a stable outlet such as a vegetated area or where harvesting slash is present. Points in the landscape to focus on include:
   - up-slope of any significant curve in the extraction track or road to reduce the likelihood of the accumulated surface water flow increasing its erosive capacity as a result of the change of direction;
   - on the inside of a curve, disperse the water so that it is not collected again on the next downhill section of the extraction track or road;
   - up-slope of the entry point to any landing or road, to ensure that the water collected 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 river and stream reserves to spread and filter flows in the reserve rather than directly into the river or stream;
   - immediately prior to a soil or landform change where downhill soil represents an erosion risk; and
   - on the up-slope 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.

   A photographic example of a situation where a spreader is required and where it is not required on an extraction track is shown in Figure 4 below.
3. Spreaders are required at closer spacing on steeper slopes. Use the recommended spacing shown in Appendix 3. On stable soil types the spacing varies from around 150 m apart on a grade of 1 per cent to as close as 30 m apart on a grade of 20 per cent. Closer spacing is required on unstable or poorly drained soils.
4. It is more important to locate spreaders according to landscape features and adjacent to a stable outlet than to exactly follow recommended spacing in Appendix 3.

5. Spreaders should be constructed on a grade of approximately 0.5 per cent in order to gently move water to the outlet without causing erosion. The use of a digital level is recommended to accurately determine the grade.
6. Because spreaders are generally built to protect a rehabilitating surface, they should be constructed to dimensions that ensure they continue to effectively handle flow generated by rehabilitation operations such as a silviculture burn. The height of the bank after compaction and settling should be around 40 cm. The recommended cross-section for a spreader is shown in Figure 5 below. Dimensions will vary depending on track slope, type of machine used for construction and soil type.
7. It is more important to ensure that the spreader has an outlet that discharges water into the surrounding vegetation than to build a structure with large dimensions (Figures 6, 7 and 8).
8. After construction, it is important not to drive over the spreaders, which can cause them to be ineffective.

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 surface water. Slope is not excessive and the track slopes naturally to the right of picture. Water generally follows natural overland flow paths.

No spreaders 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. The sides of the track are elevated above the general level of the track surface and will contain water within the track. Levelling of the log gouges and installation of spreaders to divert surface water flow off the track to stable areas is required

Figure 4: Comparison of the need for spreaders on different extraction tracks**.**

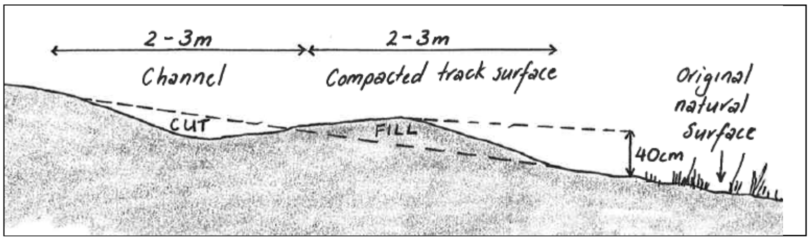


Figure 5: Cross-section through a non-trafficable spreader.

Figure 6: A spreader must *not* act as a dam.

Figure 7: Damming can result in catastrophic failure due to overflowing

Figure 8: An example of a spreader that is well constructed with an outlet that moves water off the extraction track to a stable surface.

7. Rolling dips

Background

A rolling dip is a trafficable dip excavated on a grade and with gentle side slopes to divert water off a track or road. The objective of a rolling dip is to remove water from a track, gravel road or firebreak while maintaining a trafficable running surface. Rolling dips are also known as cross-banks, check-banks, rollover-banks, whoa-boys and humpty-doos. They are like a broad, flat spreader bank. The advantage over a spreader is that although it takes a bit more work to construct, a rolling dip is trafficable. When correctly located and built, rolling dips provide effective, cheap, long term and low maintenance road drainage.

Objectives

- Dimensions of rolling dips are appropriate for anticipated vehicle configuration, traffic load and speed.
- Rolling dips are installed at intervals according to slope and soil stability.
- Rolling dips discharge water to a stable outlet.
- Rolling dips are sufficiently compacted during construction to avoid subsidence and failure under load.

Operational controls

1. Rolling dips are suitable for tracks or firebreaks with a grade up to about 10 per cent. Rolling dips are most suitable for access ways that are mainly used in drier weather and have side slopes greater than five per cent.
2. Rolling dips should not be used for slopes above 10 per cent. Where slope is greater than 10 per cent, consider using trafficable spreaders.
3. Use rolling dips where frequent cross-road drainage is required and the cost or maintenance requirements of culverts are prohibitive.
4. Rolling dips are the preferred structure to use when rehabilitating old roads due to the lower maintenance requirements compared to culverts. In the rehabilitation of a closed road, it is recommended that culverts are removed and replaced by rolling dips.
5. Place rolling dips where water can be diverted to a stable outlet such as a vegetated area or where harvesting slash is present. Points in the landscape to focus on include:
    - at bends where water would pond on the uphill side of the road;
    - above river and stream crossings to spread and filter flows in the informal reserve rather than directly into the river or stream; and
    - immediately prior to a soil or landform change where downhill soil represents an erosion risk.
6. Rolling dips are required at closer spacing on steeper slopes. Recommended spacing is shown in Appendix 4 and varies from around 150 m apart on a grade of 1 per cent to around 50 m apart on a grade of 10 per cent.
7. It is more important to locate rolling dips according to landscape features and adjacent to a stable outlet than to exactly follow recommended spacing in Appendix 4.
8. Rolling dips should be constructed on a grade of 0.3 to 0.5 per cent in order to gently move water to the outlet without causing erosion.
9. The use of a digital level is strongly recommended to accurately determine the grade. Rolling dips are most efficient when constructed approximately at right angles to a road. However, diagonal banks may be constructed where this is necessary to obtain sufficient gradient or direct water to the most suitable outlet.

10. The height above the original road surface should be 50 cm once the structure is compacted and has settled. The length of a rolling dip varies depending on track slope and vehicle requirements from around 60 m down to 6 m. Length shortens with steeper track slopes and as dimensions become shorter, the rolling dip becomes less trafficable for larger vehicles.
11. 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. An example cross-section for a long rolling dip suitable for log truck passage is shown in Figure 8 below.
12. The recommended sequence of construction for rolling dips is shown in Figures 10 and 11.

