E

Integrated Design

PART E

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E

INTEGRATED DESIGN

E1 Integrated Design

Goal

Design roads in the wet tropics region which are consistent with their function and the significant natural and cultural values through which they traverse.

Principles

Design of roads in the wet tropics region should be based on the following principles:

- Design road corridors to minimise environmental and social/cultural impacts and maximise user safety, reliability and enjoyment.
- Integrate the results of the planning process into design. Specifically, ensure recommendations of the EMP (Planning) are considered in the design process.
- Identify appropriate design options to minimise impacts of the proposal and be compliant with the design brief.
- Provide an Environmental Design Report that sets out various criteria from elements of the EMP and corresponding design elements.
- Consider the objectives of all road users, and the natural and cultural values of the wet tropics biogeographic region.
- Disturbance to natural vegetation and landscapes is to be minimised as far as possible.
- Road drainage systems are to use natural drainage lines and maintain catchment integrity at all times.
- Minimise and control sediment and erosion hazards. Develop both Construction Phase and permanent erosion and sediment control measures as integral components of design.
- Design to avoid or minimise the exposure of acid sulfate soils in low lying coastal areas.
- Ensure design identifies requirements to revegetate with indigenous vegetation immediately to conserve the ecological values of the region.
- Design to minimise habitat fragmentation whilst maximising the provision of canopy and understorey connectivity.
- Provide opportunities for scenic and visual experience and recreational activities.
- Ensure the speed environment, design vehicle and function of the road consider the implications on conservation values of natural areas traversed.
- Ensure vertical and horizontal alignment is consistent with the surrounding landscape and speed environment.
- Earthworks are to be minimised where possible.
- Provide safe access to all designated scenic locations and onto off road corridors through intersections.
- Eliminate the introduction and spread of exotic weeds and pathogens from roadworks.
- Consider the methodology of construction and maintenance requirements.

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E2 Design Process

Overview of the Design Process

The environmental aspects of the design process are set out in section four. Essentially the design process involves:

- **Planning Review:** This comprises a review of the Planning Report and EMP (Planning). This phase is particularly important when more than one year has passed since the Planning Phase was undertaken as land uses and environmental conditions could change.
- **Detailed Design (DMR Form 2291):** This is the main design phase where the road is designed in accordance with the *Planning Report* and the *EMP (Planning)*. In order to communicate the environmental measures embodied in the design an Environmental Design Report is prepared. If required ongoing maintenance requirements and contracts may also be prepared at this time.
- **Contract Documents:** This phase is fundamentally critical to the construction of the road using the environmental protection measures identified during the design. The phase involves the preparation of contract documents for the construction of the road. Importantly the contract documents include *specific environmental requirements*.

  As far as possible these environmental requirements should be set out as part of the certified plans as well as in binding contract clauses.

Integrating the Planning

The desired outcome is that road design is based on the outcomes of the planning phase, particularly environmental impact assessment outcomes.

Promoting balanced environmental planning principles during the design phase of a road project will provide a road service to the user appropriate to community requirements.

Design parameters are essential for the consistency of road corridor design. The optimum design of a road corridor will balance the purpose of the road, expected traffic volumes, landscape terrain, design standards, costs and the standard of maintenance.

Best Practice Guidelines:

Ensure that the recommendations, environmental elements, mitigation strategies and other consideration identified during the planning phase form the primary considerations during design.

Undertake further investigations of any outstanding issues identified in the planning report.

Incorporate the typical cross section, design speed and alignments determined during planning into the road design.

Ensure any environmental controls are noted and receive appropriate treatments on the preliminary planning/concept drawings and are incorporated into the design.

Identify areas requiring detailed design such as fauna crossings, scenic stops etc. and establish design briefs for these items.

Design Options Identification

The desired outcome is to consider design options that will meet the design brief and reduce the environmental impact of the proposal.

To enable the most cost effective solution to be adopted while minimising the impact of the road proposed the development of various design options is required.

The planning phase will have developed a possible solution along the road corridor. This will require refinement during the design phase to confirm the detailed aspects of the design.

Aspects that may need to be considered in detail include fauna crossing areas, sedimentation control structures, drainage designs and structures and their relationship with fauna crossings.

Best Practice Guidelines:

Develop design options that meet the design criteria and minimise environmental impacts. Specifically, consider design options which:

- provide fauna crossings;
- minimise clearing natural vegetation;
- use areas already disturbed;
- minimise landscape alteration;
- maximise the ability to present the scenery from the road;
- minimise ecological impacts and disturbances;
- add and match design standards to road function; and

which overall balances the transport utility of the road whilst minimising environmental impacts.

Consider designing for manoeuvring sight distance to reduce the depth of cuts required.

Develop alternative treatments for access to scenic areas such as providing off road facilities clear of the through carriageways.

On new alignments consider locations for scenic viewing areas and develop safe areas for stopping.

Develop alternative grade lines to minimise earthwork impacts.

Consider reducing design speed where this involves more disturbance, clearing and/ environmental impacts. As far as possible, locate overtaking lanes clear of high value scenic areas/environmental areas.

Minimise the total cleared width in high value scenic areas.

Where more than two lanes are required consider a split carriageway with wide median.

Economic Considerations

The desired outcome is to provide solutions that offer the most cost effective solution within environmental and budgetary constraints.

The major costs in constructing roads tends to be the earthworks, structures and pavements. Adopting minimum pavement widths, minimising the length of structures and reducing earthworks within the design speed environment may result in the lowest cost solution. However, it is often necessary to spend money upfront to save substantially more in the long term. This is particularly the case with erosion and sediment control and revegetation.

Best Practice Guidelines:

The design should be the most economical possible given all the constraints (including environmental). Use cost benefit analysis to determine the whole of life costs of all design options, including those that might be initially cheaper but have long term environmental impacts and/or substantial ongoing maintenance

Reuse existing pavements where cost effective and practicable.

Design for the lowest design speed which meets essential transport planning requirements.

Plan to minimise future maintenance costs by implementing best practice erosion and sediment control and revegetation.

Environmental Design Report

The desired outcome is to provide an Environmental Design Report that records the criteria, solutions and documented contracted provisions for the various design elements within the design.

The Environmental Design Report should provide details on the various elements included in the design and the reasons they have been included. EMP (Planning) from which the design has been developed should be aligned with the design and contract documentation.

During the construction and maintenance phase it is important that those responsible for this aspect have an understanding of the reason various elements have been included in the design. This will hopefully prevent changes being made during construction that would result in a design element being ineffective. For example elimination of a fauna crossing culvert.

Best Practice Guidelines:

The road designer should prepare an Environmental Design Report that sets out the reasons and needs for the various elements within the design. Primarily this sets out how the design meets the requirements of the EMP (Planning).

In addition, for major highways a data base of environmental controls and structures should be set up so that maintenance staff have a source of information that is easily accessible and can be incorporated into any maintenance work instructions.

E3 Design Elements

Minimising Disturbance

The desired outcome is to minimise disturbance of natural areas and landscapes.

Minimising the disturbance of vegetation assists in maintaining the quality of wildlife habitat for shelter, food resources and movement, the quality of upstream and downstream water courses and enhances the visual experience for everyone. Disturbance to soil and vegetation encourages weed species which compete with native vegetation, preventing the regeneration of native species and often increasing maintenance costs. The risk of soil erosion and sedimentation is significantly increased when the natural vegetation is disturbed.

The removal of vegetation for safety reasons, such as line of sight for vehicles, often conflicts with the values of vegetation conservation.

Best Practice Guidelines:

Ensure a design priority is to minimise disturbance to native vegetation (particularly where it includes rare or threatened species or critical habitat).

Stripping of topsoil should only be undertaken to the limit of earthworks. Design should include topsoil management strategies.

Retain native vegetation along the route as far as possible. Consider using Brifen wire rope fence, guardrails, or berms in lieu of tree clearing to provide clearance for safety reasons.

Designs should include requirements for prompt revegetation of disturbed areas with suitable local endemic plant species.

Designs should determine areas which are or can be cleared for stockpiles, turn around area, camp site, waste and chemical storage area and machinery maintenance area.

Designs should identify necessary temporary measures during construction necessary to build roads and structures whilst minimising disturbance (eg. temporary retaining walls).

Drainage and Stormwater

The desired outcome is to use natural drainage lines, maintain catchment integrity and maintain the receiving water's water quality.

Throughout the wet tropics region high rainfall levels and intensity are major factors in erosion, catchment dynamics and water quality. High rainfall along road corridors presents two major problems, increased water on the road surface which decreases driver safety, and increased volumes of water impacting on the immediate and adjoining environment.

Water on the surface of a road can decrease the ability of a driver to handle a vehicle in a safe manner. Further, when large amounts of water do cross the surface of a road it tends to runoff into the nearby environment, often causing erosion of soils and sedimentation of water courses which impacts upon the quality of water. Uncontrolled runoff can damage adjoining properties and the road structure itself.

Appropriate and effective drainage systems should be incorporated into the design of road corridors. Roads should allow for adequate surface drainage, cross drainage and side drainage. It is highly desirable to take water off the road as quickly and as frequently as possible. This allows for a safe driving environment and control of water until it can be disposed of in the local environment through the use of environmentally sound techniques.