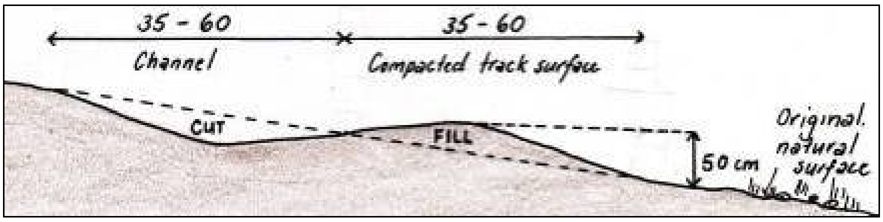
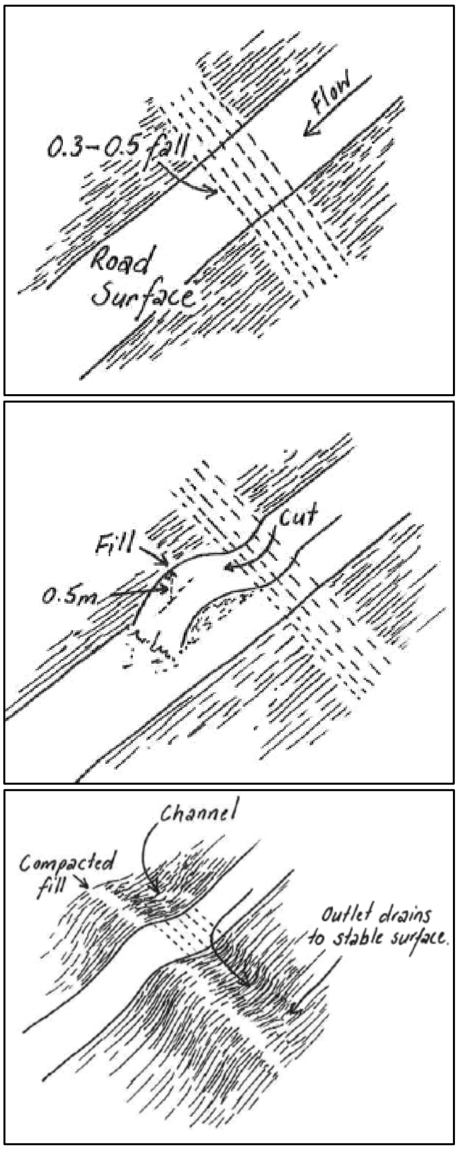


Figure 9: Cross-section through a long rolling dip on a haul road suitable for log truck passage.



Choose an area where flow can be diverted to a stable, vegetated surface. Survey a grade of 0.3 to 0.5 per cent and mark this on the road surface. 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. An armoured outlet or bank to a level sill can be used to discharge water where a stable surface is not immediately adjacent.

Figure 10: Recommended sequence of construction for rolling dips.
Source of diagrams: Adapted from Department of Natural Resources, Environment and the Arts (2006).

1. Pegging the alignment.

2. Cutting and pushing the bank.

3. Compacting spoil on the bank.

4. Clearing and compacting the inlet and outlet

Figure 11: A photo sequence showing the construction of a small rolling dip trafficable to four wheel drive utilities and light fire fighting units.

8. Road drainage

Background

Road drainage is the process of removing and safely disposing of water from the road surface before it accumulates volume or velocity. The objective of road drainage is to safely divert water flowing along or onto a road before it results in unsafe conditions or causes damage to the road or surrounding environment. All roads and tracks should be constructed in a manner that enables surface water to be safely discharged. If this is not removed from the road surface, it may lead to excessive moisture or deterioration of the surface and accumulation at critical points resulting in unsafe conditions, erosion or premature failure.

Objectives

- Control the flow of surface water generated by roads using a combination of the appropriate road cross-section and water diversion structures within the roadbed itself.
- Avoid carrying water long distances in up-slope table drains by installing cross road drainage structures such as relief culverts or rolling dips.
- Discharge water from table drains at regular intervals according to slope and soil stability.
- Avoid erosion or contamination when discharging road drainage into the surrounding environment.

Operational controls

1. Select the most appropriate road cross-section for the landscape, intended road use and environmental values. Background to the different types of road cross-sections is provided in Section 8.1.
2. Install and maintain table drains capable of safely carrying road drainage to disposal areas (Section 8.2).
3. Use a sufficient number of appropriately placed mitre drains to discharge drainage to safe disposal areas (Section 8.3).
4. Install relief culverts with sufficient capacity to carry water from up-slope table drains to safe disposal areas (Section 8.4).

8.1. Road cross-sections

Background

Crowned and cross-fall cross-sections are generally used in timber harvesting and associated activities. The objective is to select the appropriate road cross-section at the design stage, to ensure that the associated drainage will be as effective and cost-effective as possible.

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. Crowned roads concentrate water in table drains and culvert outlets (Figure 12). They are used where there are unstable or erodible fill slopes, on steep grades, where traffic volumes are high or slippery conditions are expected.

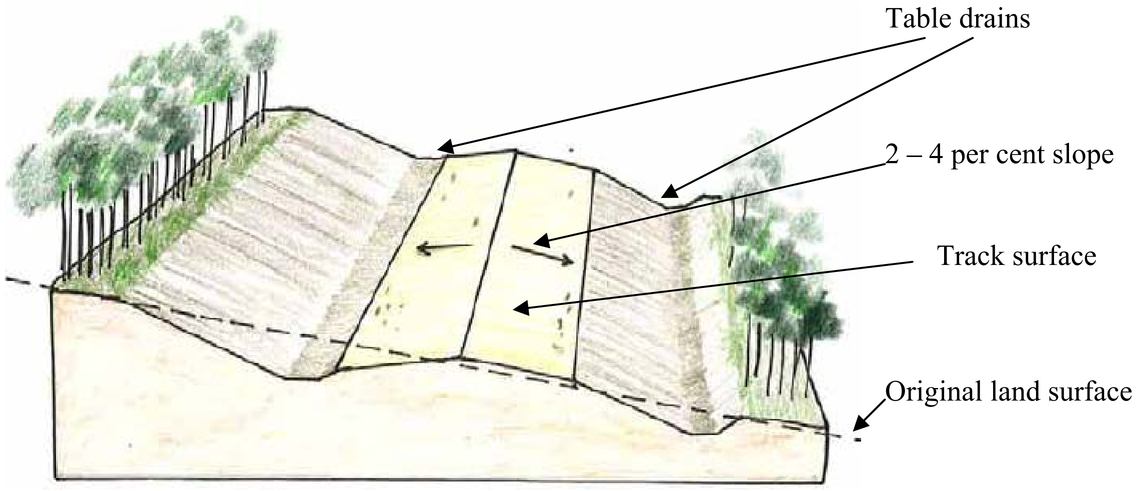


Figure 12: Cross-section of a crowned track.

Cross-fall roads or tracks

On land with cross-fall, where a track is not crowned, the surface may either slope into the hillside or out from the hillside. There are two types of cross-fall roads, in-slope and out-slope. Cross-fall roads and tracks are generally not used on major access roads due to safety and design speed limitations. They are most appropriate for minor access routes that have limited use and low design speeds, for example less than 40 km/hr. Cross-fall roads should only be used where the road grade is less than 8 per cent.

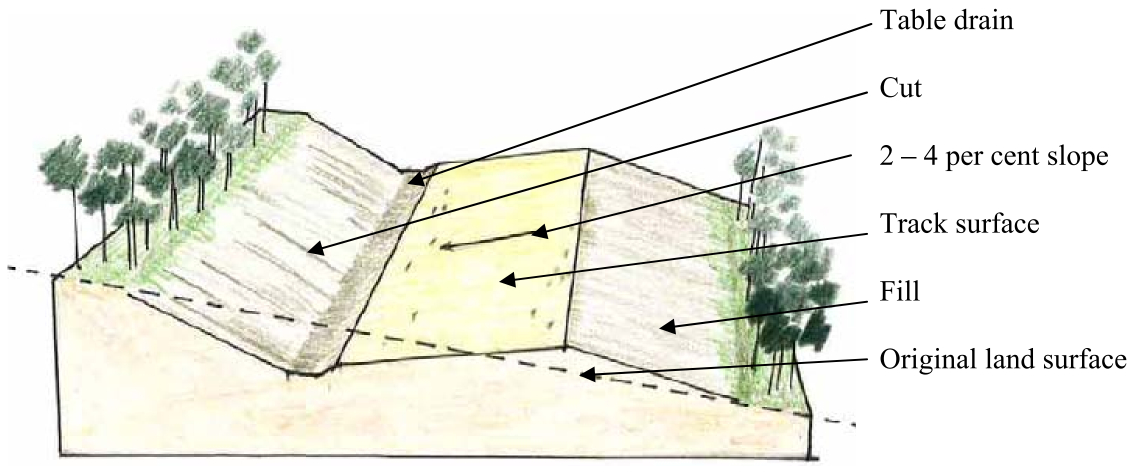


Figure 13: Cross-section of an in-slope track.

In-slope roads and tracks are constructed with a table drain to remove surface water from the track surface (Figure 13). Water drains towards the cut slope on the uphill side and is collected in a table drain. Relief culverts are installed under the road to relieve the table drains at spacings recommended in Appendix 6 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 steeper 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 becoming blocked.

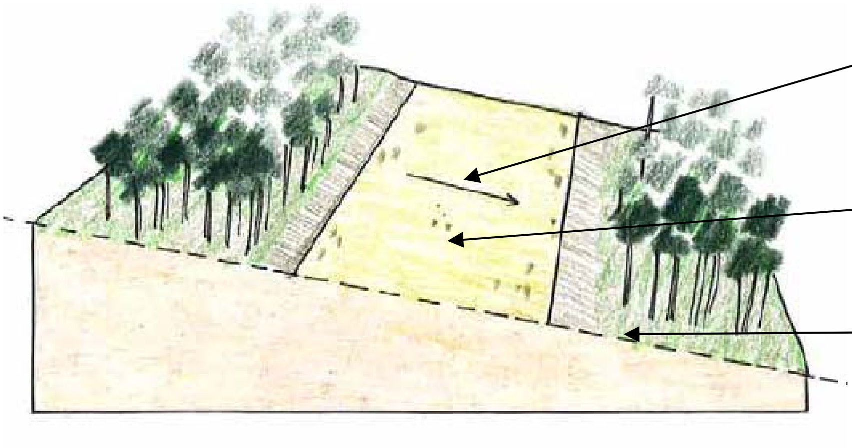


Figure 14: Cross-section of an out-slope track.

Out-slope roads and tracks usually require less excavation and clearing than other road types. Surface water from the road runs directly off the side of the road, often negating the requirement for constructing table drains and culverts (Figure 13). Out-slope tracks are constructed with rolling dips to remove water at spacings recommended in Appendix 4. Rolling dips are required to remove surface water from the track surface and prevent water being channelled long distances in wheel ruts and where the grade of the track is greater than the cross fall and water will tend to flow along the track. Discharge from the 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 on a grade of less than 8 per cent. 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. Out-slope roads are generally the least expensive type of road to build and maintain.

8.2. Table drains

Background

A table drain is the side drain of a road or track constructed adjacent and parallel to the road shoulders. A table drain collects water from road surfaces and sometimes also surface flow from the adjacent up-slope area such as the road batters. The objective for table drains is to capture drainage from the road surface and safely move the water to a suitable location for discharge. Water must be discharged from table drains at frequent intervals because there is limited scope to alter their gradient. The main risk is that scouring or overtopping will occur due to excess volume and velocity of accumulated flow.

Objectives

- Avoid overtopping or scouring in table drains by managing the cross-sectional shape, the spacing between outlets and the area contributing to table drains.
- Discharge water from table drains to suitable stable outlets.
- Prevent table drains from blockages or becoming ineffective due to berms created by road grading operations.