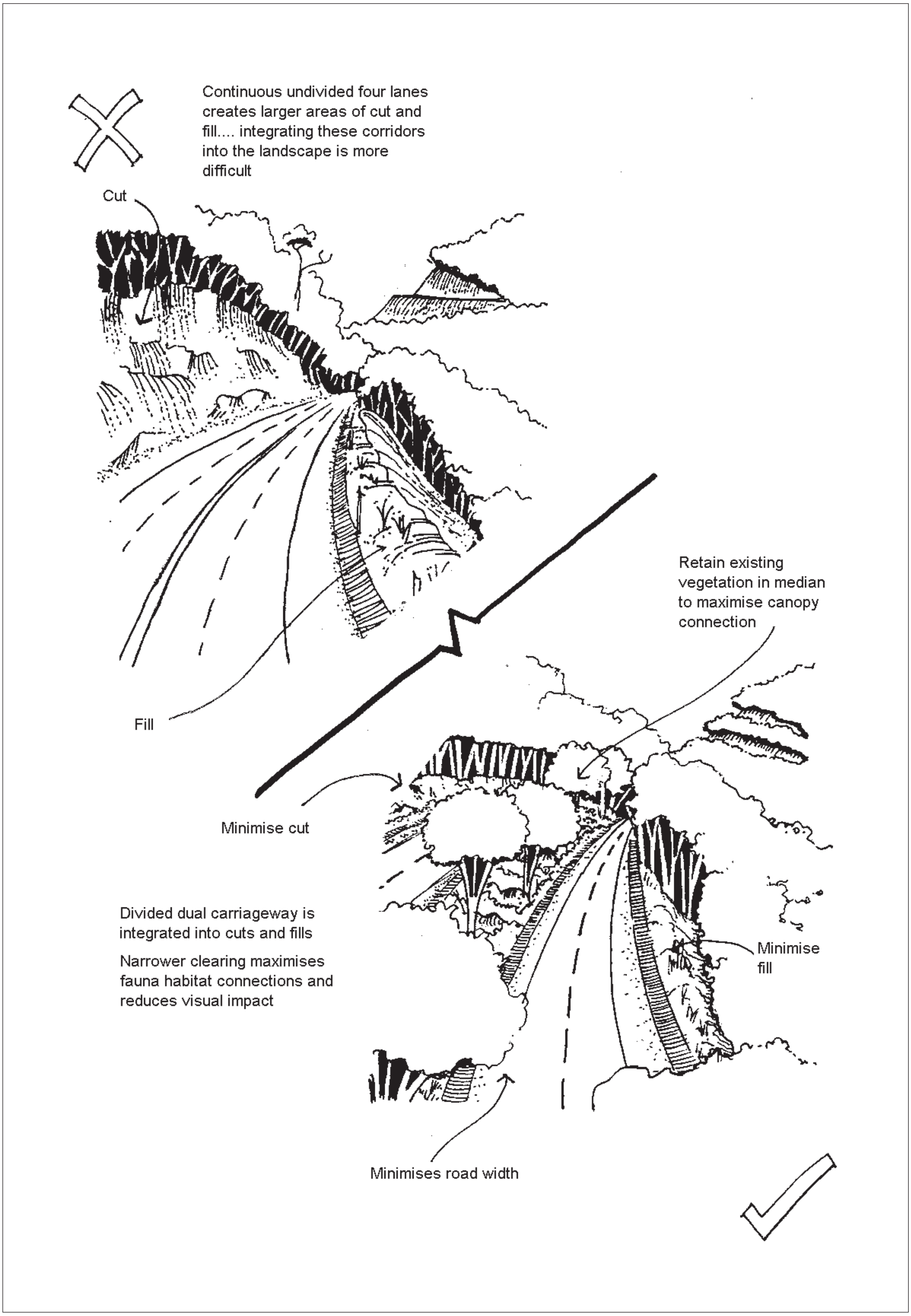

Figure 22 Minimise Disturbance

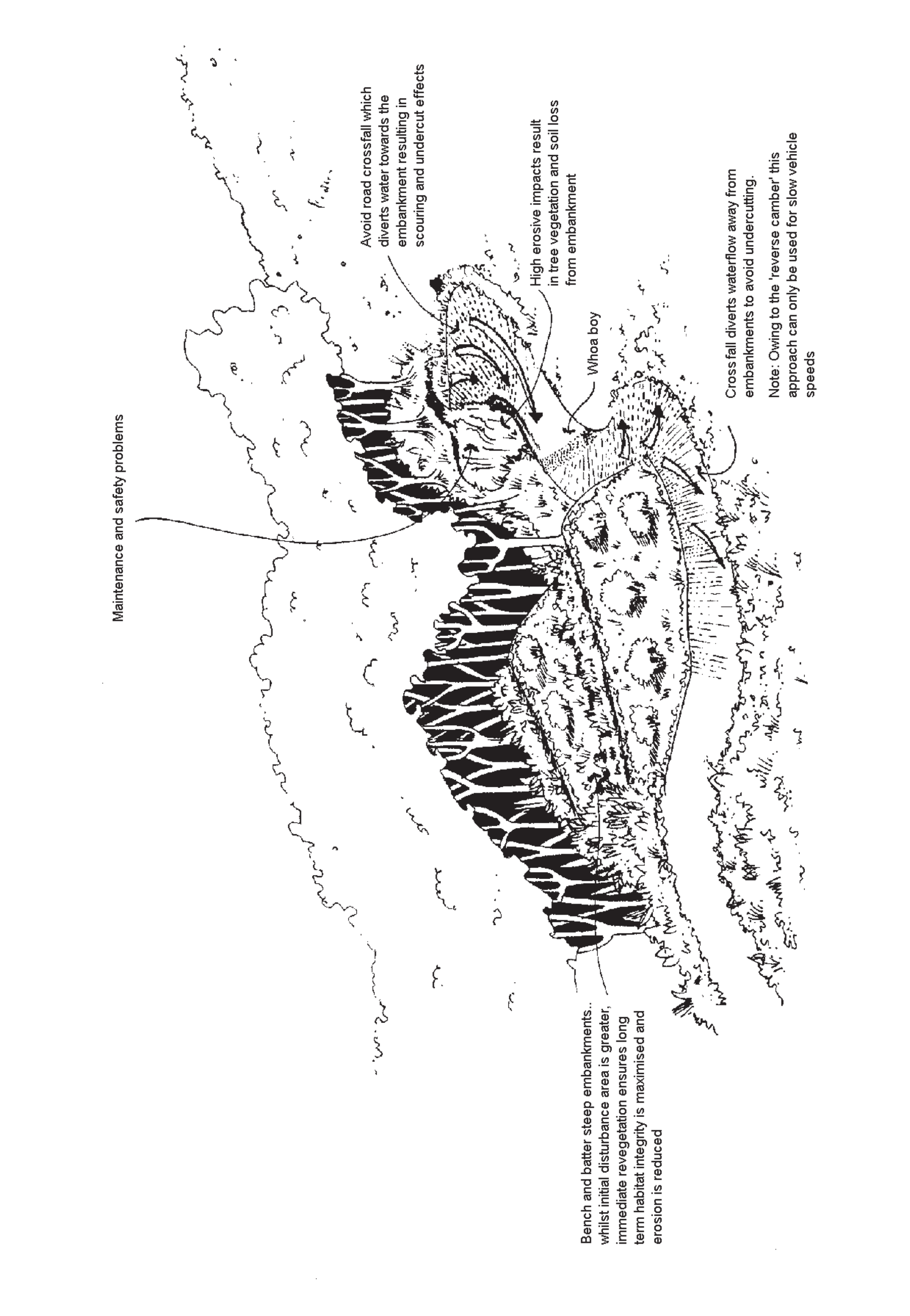

Figure 23 Drainage on Unsealed Roads

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Table 10 Drainage Techniques

Drainage Control Technique	Application/ Function	Limitations	Advantages	Disadvantages
Check Drains and Perimeter Banks	Used to limit the flow path down steep grades on unstable newly grassed areas. Can be used to divert flow around disturbed areas or used within disturbed areas to direct contaminated flow to sediment traps. Around stockpiles perimeter banks are used to divert up slope runoff around the stockpile and to direct stormwater from the stockpile to a sediment trap.	Limited to catchment areas less than 0.7ha, otherwise a formally designed diversion channel will be required. Typical gradient is 0.5%, may be as low as 0.25% or as high as 0.75%.	Quick to establish or re-establish if disturbed. Inexpensive to construct, usually do not require any formal design. Flow velocities are usually enough to avoid special channel linings.	Can cause sediment problems and flow concentration if over topped during a heavy storm. Can restrict movement of equipment around the site and access to stockpiles.
Check Dams	To control minor gully erosion. To control flow velocity in drainage channels, especially during the early stages of revegetation. May be used as a substitute for special channel linings in temporary channels. Entrapment of sediment is only a secondary function.	Check dams should be in height to around 0.5-1m. Catchment area generally limited to 1 ha (depending on width of channel). Except for straw bale check dams which are limited to 0.4ha. Not used in 'defined' watercourses.	Quick and inexpensive to install. Permeable dams are free draining. Can be a quick maintenance option on eroding channels during or after the establishment period. May allow small channels to be seeded rather than turfed.	All dams made of vegetation (eg Brushwood or straw bales) have a very limited working life. Check dams may cause erosion downstream of the dam if poorly designed, maintained or if subjected to high flows. Possible weed problems associated with dirty straw - may not be appropriate in sensitive areas.
Chutes and Flumes	Transportation of concentrated flow down an embankment. Redirect a portion of flow from a diversion channel. Divert 'clean' stormwater around a work site. Direct contaminated flow to a sediment basin/trap.	Topography must allow collection of flow at the inlet. Usually only economical for low flows. Bitumen is generally not suitable as a permanent chute liner. Should have stilling basins or outlets.	Economical for low flow and high, steep drops. Some structures require limited earthworks and construction skills. Some chute types are quick to construct.	Usually have a defined service life. May be damaged by overtopping flows. The chute may be subject to slippage caused by poor foundations.
Diversion Channels	Used when the catchment area is too large for the use of catch drains or perimeter banks. Used above batters, borrow pits and exposed surfaces to protect them from up slope stormwater runoff. Used at the base of cut or fill slopes to direct sediment laden flows to sediment traps.	Allowable flow velocity depends on the properties of the channel lining. Excavated channels within highly erosive soils will require a suitable channel lining. Typical gradient is 0.5%, may be as low as 0.2% or as high as 0.6%.	Can cope with large flows. Keeps the water away from the toe of the embankment and tops of cuts. Low maintenance. Reduces erosion.	Can limit trafficable access to the site. Channels may be subject to erosive flows and thus require the added cost of channel lining. Outlet flows are concentrated and may require energy dissipation and/or a flow spreader.

Table 10 Drainage Techniques (cont.)

Drainage Control Technique	Application/ Function	Limitations	Advantages	Disadvantages
Drop Pipes	Transportation of concentrated flow down embankments, usually greater than 3m in height or slop length, otherwise a chute may be cheaper. Redirect a portion of flow from a diversion channel. Divert 'clean' stormwater around a work site. Direct contaminated flow to a sediment basin/trap used as an outlet from sediment traps located at the top of steep slopes.	Topography must allow collection of surface flow at the pipe inlet. Usually only economical for low flows. Commercially available 'lay-flot' pipe sizes are limited to a maximum of around 300mm diameter.	Requires limited earthworks and construction skills. Economical for low flows and high, irregular drops. Can be relocated with relative ease. Reusable.	Pipe entry subject to blockage by sediment and debris. Pipes may also be subject to damage by corrosion, high flows or vandalism. Usually only suitable as a temporary structure. A bypass spillway may be required.
Geosynthetic Lined Channels	Geosynthetic Linings provide temporary protection to earth drains that are intended to be removed or upgraded within 6 months, and newly formed grass channels established with seed or runners. In high velocity areas, buried geosynthetic mats can be used to reinforce turfed channels.	Geosynthetics are best used with vegetation. Non-biodegradable produces have limited use in fauna inhabited bushland areas. Biodegradable mats generally have a lower allowable velocity limit. Impermeable fabric should be considered on highly dispersive soils.	Quick installation. Wide variety of products and uses. Most products provide instant erosion protection. Can be used for emergency repairs, products are available for short and long terms use.	Some fabrics have a very limited working life. Environmental problems associated with non-biodegradable fabric used in bushland areas. Maintenance problems with some buried mats. Bitumen based products can release phosphorus to receiving waters.
Grassed Channels	Transportation of concentrated flows. Grassed channels slow down surface runoff giving sediments an opportunity to settle or be filtered out by the vegetation. Also used to increase stormwater infiltration.	Unreinforced grass channels are limited to a design velocity of around 1.5 to 2m/s and slopes of 0.2% to 5%. Temporary clover crops can provide surface stability for a period of 3-6 months.	Can remove sediment and nutrients thus improving the site's overall discharge water quality. Can improve infiltration of stormwater, reduce runoff volume and allow downstream sediment basins to drain more effectively between storm events.	May require relatively flat slopes when draining large catchments. Problems exist with the control of trickle flows that can cause rilling in high velocity areas and boggy ground in low velocity areas. A concrete invert may be required to alleviate low flow problems.

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Table 10 Drainage Techniques (cont.)