Operational controls

1. Aim to construct table drains with a flat base and a side slope of 4:1 (maximum 3:1). This cross-sectional shape is known as Trapezoidal and is shown in Figure 15 below. Trapezoidal drains, allow greater volumes of water to be carried at lower velocity and shallower depth. Parabolic (U-shaped) cross-sections where the width is three times the height are also effective.
2. Try to avoid V shaped cross-sections which increase the depth and therefore erosive power of water. Doubling the depth of running water increases its erosive power approximately ten fold.

3. In some cases, such as where there is a need to reduce the width of a road corridor, a V-shaped table drain may need to be constructed. If this occurs it is important to pay attention to soil stability and remember that additional relief drainage will be required to reduce soil erosion.
4. Use mitre drains, culverts and rolling dips to remove water from table drains at the intervals recommended in Appendices 4 – 6.
5. For areas with grades over 5 per cent on erosive soils and on grades over 10 per cent on normal soils armour table drains to prevent scouring and erosion. Armouring may be in the form of riprap, rock, concrete, geo-textile or native grass.
6. Ensure that table drains are discharged to stable surfaces and up-slope from river and stream reserves.
7. Periodically conduct surveillance on the condition of table drains to ensure they are not becoming blocked or ineffective. Surveillance is important after road grading operations, after the first rains in autumn and following heavy rainfall events.

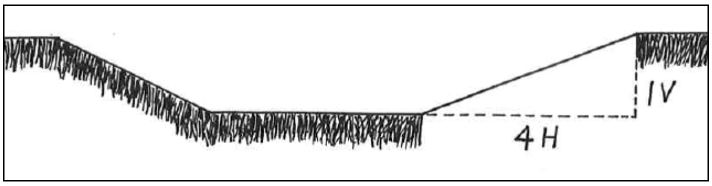


Figure 15: Recommended cross-section for table drain channels (Trapezoidal).

8.3. Mitre drains

Background

A mitre drain is a drain to conduct surface water from table drains to a disposal area away from a road. The objective is to discharge surface water flow from the road surface and associated table drains at stable points in the surrounding landscape (Figure 16). Mitre drains are also known as cut-off drains, off-shoot drains, diversion drains, turnouts and runoffs. They are designed to prevent water flows building up in the table drain beside a road and causing overtopping or erosion.

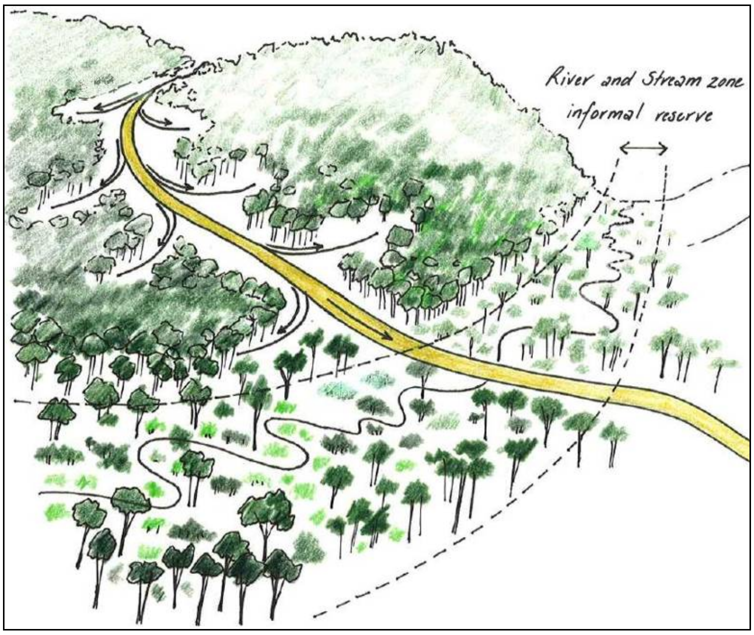


Figure 16: Mitre drains remove surface water at regular intervals to stable areas before the road enters an informal reserve. Install additional structures to control surface water in the informal reserve as required (within the road corridor).

Objectives

- Effectively remove water from table drains.
- Have sufficient capacity to handle flows generated by the up-slope catchment area.
- Discharge accumulated flow at safe disposal points.

Operational controls

1. Install mitre drains at intervals according to local slope and soil type as shown in Appendix 5. Spacing is closer for steeper grades and less stable soil types.
2. A mitre drain should have sufficient capacity to handle anticipated flows. Ideally, they should be constructed so that they have a broad flat base 2 – 2.5 m wide (1 grader width) and a trapezoidal cross-section (as for table drains shown in Figure 15).
3. Mitre drains should intersect the road level with the edge of the running surface.
4. Mitre drain outlets should be located in stable, undisturbed areas and up-slope of river and stream reserves.
5. In order to slow the discharge velocity and remove suspended sediment, the grade of mitre drains should not exceed 1 per cent (0.5 per cent on less stable soils). Ideally, mitre drains should have a level sill at the disposal point.

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

8.4. Relief Culverts

Background

A relief culvert is a relatively short section of drainage pipe installed on a grade under a road to safely transmit water from the up-slope to the down-slope side. The objective is to divert water contained in an up-slope table drain underneath a road surface to a safe disposal area before it concentrates and causes erosion. Culvert pipes are commonly made of concrete, steel or PVC. A relief culvert has an inlet and outlet which may incorporate design elements for the capture of sediment or debris, or facilitate the safe disposal of discharge water.

Relief culverts are considered separately from culverts that are used for river and stream crossings. These are covered in Section 9 of this manual.

Objectives

- Relief culverts are designed and located considering the safety of road users.
- Relief culverts have sufficient capacity to handle anticipated flows.
- Inlets capture sediment and are designed to reduce the chance of becoming blocked.
- Outlets discharge water without causing erosion or contamination.

Operational controls

1. Culverts should be constructed to minimise potential impacts on the safety of road users. Guide posts should be installed to alert road users to the presence of culverts. Sufficient capacity to handle expected flow is a safety consideration where failure or overtopping presents potential risks to road users.
2. Culvert size should be selected based on a return interval appropriate to the road and catchment characteristics. Appendix 6 provides recommended spacing of culverts. A 300 mm diameter pipe is the minimum recommended size for relief culverts.
3. The recommend fall of the culvert pipe is around 0.5 per cent and up to 2.0 per cent. Increasing the fall reduces the chance of sedimentation, but raises the discharge velocity of water. Above a fall of 2.0 per cent, discharge velocity can create significant scouring and soil erosion. Culverts should be firmly seated, and earth packed firmly up the side of the pipe during installation.
4. At culvert inlets 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. 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.
5. 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 geo-textile overlain with stone, concrete half pipes, corrugated iron or concrete sandbags.

6. 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.

Figure 17: A culvert inlet and inlet sump.

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. The sand/cement mix bags in the photo are called a headwall. Ideally, these should also be installed on the uphill and downhill faces of the sump.

8.5. Catch drains

Background

A catch drain is a surface bank or channel constructed along the high side of a road or embankment outside the batter to intercept surface water from higher surrounding areas and direct it away from the cut batter slope and road surface below. The objective is to prevent water flowing onto areas prone to erosion. Catch drains are often used at the top of deep cuts to avoid erosion of the cut batters and accumulated flow or sedimentation of the table drains (Figure 18).

Objective

Divert water away from susceptible sections of the road corridor to safe disposal points.

Operational controls

1. Construct catch drains to the same cross-section dimensions recommended for table drains and mitre drains (Figure 15).
2. Where possible divert water flow to culverts or natural water courses.
3. The grade of catch drains should be around 0.5 - 1 per cent to prevent scouring and erosion.
4. Incorporate access requirements for the maintenance of catch drains into the road alignment.
5. Where it is not possible to install catch drains, special provisions may be required to stabilise cut batter slopes.

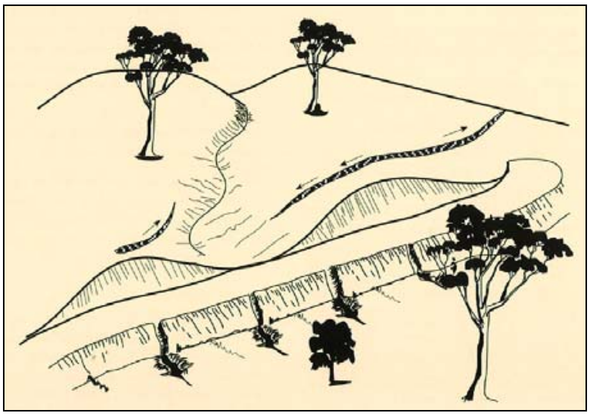


Figure 18: Schematic diagram showing the location of catch drains on the high side of a roadway.

Source of picture: AARB Group Unsealed Roads Manual (2009).

9. River and stream crossings

Background

Crossings are structures that allow vehicular access across a river or stream. There are a number of different types of river and stream crossing including fords, culverts and bridges. The objective is to allow traffic to safely cross using a structure that is cost effective and has minimal environmental impact. River and stream crossings are key elements in any road network and represent considerable investments. They are high risk areas that require planning at a number of levels. The areas that need to be addressed include safety, environmental and economic considerations. On DEC-managed land in the south-west forests, the creation of new river and stream crossings is generally discouraged because there are many existing crossings already in place.

Objectives

- Crossings are safe and design is based on the appropriate return interval and engineering advice.
- Crossings are placed at the most appropriate locations.
- Design, installation and maintenance addresses potential environmental risks.
- The most appropriate structure is used according to site conditions and access requirements.

Operational controls

1. For safety it is recommended that the appropriate engineering advice is sought for the design and construction of river and stream crossings where there is public risk.
2. Locate river and stream crossings using the following guidance:
   - Cross at well defined banks. Rivers and streams are generally narrower at these locations and stable banks generally indicate stable flow;
   - Cross away from curves in a river or stream which may be unstable or prone to erosion or migration;
   - Cross in an area that has a uniform river or stream gradient to minimise potential erosion or deposition risks to the infrastructure;
   - Cross where there is minimum erosion of the river or stream bed;
   - Cross at right angles to the river or stream to reduce the crossing length;
   - Adopt the minimum elevation based on the design flood flow; and
   - If the existing location of a crossing is inappropriate, consider relocation based factors such as maintenance requirements, cost, usage and safety.
3. On DEC-managed land, river and stream crossings occur inside informal reserves and must comply with conditions outlined in *Guidelines for the Protection of the Values of Informal Reserves and Fauna Habitat Zones.*
4. River and stream crossings that occur within Public Drinking Water Source Areas must address Department of Water policy.
5. All vehicles and machinery must not enter a river or stream reserve other than at authorised crossings. Although the placement of logs or cording into stream beds has historically been used for stream crossings, this practice is no longer allowed on DEC-managed land. One exception exists for emergency access at wildfire incidents where rehabilitation occurs immediately following suppression operations.
6. All construction and maintenance work must minimise the area of the bed and banks of the river or stream that is disturbed and take place within the approved corridor.

7. All soil or vegetation material resulting from construction and maintenance must be carted outside the river or stream reserve, or a minimum of 40 m from the river or stream and disposed of or burnt within the road corridor.
8. Refuelling or washing of equipment is not allowed in river or stream reserves.
9. Use structures to manage surface water to divert water from road surfaces up-slope from river or stream reserves and dispose of surface water generated within the river or stream reserve in a manner that maximises the removal of turbidity.
10. The felling of trees is not allowed within river and stream reserves, with the exception of tree removal for safety.
11. Following construction or maintenance works, the river and stream must be free of debris with no obstruction to natural flow.
12. River and stream crossings must consider the requirements for the passage of aquatic fauna including factors such as water velocity, timing and depth of flow.

9.1. Considerations for various crossing types

Fords

For unsealed roads with low usage, it is not always possible to cost effectively construct bridges or culverts that accommodate design drainage for infrequent storm events. In these cases, a ford or low level crossing may be the most appropriate type of crossing. Under high flow conditions, water runs over the roadway at depths that are unsafe and preclude access by vehicular traffic.

Fords or low level crossings are most appropriate where:

- bank height of the river or stream is less than 1 metre;
- depth of normal water flow across the ford is less than 0.5 metres;
- approaches to the river or stream are on a grade of less than 10 per cent; and
- the river or stream bed is solid (gravel or stone), with rock accumulation down-stream.