Drainage Control Technique	Application/ Function	Limitations	Advantages	Disadvantages
Level Spreaders	Used on the outlets for diversion channels, catch drains or perimeter banks. Converts concentrated flow into sheet flow before discharging it at non-erosive velocities onto undisturbed, stable vegetated slopes of less than 10%.	Catchment areas limited to around 0.5 hectares. Maximum discharge of 0.85m³/s. Level spreaders should be used only where the spreader can be constructed on undisturbed soil, otherwise chutes or drop pipes should be considered. Traffic should be prohibited from the area of the level spreaders.	Inexpensive to construct and maintain if the site drainage is well planned and grassed discharge areas are left undisturbed or prepared well in advance. Allows for limited capture of sediment.	May require a considerable width of undisturbed land. May require the land to be free of trees, shrubs and other surface irregularities to avoid local erosion problems.
Bridge	Used in creeks and rivers of large flows or wider spans usually when flood immunity must be achieved.	Economic factors.	Minimal disturbance to flow path and banks. Flood immunity possible. Handles large flows and velocities. Doesn't get blocked. Good fauna paths. Minimal maintenance. Less erosion potential than other structures.	Very expensive. Special construction techniques.
Reinforced Grass Channels	Grass reinforcing is used to protect recently established or damaged grassed areas from the erosive forces of concentrated flow and raindrop impact. It can also be used to improve the trafficability of permanent grass channels.	Woven fabric, mats and cellular grids can withstand maximum flow velocities in the order of 3m/s, 5m/s and 8m/s respectively. When in good condition, however extreme caution should be exercised when designing for such high velocities. Design should be in accordance with manufacturers advice.	Grass reinforcing helps to control soil erosion, improves trafficability and allows for smaller and steeper channels. Most products provide immediate erosion control.	Some maintenance problems exist in permanent channels resulting from mower induced surface damage.

Table 10 Drainage Techniques (cont.)

Drainage Control Technique	Application/ Function	Limitations	Advantages	Disadvantages
Rock Lined Channels	Rock lining of drains and channels is one of the simplest kinds of surface treatment. It is particularly useful in critical sections of channel such as bends and stormwater outlets used on channel slopes steeper than 5% and in heavy traffic (vehicular or human) areas.	Generally limited to channel grades less than 10%. Success often depends on the introduction of suitable vegetation to anchor the rocks. There is often only a limited range of rock sized available or the calculated rock size (for the given flow velocity) is too large in proportion to the drain size. Rock to be of the class and size locally available.	One of the most common and inexpensive channel lining materials. The porous nature of rock protects the channel from uplift and also for revegetation. Does not require a well formed channel cross section.	Problems of infestation by rodents and unsightly weeds. Undersized rocks can migrate downstream and cause further erosion as they move along the creek bed during periods of flood. Often difficult to desilt rock lined channels. Some rock types may cause pH problems in low flows.
Rock Mattress Channels	Used for channel linings, spillway protection and energy dissipation areas downstream of high-flow check dams. Can be used to line open channel chutes.	If poorly constructed, they can be expensive to rectify. Water transported sediment (sand and gravel) can reduce the service life of the wire. The turbulent transportation of bed load (gravel and debris) can break the wire through a hammering action. This can shorten the service life of the cages considerably.	Rock filled cages are a well proven protection measure. Gabions and rock filled mattresses are very useful for small localised drainage problems where immediate lining and/or protection is required.	Unsightly weed infestation can be a maintenance problem in urban areas. Sediment is difficult to remove from the cages without damage to the wire, especially if the location or shape of the cage is difficult to distinguish under the sediment load. Some rock mattress and gabion structures have experienced durability problems caused by trickle flows, high sediment loads and debris.
Temporary Watercourse Crossings	Temporary crossings provide safe access for construction equipment with minimal disturbance to the watercourse. To help keep sediment generated by construction traffic out of a watercourse. To restrict construction traffic stabilised water crossings.	Generally restricted to minor streams or creeks, culverts and bridges may be subject to flood damage. Fords require a rock bed and should not be used where the base flow exceeds 75mm depth.	If managed well (and in appropriate locations), they can provide ease of site access with acceptable impacts.	They can be a direct source of water pollution. They may aggravate flooding and/or create safety hazards. Expensive to construct and costly to repair if damaged by flood waters.

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Best Practice Guidelines:

Protect water quality by designing to reduce soil disturbance near watercourses during both construction and maintenance (see Table 10).

Design drainage structures and techniques which capture, control and dispose of water taking into account the likely highest rainfall intensity, frequency and duration.

Road design should consider the grading of the roadway, flow and flow widths across the surface, subsurface drainage and the capacity of channels.

Control the flow of water from the road to the natural watercourses. Flow velocities should be kept below 2 m/sec. If not then protective treatments should be used to prevent erosion.

Consider lining channels and drains where flow velocities exceed 1m/sec or where grades exceed 1%.

Divert clean stormwater away from disturbed areas.

Ensure that design of bridges and roads near watercourses includes strategies to minimise adverse effects to channel form, stream flow and associated habitats (see Table 10).

Wherever possible, do not transfer water flows between catchment areas, even at a micro catchment scale.

Erosion and Sediment Control

The desired outcome is to firstly minimise erosion and secondly minimise sediment loss from disturbed areas.

Highly erodable soils in areas of rugged terrain within the wet tropics region are particularly vulnerable to substantial erosion after clearing and altered drainage patterns as a result of road construction. The slope and steepness of this land magnifies the hazard of erosion and sedimentation due to large runoff volumes and high runoff velocities. Erosion can be reduced by protecting the soil, avoiding concentration of run-off and reducing flow velocities. Methods for soil conservation should be developed as part of the design phase of a road project and designed for long-term management.

Erosion and sediment control can be divided into two parts:

- Erosion caused by rainfall impact on the exposed soils. Control of this can be achieved by rapidly revegetating the site using such techniques as hydromulching and seeding, planting, applying erosion mats such as jute mesh, or applying brush and mulched vegetation.
- Sedimentation caused by high flow velocities eroding soil and then depositing it downstream in natural watercourses.

The Universal Soil Loss Equation is described by Witheridge (1996), and has been established to enable calculation of rates of erosion and what remediation and protection measures are required. The Universal Soil Loss Equation is commonly used to predict long term average soil loss rates in runoff from a site under defined land and cover management. It does not attempt to predict sediment deposition or transport within a catchment nor does it take account of gully erosion.

The estimated annual soil loss (A - R x K x LS x C x P tonne/ha/yr) from a site is the product of five (5) major factors.

- Rainfall erosive factor (R) which is derived from rainfall statistics and is calculated using the 2 year rainfall intensity for a 6 hour average storm.

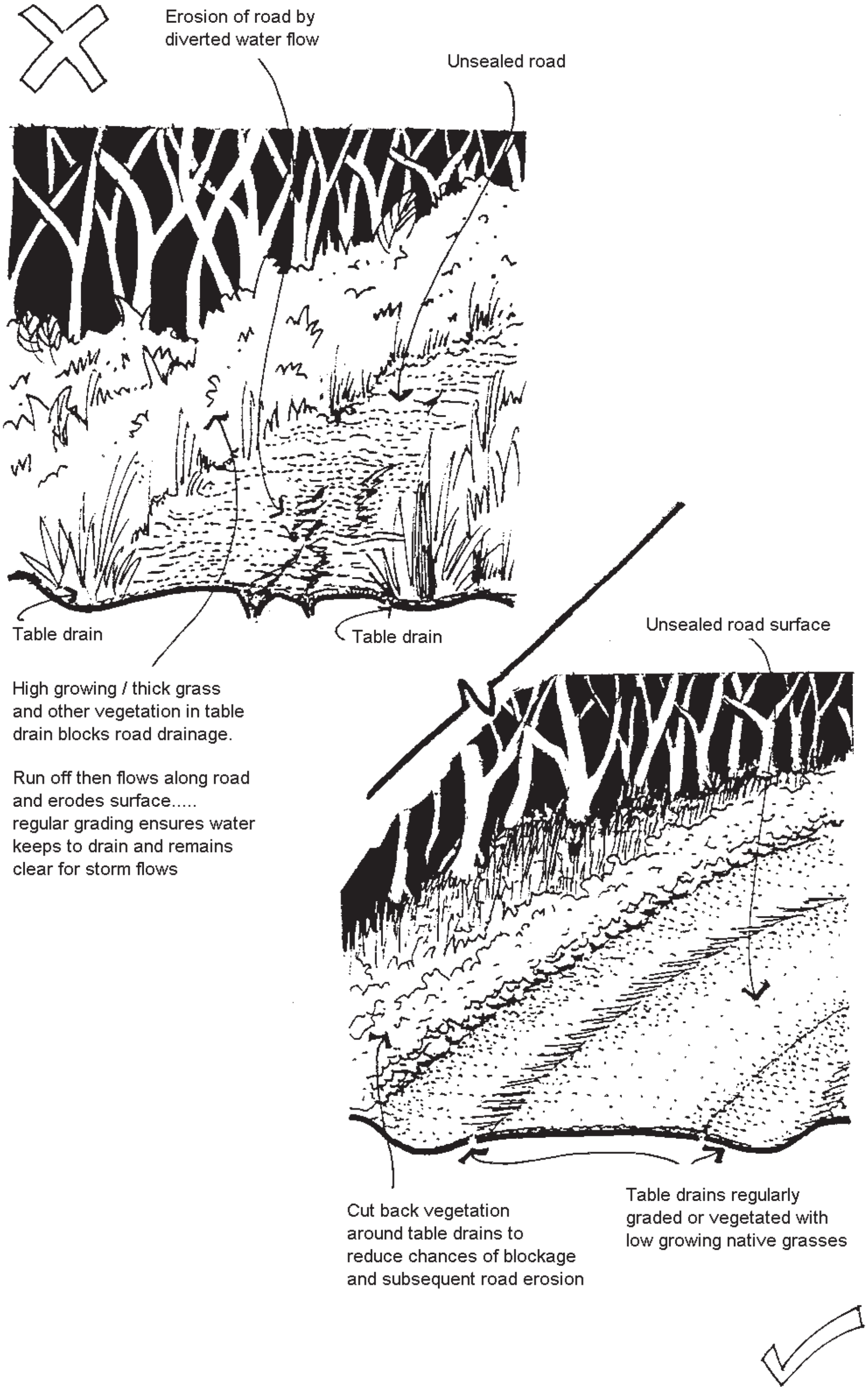

Figure 24 Unsealed Roads - Table Drains

- Soil erodability factor (K) is a numeric representation of the ability of soils to resist the erosive energy of rain. This has been determined for a number of Queensland soils.
- Topographic factor derived from slope length and slope gradient.
- Cover and management factor is determined from the soil cover, tree canopy and percentage of ground cover.
- Erosion control practice factor (P) measures the combined effects of all support practices and management variables. The P factor is reduced by practices that reduce both the velocity of runoff and the tendency of runoff to flow directly downhill. At construction sites it reflects the roughening or smoothing of the soil surface by machinery.

Only limited data is available on soil erodability factors. Generally, laboratory analysis will be required to determine erodability values.