For large catchments a floodway with scour protection may be used to supplement a culvert designed to take low flows only. For smaller catchments a drop section may be used where a section of the grade line of the road is lowered close to the natural surface to allow part or all of the storm generated discharge to pass over the road with the minimum of obstruction. The maximum safe depth of water on a road is usually not greater than 150 mm.

Low water crossings involve compromises and between providing cost effective access and providing for traffic safely. Safety is a major concern for fords. In Australia, a number of deaths have occurred when people have driven into flooded crossings.

Fords should not act as a dam and pond water or prevent water movement during periods of low flow.

Culverts

Culverts are commonly used for small to medium sized rivers and streams where the required diameter of the culvert is less than one metre. Culverts are generally more cost effective to construct and maintain than a similar span bridge. For culverts where pipe diameter is greater than one metre, additional engineering considerations such as the depth of embankment become important and it may be appropriate to seek engineering advice. The following operational controls should be observed when using culverts for river and stream crossings.

1. Entry and exit points should conform closely to the natural slope of the river or stream.
2. Inlets should provide smooth entry without abrupt changes in direction or drops which can cause turbulence.

3. Estimated outlet velocity will determine if there is potential for erosion at the exit point. Refer to local drainage design manuals for information on maximum permissible velocity of water for various soil types.
4. Where high water velocities and erosion are anticipated, protect entrance and exit points with armouring. Energy dissipaters such as riprap will help spread the flow and prevent scouring and sedimentation. The armouring or dissipation structures must coincide with the existing channel grade to avoid the creation of an overfill.
5. Ensure that adequate compaction is achieved around culverts so that water does not enter the headwalls and undermine their stability.
6. The use of laser levels to set grades for culverts is recommended.
7. Avoid the use of galvanised steel pipes where water flows have a high acidic value.
8. Consider the impact of the structure on aquatic habitats and the movement of aquatic fauna. It may be necessary to consult with local natural resource managers. Where fish or other aquatic fauna are present, it is preferable to use open bottom culvert, arches or bridges which maintain the natural shape of the channel. Culverts with a roughened base installed below the natural river or stream bed can minimise fish impacts. In some cases it may be appropriate to design one culvert for fish passage during low flows and others to come with flood events.

Use of the *Tools for the Management of Surface Water* (DEC SFM Form number 017) is recommended for estimating the capacity of culvert pipe required according to return intervals, catchment characteristics and climate. The appropriate minimum return intervals to use when estimating culvert capacity are shown in Appendix 6.

Bridges

Bridges are sometimes preferred to culverts because they are more open structures and require minimum modification or disturbance of the river or stream channel under the crossing. Bridges are often the most appropriate structures in steep gullies where the predicted height of flow is too high for culverts. Engineering advice is recommended for the design and construction of all bridges.

10. Sediment fences

Background

A sediment fence is a fence constructed of open weave geo-textile or hay bales, partly buried and supported by posts or stakes. The objective is to capture soil or other substances carried in surface water before it can cause off-site contamination. Sediment fences are also known as silt fences or filter fences.

Objectives

- Slow the flow of surface water allowing sediment to drop out or be trapped.
- Allow the passage of water through the structure without going around or underneath.
- Have sufficient capacity to handle flow generated from the catchment above.

Operational controls

1. Sediment fences are suitable to use on slopes with a grade of less than 20 per cent.
2. Install sediment fences at intervals of approximately 60 m. Closer spacing is recommended where the grade is greater than 10 per cent.
3. Do not use sediment fences in areas of high flow concentration unless they are reinforced or at closer spacing.
4. Place in areas that facilitate maximum up-slope capacity to collect sediment.
5. Maintain sediment fences by checking after rainfall events to repair broken bales or torn fabric, clear out excess accumulated sediment load, ensure the bottom of the fence is securely keyed in below ground level and check for evidence of water flow and scouring around or under the fence.

Construction technique using geo-textile (Figure 19):

1. Use specially manufactured geo-textile sediment fence, not shade cloth.
2. Mark the location for the trench, surveyed level (on the contour).
3. Dig a 150 mm deep trench line for the bottom of the fabric to be buried in.
4. Run fabric down the trench with the end on the up-slope side of the trench.
5. Bury fabric and backfill, then compact or wheel roll to firm up the placement.
6. Drive support posts a minimum of 400 to 500 mm into ground at 2 to 3 m spacing on the down-stream side of the fence.
7. Posts may be either metal star pickets with UV stable zip ties or galvanised tie wire to secure fabric or 40 mm square hardwood posts with staples.
8. The height of the geo-textile should not exceed 600 – 700 mm above ground.
9. Steel mesh may be installed behind fence to provide extra support in areas of high flow.
10. Join fabric at support posts with an overlap of 150 mm.
11. Ends of the sediment fence may be turned up-slope slightly to prevent water flowing around the edges.

Construction technique using straw bale (Figure 20):

1. Only use straw bales that are weed free.
2. Mark the location for the trench, surveyed level (on the contour).
3. Tightly abut bales together and partially bury 100 mm into the ground to prevent water flowing under or around them.

4. Secure with 2 star pickets per bale.
5. Straw bale sediment fences often fail when they have not been firmly staked or are not butted firmly together. One option is to combine bales with geo-textile on the up-slope edge stapled to tops of bale and buried to a minimum depth of 150 mm.