Typical earthworks on Krasnozen soils in the wet tropics region compacted to a smooth batter with no vegetation cover established would have annual erosion rates of 1 600 tonne/ha/annum. If weeds are allowed to establish the annual rate would drop to 1 000 tonnes/ha/annum. Placing top soil on batters, hydromulching and revegetating will reduce the soil loss to 0.9 tonnes/ha/annum.

The following soil losses should be used as a guide.

- **Soil Loss Class 1:** This comprises development areas where the compounded soil loss rate does not exceed 300 tonnes per hectare per year without application of soil conservation techniques.
- **Soil Loss Class 2:** Comprises more marginal sites with soil loss rates between 300 and 900 tonnes per hectare per year. Special emphasis should be placed on the appropriate staging/timing of earth works and the rehabilitation/revegetation program.
- **Soil Loss Class 3:** These areas are highly prone to sediment pollution with compounded rates exceeding 900 tonne per hectare per year without implementation of soil conservation techniques. Development should only proceed in accordance with strict adherence to an approved erosion and sediment control plan.

The aim of erosion control is to prevent erosion by ensuring rapid stabilisation and revegetation of exposed sites and controlling flow velocities through the site. The aim of sediment control is to remove all sediment (which has been mobilised by erosion) from waters leaving the site. As a general guide, the rate of erosion depends on:

- vegetation cover;
- the soil loss class;
- soil type;
- slope angle (grade);
- slope length;
- rainfall intensity; and
- land capability.

Most earthworks in the wet tropics region with their high rainfall intensity will be in the soil loss Class 3 category and will require an erosion and sediment control plan to be developed, implemented and monitored.

Tables 10 and 11 set out the various techniques for erosion and sediment control.

Best Practice Guidelines:

Design road corridors for minimal vegetation removal.

Ensure all erosion and sediment control measures are incorporated into the design of roadways and bridges.

Design road corridors which utilise the natural slope of the land rather than designing roads requiring large cutting and embankment techniques that alter natural drainage patterns.

Assess erosion potential along the proposed alignment identifying problem areas requiring specific design techniques to minimise erosion and sedimentation during construction and operation. Identify areas which may constitute high or extreme erosion hazards and avoid construction. Where there is unavoidable high or extreme erosion hazard design extensive soil conservation techniques.

Consider climatic factors such as rainfall, wind and temperature during the design of soil conservation techniques.

Appropriately designed culverts (taking into account peak discharge, velocities and time of concentration) are required to reduce flow concentration where embankments traverse natural drainage lines. Culverts and drains should have sufficient capacity to allow design flows to pass without concentrating flows and increasing flow velocities. If this cannot be achieved, install stilling basins if there is available space, and grade stabilisation structures.

Avoid placing culverts at locations already affected by erosion or meanders and locate cross-drainage culverts to minimise alterations to existing drainage patterns.

Ensure that design of culverts keeps outlet velocities below the likely erosion levels of the natural stream bed. This may mean providing protection of outlets using:

- lined stilling ponds;
- energy dissipators; and
- rock rip-rap, gabions or grouted rock.

Where large cut and fill slopes are required, bench slopes so that slope length is reduced and run-off can be disposed of safely along the benches. Batters should be hydromulched, haymulched, covered with a mat or rock mulched to prevent erosion. Topsoil batters, seed (or plant) and mulch as work progresses in approximately equal increments with maximum falls of 3-5 m.

Keep roads and associated disturbed areas away from streams and outside riparian buffer strips unless unavoidable.

Ensure all clean and dirty water catchments are separated. Ensure, where practicable, all clean runoff is diverted away from disturbed areas.

Where grades are excessive, use drop structures in the drainage system or culverts to reduce culvert grades and hence velocity. This grade reduction can also be achieved to some extent by providing a change in grade along a culvert (this can be obtained in concrete pipes by specifying rubber ring joints and special bends).

Provide stabilised or lined stilling ponds or energy dissipators at culvert outlets to reduce flow energy and erosion potential. Caution should be taken where culverts provide dual purposes for stormwater and fauna movements.

Consider the use of binding agents in gravel (eg Endurazyme) to prolong life of surface, reduce runoff and prolong intervals between maintenance.

Disperse runoff from pavement and cuttings to stable locations. Where concentrated, runoff from roads should not discharge directly over the embankment batters.

Unsealed roads do not generally have much erosion protection at culvert exits. As such flow velocity at the exit must be reduced as far as possible to minimise erosion. This can be achieved by aligning culverts at a more acute angle to the road to increase the length and hence reduce the grade.

For unsealed roads the need to regularly grade road surfaces and drains results in potential for significant erosion and consequent sedimentation. The key mechanisms to reduce problems are:

- minimise water collection to points as far as possible (use crossfall to drain water to downslope side of road without concentrating it in a drain);
- keep the grades of drains and pipes as low as possible (less than 2%) to reduce water velocity;
- use whoa-boys to collect and divert water when grade of road is more than 5%;
- wherever possible, maintain grass in table drains;
- remove water from drains as often as possible (with pipes, turning out table drains etc.) to minimise water concentration and volume;
- where possible maintain canopy cover over roads (reduces volume energy and impact of rainfall); and
- stabilise or seal areas where erosion is occurring (such as creek banks and "jump-ups").

Table 11 Erosion Control Techniques

Erosion Control Technique	Application/ Function	Limitations	Advantages	Disadvantages
Chemical Surface Stabilisers	Generally effective for dust control or the control of erosion caused by raindrop impact. Also used for tacking organic mulches.	Products have a limited life and consideration should be given to the use of geotextiles if the exposed surfaces need to be protected for extended periods or during the wet season.	Provide instant protection. Suitable for temporary stabilisation while construction is in progress.	Usually less effective than mulches. The established surface crust must remain intact to be effective. Bitumen products can breakdown and release phosphorus and oils to receiving waters. Vegetation may also root through cracks causing crumbling of the surface. Some products can reduce water infiltration.
Erosion Control Mats	Protection of exposed surfaces and stockpiles against the erosive effects of wind, raindrop impact and stormwater runoff, selective control of vegetation growth, often used when revegetating slopes steeper than 4(H):1(V). Can control soil temperature and moisture loss. Some products may be used as mulch.	Non-biodegradable mats and nets have limited use in bushland areas. Small ground dwelling fauna such as lizards have been known to entangle themselves in the netting. These products have limited use in areas used by grazing animals. Few totally biodegradable products can withst and the erosive effects of concentrated flow.	Can be used to protect dispersive soils. May be reusable. Quick to install and provide instant protection. If properly designed and installed, geotextile products may reduce the maintenance of some sediment control structures.	Some fabrics have a very limited working life. Some synthetic grass reinforcement mats can be damaged by mowing unless suitably installed deep within the topsoil layer. Can be difficult to maintain if maintenance requirements are not given adequate consideration during the design phase.
Mulching	Applied to clay soil surfaces to limit runoff, turbidity caused by raindrop impact. Applied to mild slopes to control raindrop impact as well as erosion caused by sheet flow. Applied to steep slopes (>20%) to control erosion but usually reinforced with netting. Used to control soil temperature and moisture loss. Mulch can be used to aid or inhibit seed germination and to control weed growth.	Some mulches are not suitable in bushland areas due to possible introduction of unwanted seeds. Not suitable for areas subjected to concentrated flow unless a suitably sized gravel mulch is used. Mulch should cover 70-75% (minimum) of the soil surface to give adequate protection against erosion.	Most effective and practical means of controlling erosion prior to vegetation establishment Can be applied on irregular and steep terrain. Particularly useful in higher rainfall areas to protect against raindrop impact. They also restrict moisture loss, increase infiltration rates and minimise temperature fluctuations.	Decomposition of some wood products can tie up significant amounts of soil nitrogen, thus requiring modification to the fertiliser application rates. Associated bitumen-based fixers can release phosphorus to receiving waters. May be displaced if subjected to flooding or concentrated overland flow.

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Table 11 Erosion Control Techniques (cont.)

Erosion Control Technique	Application/ Function	Limitations	Advantages	Disadvantages
Revege-tation	Soil surface protection and soil reinforcement. Stabilisation of shallow land slips. Interception and retention of stormwater runoff. Reduce rainfall impact energy. Increase soil permeability and evaporation, thus reducing the volume of total annual runoff.	There are limits to the role vegetation alone can play in controlling erosion before it becomes established. Both soil strength and vegetation cover (including root system) can take years to develop the required conditions. Usually not suitable in heavy traffic areas or for long slopes greater than 2(H):1(V).	In terms of soil surface protection. Vegetation is the best long term defence that can be used to protect soil against wind and water induced erosion. Environmentally sound and inexpensive long term erosion control measure. Self regenerating properties reduces the long term loss of topsoil.	Long establishment time, subject to damage in heavy traffic areas. Conflicts can exist between the choice of native and exotic species. Introduced non-native species can migrate from the local area. Block down stream watercourses. Indirectly increase bank erosion.
Soil Cement Treatment	Used to increase the strength of on site soils. Soil cement has been used in the construction of levees, channel bank protection, drop structures and merits consideration as a substitute for rock protection in areas where rock is not economically available.	Limited design information available. Limited interaction with vegetation. Not suitable for all soil types.	Its primary advantages are low cost, durability and permeability. Soil cement requires a cheaper aggregate mix than concrete because more fines are acceptable.	Can limit vegetation cover. Some soil cement mixtures break readily if subjected to traffic or high volume flows.May result in alkalinity or pH problems.
Surface Roughening	On recently seeded or exposed earth surfaces, erosion protection can be improved by roughening the soil surface to increase infiltration and delay the formation of rutting. Limit wind induced soil erosion.	Surface roughening or ripping is not effective during major rainfall events where concentrated runoff will break through the furrows and cause rill erosion. Tracking is generally not as effective as other surface roughening methods as it can compact heavier soils.	Increases infiltration and reduces runoff. Inexpensive. Can improve the stabilisation of topsoil when surface roughening has been applied to subsoil. Aids the establishment of vegetation.	Of only limited advantage during periods of heavy rainfall.
Energy Dissipators	Used to decrease the velocity to a non-erosive level.	Commonly used downstream of culverts or floodways.	Decrease velocity of flow to non erosive levels. Can be designed for all types of culverts. Can use a wide variety of material to make it look natural.	Expensive. Can be artificially unappealing. Used mainly on major highways.

Table 12 Sediment Control Techniques

Sediment Control Technique	Application/ Function	Limitations	Advantages	Disadvantages
Brushwood Barriers	Brushwood barriers can be used as check dams to provide temporary channel stabilisation during revegetation. In areas of concentrated flow, they can be used as a support for sediment fences. Brushwood barriers can also be used to stabilise and slowly backfill large gullies with trapped sediment. Typically used in rural residential developments.	Limited control over the finer sediments depending on the type and placement of the geotextile filter. Usually only suitable in areas where upstream flooding is not a concern. A brushwood barrier is usually not the first preference for sediment control especially in urban areas. Used with caution in high flow watercourses.	Has a natural appearance. May be left to naturally degrade with time when used in rural or bushland areas. Inexpensive to install and maintain. Can be a source of seeds native to the locality.	The brushwood can contribute to stream debris. The strength of the barrier may be questionable and will deteriorate with time.Can divert runoff and cause increased erosion, not suitable in high rainfall areas.
Buffer Zones	Used to control sediment runoff from access roads, stockpiles, masonry cutting areas and building sites. Wetlands, streams, rivers and bushland areas adjacent to construction sites should be protected with vegetation buffer zones wherever possible. Non disturbance areas contained within the site can also be used as sediment traps. Often used in rural residential developments.	Buffer zones generally only trap coarse sediments. Clays and fine silt particles will generally pass through buffer zones during periods of heavy rain. Suitable for slopes between 1% and 10% grade.	Buffer zones can reduce the need for on site erosion and sediment control measures during the construction phase. Particularly useful on low to medium slopes. On site buffer zones can reduce the total sediment transport to down slope sediment traps.	Ineffective during periods of very heavy rain. Buffer zones can be easily disturbed or destroyed by poor site management. Require large areas of land.
Construction Exits (Vibration Grids)	To remove soil, mud, clods, dust and debris from tyres of vehicles leaving the construction site. To prevent the tracking of such material onto public streets. To minimise off site road safety hazards.	May only result in limited removal of sediment from vehicles unless a wash bay or suitably designed drive through wash rack is used.	Automatic process (except manual wash bays). Vibration grid systems can be readily moved. Prefabricated steel vibration grids can be constructed then reused for several areas. Can reduce community complaints regarding the tracking of sediment onto public roads.	Requires regular maintenance and wash bay area. Runoff from washdown bays may contain seeds, contaminants, pollutants.
Grassed Filter Strips	Grassed filter strips are placed around impervious surfaces (usually on new subdivisions) to filter sediment runoff before it enters the stormwater system. Strips of vegetation retained or laid (turf) downslope of disturbed land can provide a simple method for trapping sediment. They can also be used to control flow and sediment runoff on small step embankments.	Grassed filter strips generally only trap coarse sediments. Clays and fine silt particle will pass through a buffer zone during periods of heavy rain. Cover crops can give surface stability for 3-6 months.	Efficient during regular storm events (i.e. <<Q1) can reduce the total sediment load reaching major sediment traps. Reduces onsite and offsite clean up work after storms.	Ineffective during periods of heavy rain. Can be disturbed by construction vehicles and during the establishment of underground services.

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Table 12 Sediment Control Techniques (cont.)

Erosion Control Technique	Application/ Function	Limitations	Advantages	Disadvantages
Gross Pollutant Traps	Interception of trash debris and coarse sediments. To protect the aesthetic and environmental quality of lakes, ponds creeks and landscaped drains. Protection of microphytes and fauna habitats at the upper ends of water pollution control ponds and urban lakes. Only of limited application for roads in the wet tropics.	Limited control over fine sediment <0.4mm. Limited control over dissolved pollutants. Usually limited to the treatment of flows up to the 1yr and ARI design discharge. Generally limited to catchments greater than 2ha due to the relatively high maintenance costs associated with small GPTs.	Can be used both during and after the construction phase. One of the few effective forms of litter control.	High ongoing maintenance costs. Typical annual maintenance cost can be around 3 to 5% of capital cost. Can cause mosquito problems. May not be well received by neighbouring residents. Can be unsightly and must be suitably located.
Portable Sediment Tanks	Sediment laden water is filtered through a portable tank. Treatment usually involves the use of chemical dosing to control turbidity in congested areas. The portable sediment tank may offer a practical alternative to sediment ponds.	Limited control over silt and turbidity unless chemical dosing is incorporated into the process.Of limited application in the high rainfall areas of the wet tropics region.	Small size, reusable.	More expensive than one off sediment basins, but may be cost effective is reused on several sites. Can be difficult to clean out.
Rock Filter Dams	Rock filter dams are free standing rock structures used to trap sediment in well defined gullies excavated pits and overland flow paths. Rock filter dams are typically used on temporary construction works while sediment weirs have a greater use in the control of rural gully erosion. Generally used to intercept concentrated flow. Used to form a small sediment pond where road construction crosses a minor drainage path. May be used as the outlet structure on small sediment ponds and basins can be used as large check dams.	Limited control over runoff turbidity and the trapping of fine sediments, except during low flows. Where control of upstream flow velocity is required, refer to discussion on check dams.Of limited application in the wet tropics region owing to high rainfall intensity and volume.	Cheaper than the traditional piped sediment basin outlet. Rock filter dams require little maintenance if used on short term construction work.	The gravel filter layer on the upstream face of a dam can clog with sediment and require regular maintenance if the structure is used for more than one wet season. Less effective at controlling fine sediments and turbidity than a chemically treated sediment basin.
Sediment Barriers	Sediment traps usually located immediately upstream of on grade gully inlets, or surrounding sag and field inlet. Their main application is during the construction phase when most other onsite controls would otherwise be damaged by construction equipment. Some barriers are not as effective as sediment fences and they usually require regular maintenance to be of any value.	It is rarely sufficient to rely solely on stormwater inlet sediment barriers for onsite sediment control. Catchment area limited to around 0.4ha. Limited control of fine sediment and turbidity. Not suitable for inaccessible areas. Kerb inlet sediment traps should not block the kerb inlet but should be set back to allow the drain to function during periods of heavy rain.	Simple to construct, can be readily moved as the development proceeds, relatively inexpensive and usually requires little site disturbance. Limits sediment build up in stormwater drains and culverts and reduces the cost of the final maintenance clean up. Many standard designs exist.	Requires regular maintenance on poorly managed sites. Sediment barrier can do more damage than good. High up slope erosion rates can block the barriers causing flow bypassing and downstream erosion. Most sediment barriers can be easily damaged by construction traffic.

Table 12 Sediment Control Techniques

Sediment Control Technique	Application/ Function	Limitations	Advantages	Disadvantages
Sediment Weirs	Sediment weirs are rock filters used to trap sediment in well defined gullies. Sediment weirs are typically used to control rural gully erosion, but they can also be used as an alternative to rock filter dams. Generally used to intercept concentrated flow, a modified sediment weir may be constructed around a field inlet structure to act as an outlet for a sediment pond. These outlet structures may be used when a permanent detention basin is used as a sediment pond during construction.	Limited control over runoff turbidity and the trapping of fine sediments, except during low flows. Where control of upstream flow velocity is required, refer to discussion on check dams.	Sediment weirs can be very effective temporary or permanent sediment traps for perennial streams and are particularly applicable where work is to be done in the stream itself.	Less effective at controlling fine sediments and turbidity than a chemically treated sediment basin.
Straw Bales	Straw bales provide a similar, but less efficient function to that of a sediment fence. Straw bale perimeter banks (bales lined with filter fabric) can be installed downslope of disturbed areas to direct sediment laden runoff into sediment traps. Generally not recommended if an alternative sediment trap can be used. Best used as a source of mulch.	Limited control over fine silts and clay runoff. Maximum design flow of around 40l/s. Effective on catchments of less than 0.4 ha. Not recommended in areas of concentrated flow. Bales should not be installed on top of pavements. Maximum slope gradient of 1(H):2(V). Effective service life of 3 to 4 months.	Quick to install and repair. Provide instant service.	Generally ineffective and rarely installed correctly. When used to control sheet flow on long slopes, isolated failure points can result in the concentration of flow. Consequently the use of filter fabric is preferable. The bales can release unwanted seed to downstream creeks and rivers. Bales are regularly burnt or otherwise vandalised.
Sump Pits	Sump pits are temporary structures built to trap and filter contaminated water before it is pumped to a suitable discharge point. Sump pits can be used in areas where contaminated water cannot flow by gravity to sediment ponds. Sump pits are particularly useful for small areas that are highly contaminated relative to the rest of the construction site, such as stockpiles, concrete preparation areas and masonry cutting areas.		Can be very effective for small catchments. Sump pits consume little construction space.	Operation of the pit usually requires manual operation of the discharge pump. Can affect ground water levels.

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Table 12 Sediment Control Techniques

Sediment Control Technique	Application/ Function	Limitations	Advantages	Disadvantages
Wash Down Bays	Wash down bays are temporary/ permanent structures constructed on the entrance and exit of construction sites. They remove silt, seeds, pathogens and other contaminants from machinery entering and leaving the site.	Will not remove all contaminates, but will remove the majority.	Prevents rapid spread of weeds, pathogens, exotic plants, soils and other contaminates. Cheaper than weed and exotic plant control.	Does not totally remove all contaminates. Expensive. Time consuming depending on type and amount wash down required. Problems with treating the water and disposal of the waste.
Sediment Basins	Sediment basins can be permanent or temporary structures that allow Ponding and settlement of sediment laden runoff. Basin operation may involve chemical dosing to improve capture of fine sediment particles. Basins are located upstream of water bodies, significant bushland areas and major stormwater systems. The installation of a sediment basin does not excuse poor onsite drainage and erosion control.	Generally used to catchments greater than 1ha. Sediment basins do not replace other onsite control measures such as drainage controls, sediment fences and sediment barriers. Limited control over fine silts or clays if chemical dosing is not used.	Very effective for coarse sediment removal. Can be an effective control of fine sediment runoff if suitably operated. Generally more effective than sediment ponds and other types of sediment traps. May be converted into a permanent wetland for stormwater treatment after the construction phase.	The dosing process is difficult to automate. Basins are difficult to relocate if the construction or drainage layout changes. Decommissioned and backfilled sediment basins generally attract lower land values and are best integrated into open space areas or the sites permanent stormwater treatment system.
Sediment Fences	Temporarily reduce the velocity of contaminated sheet flow to induce gravitational settlement of the entrained sediment. Control of sediment runoff from exposed land, unsealed roads and stockpiles. Sediment fences may also be used at regular spacings down a disturbed grade to limit the rutting caused by concentration of sheet flow.	Often called ‘silt fences’ these structures have little impact on fine silts (<0.02mm). Design flows limited to around 40 litres per second in areas of concentrated flow. Drainage area limited to 0.6 ha per 100 metres of fence, or a max slope length of 60m. Service life of around 6 months.	Easy to install, controls sediment runoff close to the source of the erosion. Highly visible sediment control measure. Cannot introduce weeds/ seeds - a problem experienced with hay bales. Generally more efficient than straw bales.	Easily damaged by construction equipment and stockpiles. Can cause concentration of sheet flow if poorly located, installed or maintained. Limited service life of around 6 months or less during the wet season. Often incorrectly installed and maintained.

Table 12 Sediment Control Techniques

Sediment Control Technique	Application/ Function	Limitations	Advantages	Disadvantages
Sediment Ponds	Temporary structures formed to allow ponding and settlement of contaminated runoff from small construction sites or land disturbances. Pond operation may incorporate chemical dosing to improve the capture of fine sediment particles. Sediment ponds are located upstream of water bodies significant bushland areas and major stormwater drainage systems. The installation of a sediment pond should not be seen as an excuse for poor onsite drainage and erosion control.	Generally used on effective drainage catchments less than 0.5ha steep catchments, 1.0ha medium catchments, 2.0ha low slope catchments. Sediment ponds do not remove the need for other onsite control measures such as drainage controls, sediment fences and sediment barriers. Limited ability to capture fine sediments unless chemical dosing is used to improve settlement.	Very effective for coarse sediment removal. Can control fine sediments if chemically dosed. More effective than most sediment barriers. Can be converted into mini wetlands for permanent stormwater treatment following completion of the construction process.	Limited control over fine silts and clays. Ponds are difficult to relocate if the construction or onsite drainage layout changes. Decommissioned and backfilled sediment ponds generally attract lower land values and are best integrated into the open space provision and/or the permanent stormwater management system.