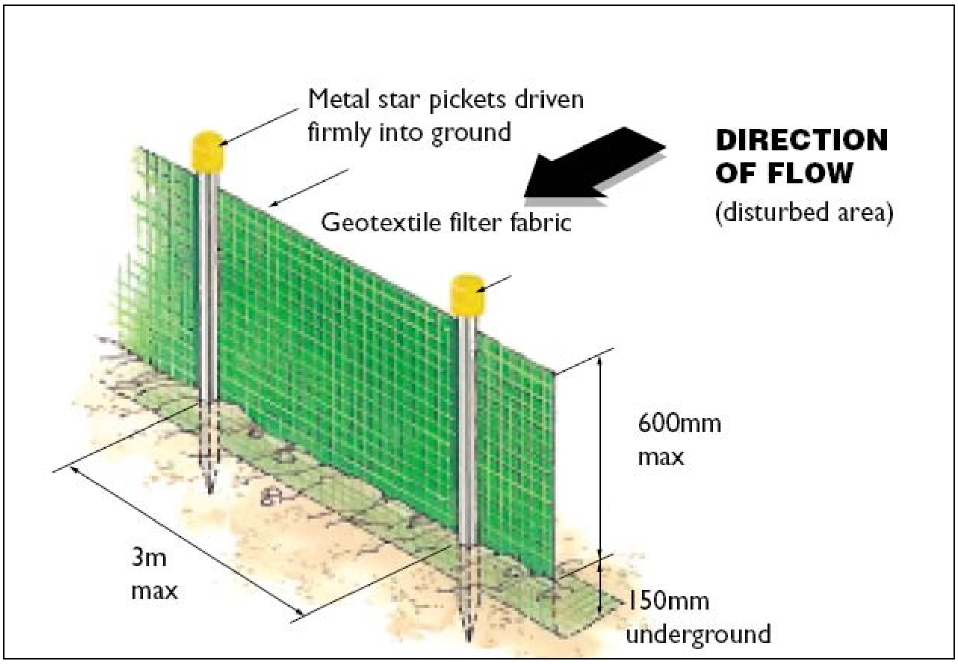


Figure 19: Recommended installation method for geo-textile sediment fence.

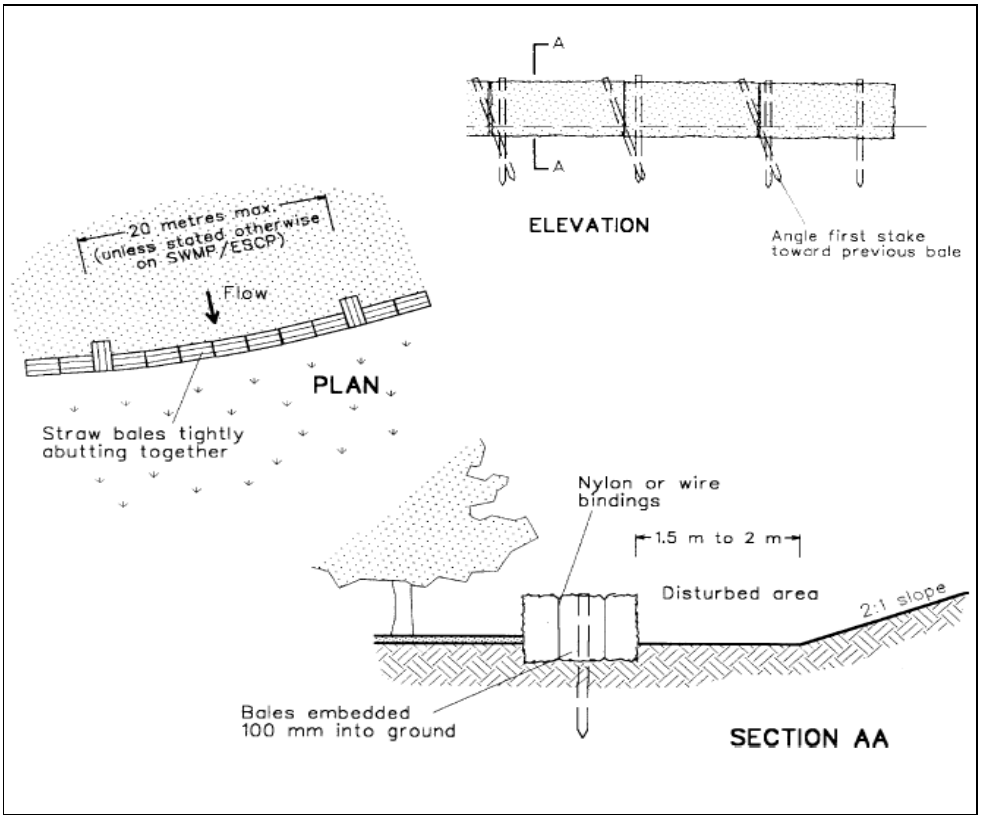


Figure 20: Recommended installation method for straw bale sediment fence.

(Source of pictures: Southern Sydney Regional Organisation of Councils Fact Sheet 14.)

11. Glossary

Term	Definition
Annual Exceed 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 exceedence of a given rainfall total accumulated over a given duration. The exceedence does not occur at regular intervals and are more random in nature.
Berm	A raised ridge of earth often resulting from the construction or maintenance of roads or vehicle movement.
Catch drain	A surface bank or channel constructed along the high side of a road or embankment outside the batter to intercept surface water and direct it away from the road and slope.
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.
Cross fall	The slope, measured at right angles to the alignment of the surface of any part of a road or track.
Design criteria	A clear set of specifications that need to be met for structures to manage surface water to be correctly built and to function effectively.
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.
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 structures to manage surface water for a given ARI.
Gabion	A wire basket filled with stones used to retain earth or control scour.
Geo-textile	A synthetic fabric used for various purposes including embankment reinforcing and stabilising, as a filter and as a strain alleviating membrane.
Grade	Grade is the amount of inclination with respect to gravity. Larger numbers indicate higher degrees of tilt or slope. Grade is usually expressed in percent as a ratio of rise over run in which run is the horizontal distance and rise is the vertical distance.
Gully erosion	The removal of soil in large channels more than 30 cm deep. Gullies are typically steep sided and have branches. Gully formation occurs as a result of surface water or a combination of surface water and seepage.
Headward erosion	Gully or rill enlargement in an up-stream direction due to incision by concentrated surface water 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.
In-slope (roads or tracks)	Cross-fall roads or tracks constructed with a grade sloping in towards the cut (uphill) section. Surface water from the track surface drains towards the cut slope and is collected in a table drain.
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.
Management of surface water	The process of managing surface water in such a way as to protect the environment and resources.

Term	Definition
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.
Mitre Drain	A drain to conduct surface water 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.
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.
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.
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	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 structures to manage surface water.
Relief culvert	A relatively short section of drainage pipe installed on a grade under a road or track to safely transmit water from the up-slope table drain to the down-slope side.
Return interval	Describes the time period that could be expected between exceedence of a given rainfall total.
Rill erosion	The removal of soil by surface water in numerous small channels (rills) which are commonly around 5 to 10 mm deep but may be as deep as 30 cm. 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.
Riprap	Medium to large size rock protection against scour sometimes applied to table drains and the face of embankments
Road	A constructed form of pavement or surface intended for access by vehicular traffic.
Rolling dip	A trafficable dip excavated on a grade and with gentle side slopes to divert water off a track or road. Spoil is moved 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.
Sheet erosion	(Or inter-rill erosion) is the removal of a uniform layer of soil by raindrop splash and/or surface water movement. 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.