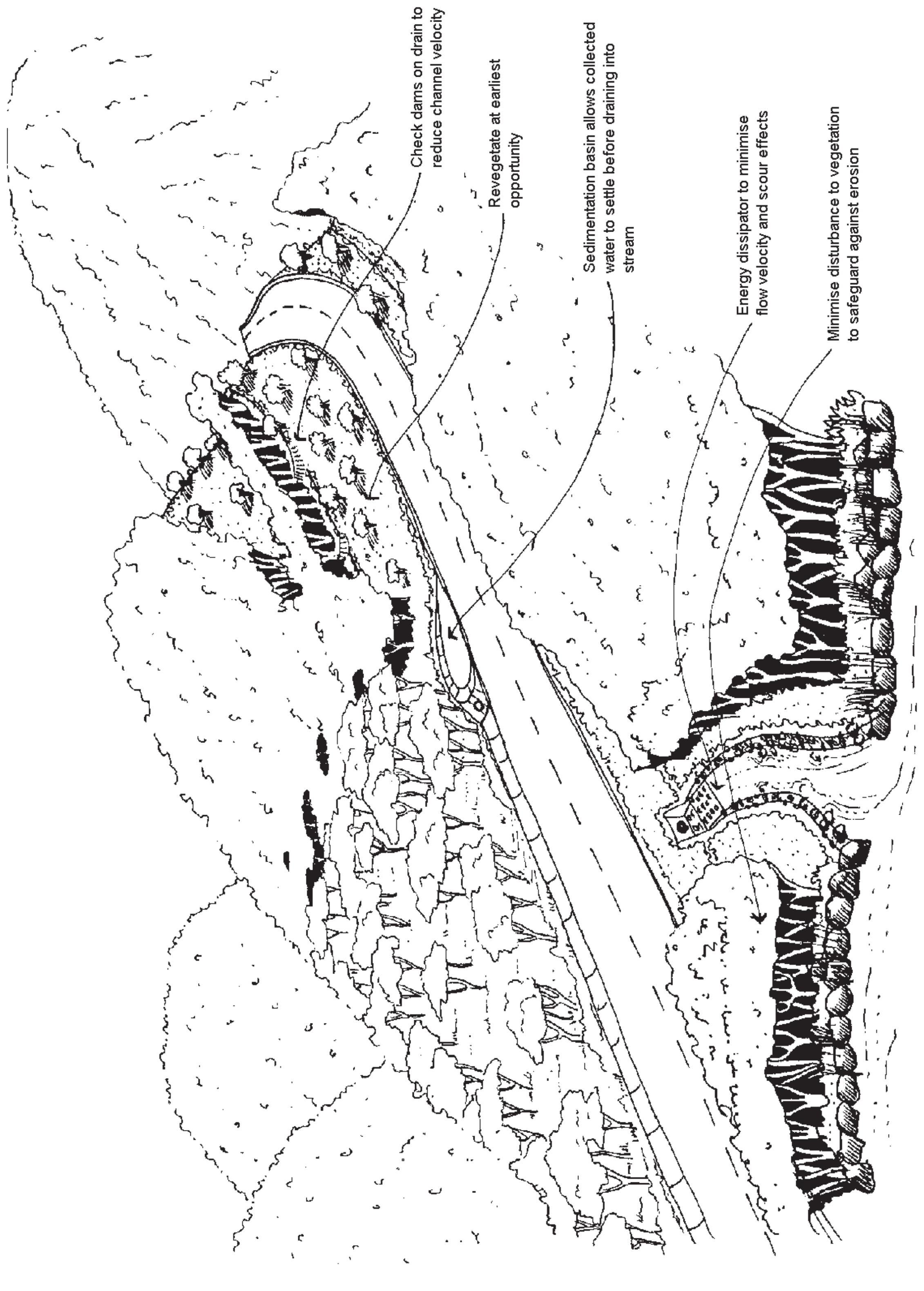

Figure 25 Permanent Erosion and Sediment Control

Figure 26 Unsealed Roads - Culvert Outwash

Acid Sulfate Soils

The desired outcome is to firstly minimise exposure of, and secondly ensure there is no acidic leachate from, acid sulfate soils.

Acid sulfate soils are a major constraint on landscape and development. Removal of vegetation and disturbance to soils, water and drainage catchments may generate 'acid sulfate soils' through accelerating the natural rate of oxidation of certain minerals in the soil. Acid sulfate soils emerge through the drainage or disturbance of the soil profile in particular areas of the coastal lowlands.

Acid sulfate soils cause sulphuric acid generation, heavy metal mobilisation and aluminium toxicity.

Their impact is widespread, resulting in impacts upon plant and animal populations and ecological integrity: habitat degradation, soil and water quality, depletion of fish stocks eg., 'red-spot' disease and other aquatic organisms, blue-green algae blooms.

Best Practice Guidelines:

Ensure the location of any acid sulfate soil zones and where the iron sulphate layer is to be found is known for all road design. In the wet tropics region specific attention is required in areas below RL (Relative Level) 5.0 AHD (Australian Height Datum).

Where acid sulfate soils do exist, ensure design is based on expert advice. Design to avoid disturbing or draining the iron sulphide layer by planning road corridors and construction works as far away from these areas as possible.

Ensure appropriate soil testing is undertaken to allow development of an acid sulfate soil management plan for the site.

Identify 'iron sulphide' indicators to prevent further acidification of soil textures and watercourses eg., blue-green algae, iron stains, poor pasture and soil textures.

Install shallow drainage treatments to avoid exposing the iron sulphide layer beneath the soil.

Consider the potential to apply a lime mix to iron sulphide areas which are disturbed to mitigate acid production potential.

Use fill to raise the road grades so the iron sulphide layer is not exposed.

Note the potential for acid sulfate soils in the topsoil stripping operation and specify works accordingly. Seek expert advice prior to the disturbing or relocation of any acid sulfate soils.

Roadside Vegetation Conservation

The desired outcome is for road design to consider short and long term roadside vegetation management in the design of roads.

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Managing to maintain the integrity of vegetation adjoining road corridors is central to maintaining the biodiversity of the wet tropics region. These areas of vegetation provide wildlife corridors, contain rare and endangered species and are an important source of food and shelter for wildlife. Further they are important for the presentation of natural habitats and scenic amenity.

During the design phase of a road project consideration of vegetation values should provide safeguards against vegetation disturbance during construction and operation and provide methods and structures which may be used to minimise impacts on vegetation. Consideration should also be given to the design of road corridors that will enable revegetation and regeneration of native flora.

Best Practice Guidelines:

Design to minimise permanent and construction disturbance to vegetation.

Design earthworks that will encourage the germination of native flora such as batters and slopes with sufficient benching or scarifying to allow for planting during revegetation of the road corridor and the long term management of the road.

Ensure that seed collection is undertaken up to 12 months prior to construction to enable all required species to be collected.

Design to retain particularly aesthetic vegetation (eg. large statuesque roadside trees).

Design should consider structures to prevent the loss of spoil offsite by gravitational forces.

Fauna Management

The desired outcome is for road design to recognise and consider fauna management requirements.

The wildlife values of a road corridor often decline as a direct and indirect result of road construction and operation. A largely vegetated corridor can minimise the road barrier between habitat areas and food sources essential to wildlife survival. Hence, the potential impacts on fauna resulting from the construction and operation of road corridors include:

- removal of habitat;
- mortality of native fauna from car strikes and machinery during construction;
- disruption of fauna movement. The latter can affect life cycles;
- result in two genetically distinct populations either side of the road.

Fauna crossing of roads can be broadly classified into two different types:

- Crossings at right angles to the road corridor. These are associated with fauna crossing from one side of the road to the other such as a corridor along a natural stream.
- Crossings running parallel to the road. In some instances fauna use the road corridor as a convenient, relatively flat route to traverse along the habitat.

Animals using the road for this purpose are more likely to be hit by vehicles as they become "trapped" on "embankments" or cuttings. They will also spend a far greater period of time on the road and thus are exposed to a far greater risk of being hit by a vehicle. The design of facilities for the longitudinal movement of fauna along roads will be confined to providing suitable escape areas at the cut/fill transition zones. Smaller animals may be provided with short lengths of culverts in cut situations for animals to hide.

Of critical significance in the wet tropics region is the effect roads have on an endangered species, for example the Cassowary. Roadkills are one of the key threatening processes resulting in declining populations in their remaining habitat.

Table 13 presents some options for fauna crossings, concept plans are shown in Appendix 5 (see Sheet 16).

Best Practice Guidelines:

As far as possible design the roads along the boundaries of fauna habitats rather than through them.

Design to reduce the effects of habitat fragmentation by encouraging canopy closure, providing for wildlife crossing points and implementing fauna underpasses along road corridors.

Identify areas where, and times when, road kills of endangered species occur and design roads to minimise the chance of roadkills.

Provide measures (eg., signage, rumble strips etc.) which increase driver awareness of fauna crossing roads.

When designing fauna culverts provide vegetation cover at either end of culvert. Also provide hiding places or escape routes for fauna using large rocks as hides. Landscape entrances and exits of fauna underpasses with suitable native plant species, rocks and logs. Encourage testing of techniques which prevent wildlife crossing in unsafe areas and/or design which calms traffic in areas where fauna frequently cross the roadway. Where possible the length of culverts should be minimised.

At cut/fill transition zones provide clear level areas as animal escape/crossing routes.

In order to enhance the connectivity of wildlife corridors and promote the safe crossing of road corridors investigate potential use of canopy bridges, where suitable/appropriate.

Undertake trials of new technology (eg. special guide post reflectors, canopy bridges) to determine if these are effective in reducing road kills and habitat fragmentation.

When designing roads in Cassowary habitat, ensure measures are implemented to reduce the likelihood of road kills.

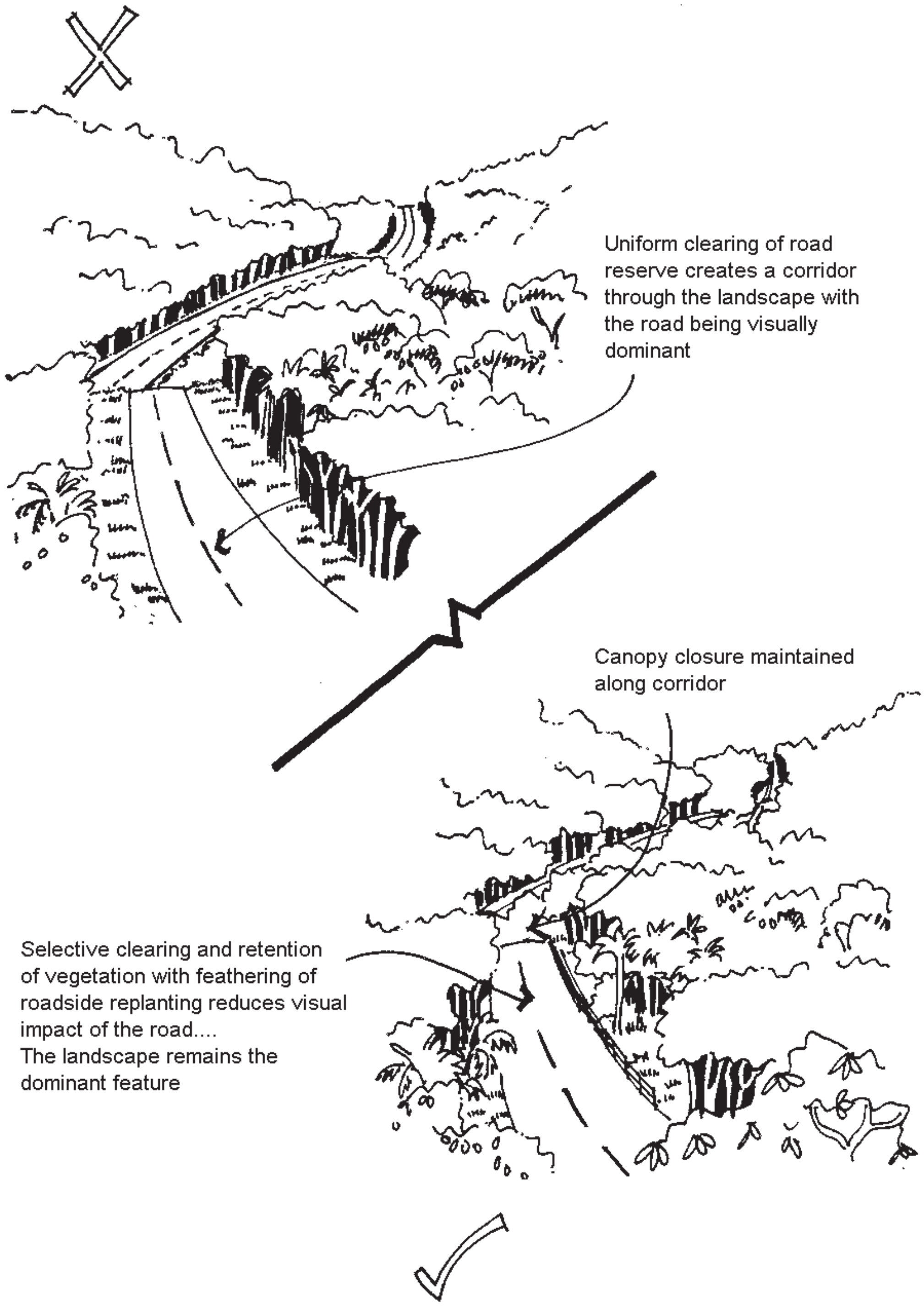

Figure 27 Design to Minimise Clearing

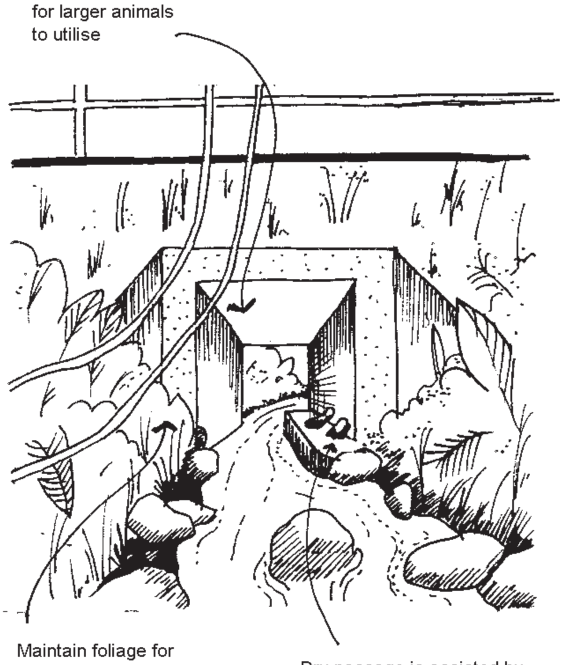

Figure 28 Fauna Crossing in Culvert

Landscape Management

The desired outcome is road design to recognise and consider landscape management requirements.

The values within a landscape can be ecological, social and economic. Land configuration, vegetation patterns and a number of individual characteristics of the region produce the overall landscape.

The design principles of a road corridor have the ability to impact upon these characteristics by altering vegetation patterns, landforms and waterforms. Design guidelines should allow for the protection of roadside scenery and landscape, and revegetation requirements consistent with the landscape management principle.

Best Practice Guidelines

Landscape cleared areas and consider the opportunity for scenic lookout locations, attractive views into the adjoining landscape and other scenic visitor experiences.

Identify landscape character types dominant to the route alignment such as vegetation patterns, waterforms, landforms and current land uses which require specific management techniques.

Design road construction and maintenance facilities to minimise their intrusion on the visual experience of the region by passing vehicles and adjoining land users. This can be achieved by minimising and screening unattractive areas containing stockpiles, temporary camp sites and construction equipment.

Design road corridors to minimise visual alteration by incorporating landscape characteristics such as form, line, colour and texture into the design process. Consideration should be given to motion, light, atmospheric conditions, seasons, distance, scale, observers position and time.

Design road corridors to give a continuity to the characteristics of the landscape by minimising visual contrasts and designing to blend changes into the surroundings of the landscape.

For roads with a significant landscape presentation role, use design speeds which are appropriate to presentation. Note this can be done over relatively short segments to avoid a major loss in transport utility.

Table 13 Fauna Crossing Techniques

Drainage Control Technique	Application/ Function	Limitations	Advantages	Disadvantages
Pipe Angled Inlet	For fauna crossing in steep terrain at cut/fill transition zones.	Does not work for all fauna species.	Ease of construction. Economical. Dual function. Works in steep terrain.	Doesn't work for all fauna species.
Specific Fauna Culvert	Fauna crossing when culvert has constant and frequent high flows fauna crossing numbers or when fauna crossing is required for specific species but a drainage culvert is not required.	Does not work for all fauna species.	Ease of construction. Economical. Place anywhere.	Doesn't work for all fauna species. Needs funnel design.
Combination Culvert Fauna Crossing	Fauna crossing combined with culvert use with constant/ frequent flow of water.	Does not work for all fauna species. Used only in creek beds.	Can provide protection for small fauna species. Economical. Dual function.	Doesn't work for all fauna species. Needs special design ledge and funnel.
Drop Invert Structure which allows Fauna Movement	Fauna crossing in very steep terrain usually cuttings.	Does not work for all fauna species. Use only if no other options are available.	Can use in very steep terrain. Dual function.	Works only for a few species. Not particularly safe for motorists or pedestrians.
Rumble Strips	Warning motorist to slow down and be alert for native fauna crossing the road.	Only a warning device.	Ease of construction. Economical. Motorists know when they pass over them.	Only a warning device can be ignored. Can't place on corners as motor cyclists may lose control.
Mid Block Deflector	Speed reducing device to physically reduce the motorists speed.	Cannot be used on major highways where higher speeds are used.	Actually physically reduces speed.	Need lighting. Only reduces speed at a single location. Permanent. Not mobile.
Traffic Slow Point Fauna Crossing	Speed reducing device to physically reduce the motorists speed.	Cannot be used on major highways where higher speeds are used.	Actually physically reduces speed.	Need lighting. Only reduces speed at a point. Permanent. Not mobile. Only on low speed roads.

Note: Fauna crossing points may require structures to funnel target wildlife species to crossing points.

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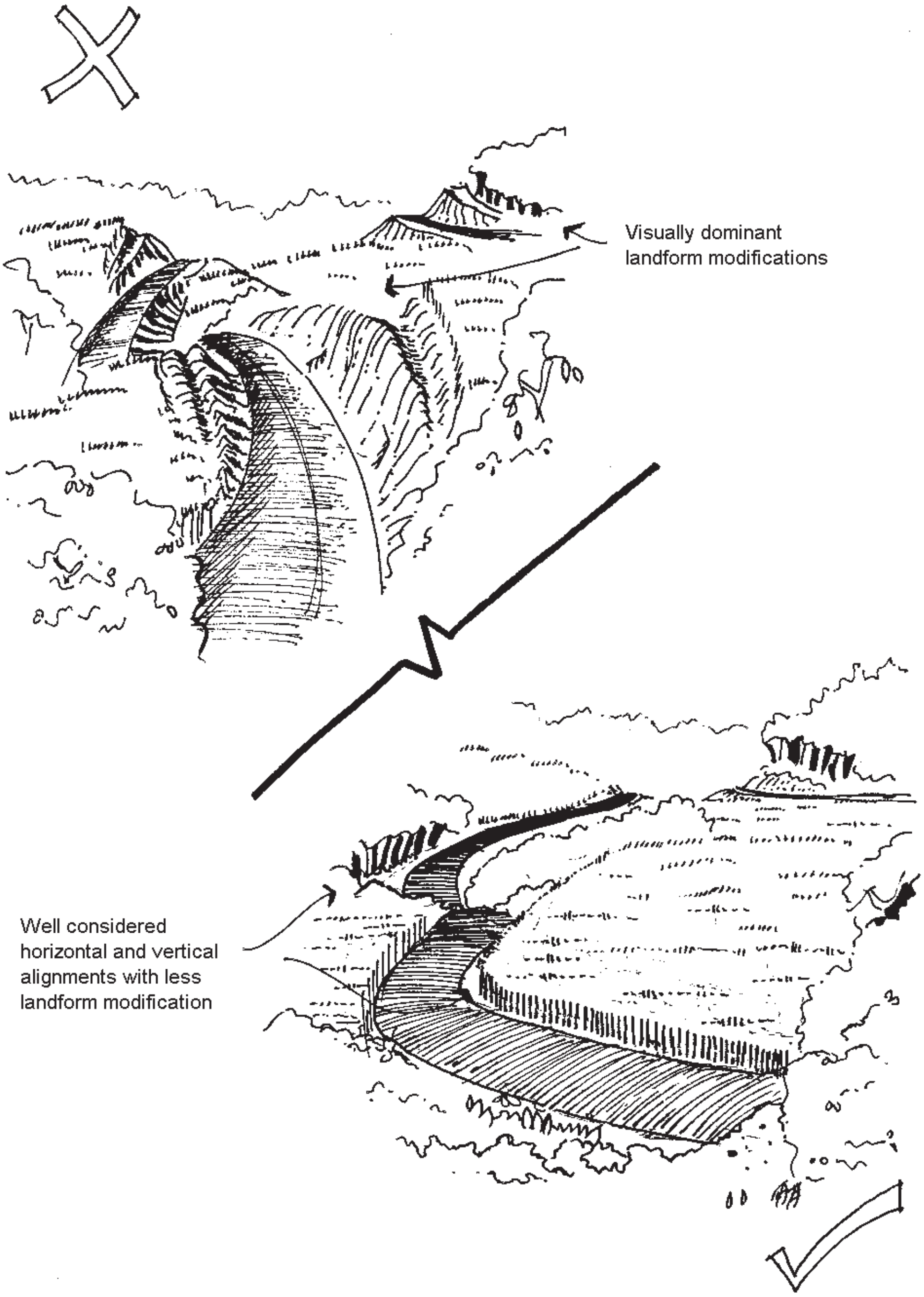