Term	Definition
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. Soil compaction can cause decreased tree growth, increased surface water movement, waterlogging and erosion.
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.
Spreader	(Sometime called catch drain). A short section of bank constructed on a grade and diverting channelled 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.
Table drain	A side drain of a road constructed adjacent and parallel to the road's shoulders.
Temporary access	A road or track of any standard that is constructed for use in a particular operation, but that is not required to be retained for DEC use at the completion of the operation, and must be rehabilitated.
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.
Track	An informal thoroughfare intended for vehicular traffic that does not necessarily conform to a formal design or construction standards.
Traverse culvert	.See **Relief culvert**
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.
Unified Soil Classification	A system classifying soil on the basis of the texture and liquid limit. The system comprises 15 soil groups, each identified by a two letter symbol. The first symbol represents the type of soil.

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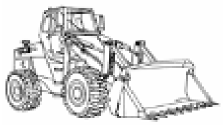
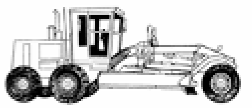
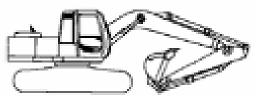
Note: Where reference is made to documents that have been subsequently revised, the later revisions of referenced documents are to apply.

Appendix 1: 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°

Appendix 2: The strengths and limitation of different types of machinery used to construct structures to manage surface water

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. Forks often have a cutting blade fitted that is suited for levelling.	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 (< 1 km). 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. Can be fitted with GPS sensors and control for levelling\grade 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). Can be fitted with a ripper finger to assist with rehabilitating compaction.	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. Can be fitted with a range of purpose built implements.	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.

Appendix 3: Suggested placement and maximum spacings for spreaders.

Placement (key positions)
Above river and stream crossings to slow and spread flow.
At bends where water would pond on the uphill side of a road or track.
Immediately prior to a soil or landform change where the down-slope soil represents an erosion risk. The outlet must be stable.

Grade of road or track (%)	**Suggested maximum spacing (m)**	
	Lateritic gravel soil	**All other soils**
0.5 - 1	180 - 130	120 - 90
1 - 2	130 - 100	90 - 60
2 - 3	100 - 80	60 - 50
3 - 4	80 - 70	50 - 40
4 - 5	70 - 60	40 - 36
5 - 6	60 - 55	36 - 32
6 - 10	55 - 45	32 - 25
10 - 20	45 - 30	25 - 15

Note: Maximum spacing can be reduced where soils are identified as less stable.
Spreaders should be constructed on a grade of 0.3 – 0.5 per cent.

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

Note: Width depends on construction technique, source of material and level of compaction.

Appendix 4: Suggested placement and maximum spacings for rolling dips on tracks and firebreaks.

Placement (key positions)
Above river and stream crossings to slow and spread flow.
At bends where water would pond on the uphill side of a road or track.
Immediately prior to a soil or landform change where the down-slope soil represents an erosion risk. The outlet must be stable.

Grade of road or track (%)	**Suggested maximum spacing (m)**	
	Lateritic gravel soil	**All other soils**
0.5 - 1	180 - 130	170 - 120
1 - 2	130 - 100	120 - 90
2 - 3	100 - 80	90 - 70
3 - 4	80 - 70	70 - 60
4 - 5	70 - 60	60 - 55
5 - 6	60 - 55	55 - 50
6 - 10	55 - 45	50 - 40

Note: Maximum spacing should be reduced where soils are identified as less stable.

Rolling dips should be constructed on a grade of 0.3 – 0.5 per cent

Rolling dips are not suitable where the grade is greater than 10 per cent. Where the grade is greater than 10 per cent, consider using trafficable spreaders.

Appendix 5: Suggested maximum spacing for mitre drains.

Grade of road or track (%)	Maximum spacing of mitre drains (m)	
	Low erosion risk	High erosion risk
< 4	250 - 150	150 -120
4 - 5	150 - 120	120 - 90
5 -10	120 - 95	90 - 70
10 -15	95 - 65	70 -35
15 - 20	65 - 50	< 35

Note: Mitre drains should be constructed on a grade of 0.3 – 0.5 per cent.

Mitre drains should intersect the road level with the edge of the running surface.

Mitre drain outlets should be located in stable, undisturbed areas and up-slope of river and stream reserves.

Appendix 6: Suggested placement, capacity and maximum spacings for culverts.

Relief culverts

Placement (key positions)		
Above river and stream crossings to slow and spread flow.		
At bends where water would pond on the uphill side of a road or track.		
Immediately prior to a soil or landform change where the down-slope soil represents an erosion risk. The outlet must be stable.		
Spacing (no greater than)		
Grade of road or track (%)	**Suggested maximum spacing (m)**	
	Low erosion risk	**High erosion risk**
< 4	250 - 150	150 -120
4 - 5	150 - 120	120 - 90
5 -10	120 - 95	90 - 70
10 -15	95 - 65	70 -35
15 - 20	65 - 50	< 35

Note: Where used to empty a table drain, minimum diameter for a traverse culvert is 30 cm.

Culverts at river and stream crossings

Minimum return intervals to be used for estimating peak flow according to river or stream order		
River or stream order	**Minimum return interval (years)**	
	Temporary roads	**Permanent roads**
First and second	5	10
Third	10	20
Fourth	20	50
Fifth	50	>50

Note: Use *Tools for the Management of Surface Water* (DECSFM 014) to estimate peak flow at the appropriate return interval.

Use a culvert or combination of culverts with sufficient capacity to accommodate the estimated peak flow.

In circumstances where the recommended return interval is not used, the proponent must provide a clear justification for this, including an analysis of the flow, the values at risk and the cost-benefit of the proposed alternative.

This table will be adapted once the DEC Road Management Manual and designated road categories are developed.