Figure 29 Avoid Landscape Modification

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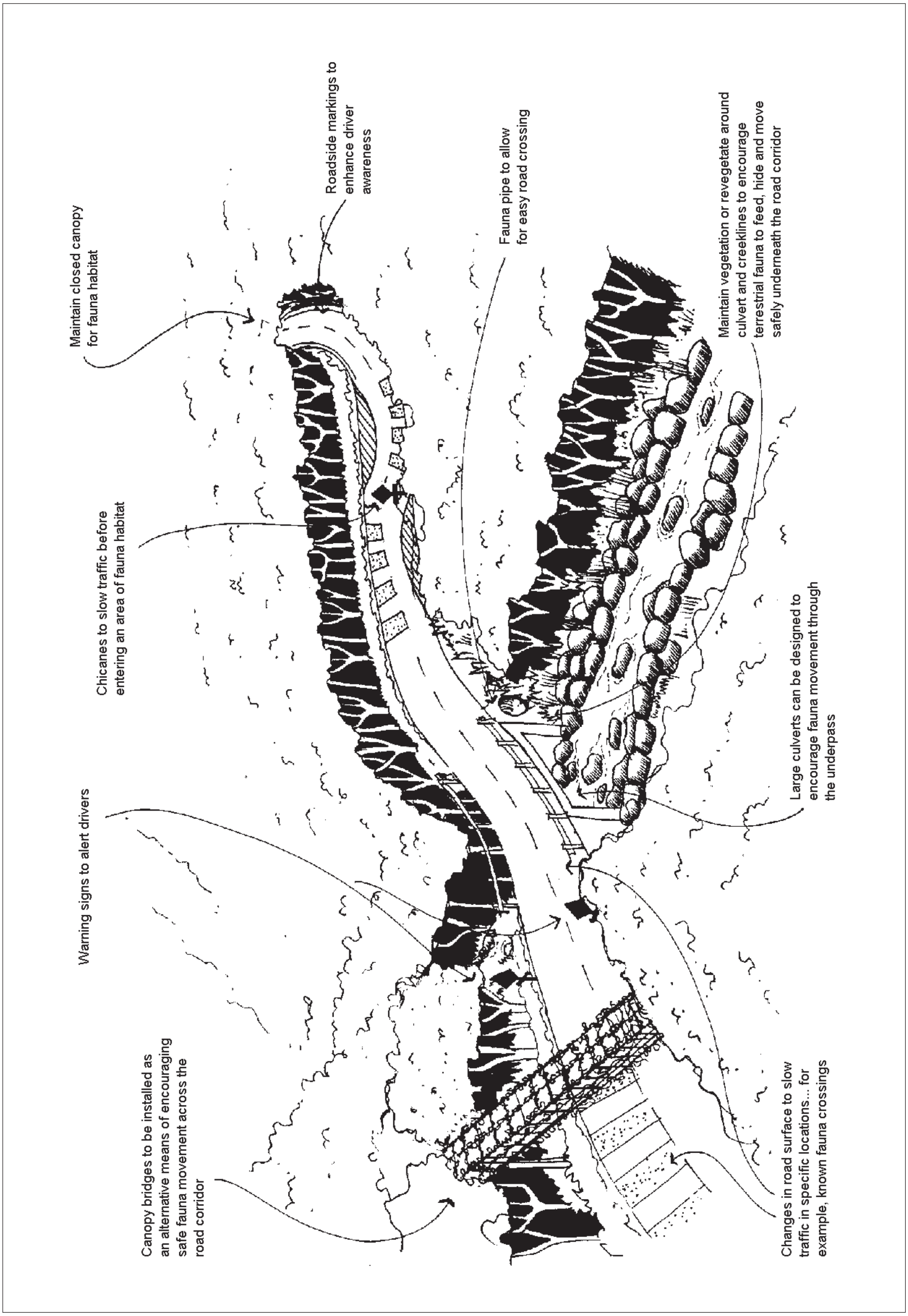

Figure 30 Fauna Management

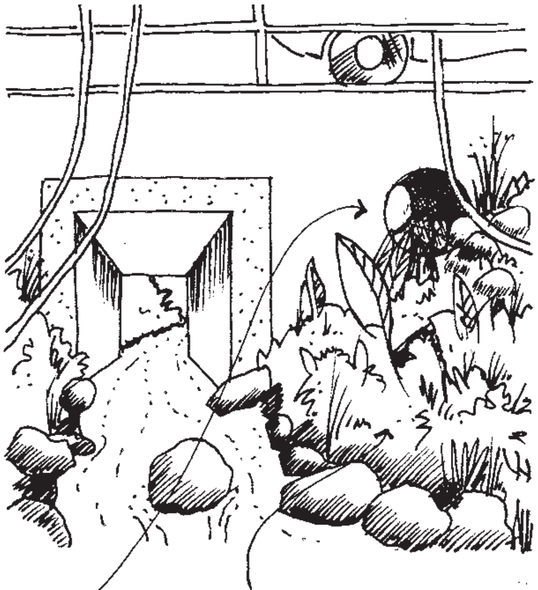

Figure 31 Fauna Culvert

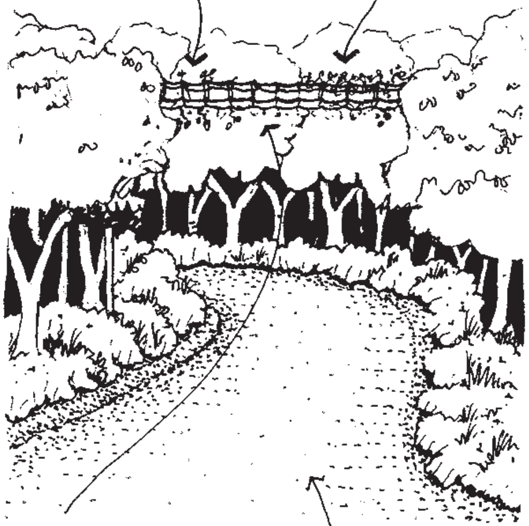

Figure 32 Canopy Bridge

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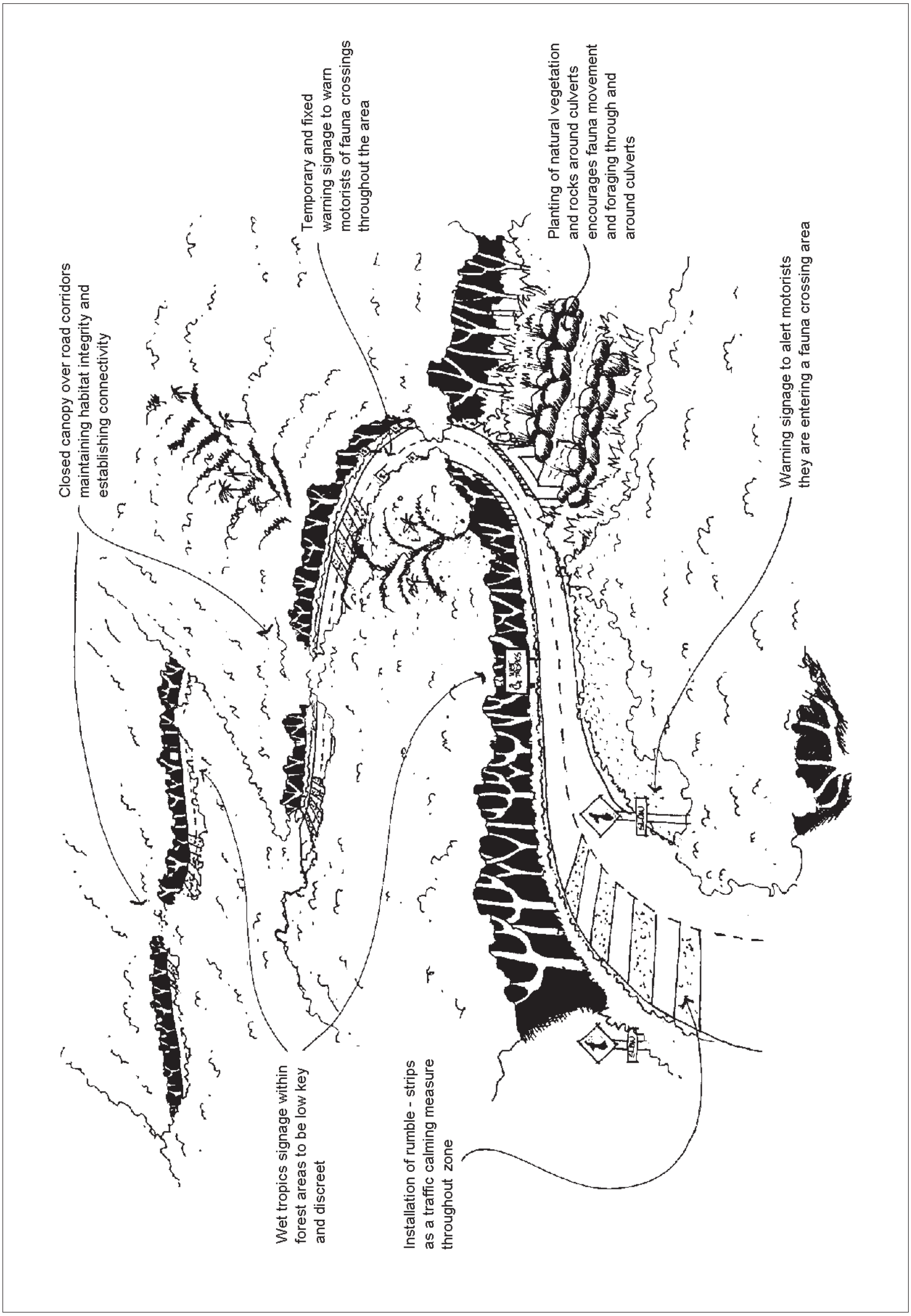

Figure 33   Cassowary Crossing Protection

Presentation

The desired outcome is for road design to recognise and consider opportunities to present natural, cultural and scenic values.

Road corridors play a major role in providing access to recreational opportunities and are also used by people as a leisure/recreation activity. Road corridors can accommodate scenic lookouts, heritage and cultural trails and other visual experiences.

Road corridors should be designed to maximise the opportunities for presentation and interpretation of the region's special qualities.

Popular scenic stopping places along the major roads attract large visitor numbers. It is estimated that the Rex Lookout on the Captain Cook Highway attracts approximately 500 000 visitors per annum.

To safely cater for this volume of traffic it is essential that the access and parking facilities are designed with appropriate turning facilities and with adequate identification.

Often the location of scenic viewing areas is in steep sidelong country with limited room adjacent to the through lanes to adequately develop the scenic stops. Alternative sites may need to be developed with the access points located where they can be fully developed with appropriate sight distance and with the scenic lookout located remote from the road.

Best Practice Guidelines:

Provide safe entrance and exit to scenic viewing locations. Entrance to be designed for the likely user numbers taking into account the traffic volume on the road. Design to incorporate viewing points in roadworks projects in appropriate areas. Table 14 provides example designs.

In association with relevant agencies, provide interpretive signage at scenic spots.

Consider the view from the road from the tourists or visitors view point:

- provide distant views to landscape scenes - some tree trimming may be required to retain the view; and
- develop tourist roads with appropriate signage to educate and inform the public on the wet tropics values.

In closed forest areas where distant views are constrained by adjoining vegetation, use small clearings to frame views of the landscape.

Access to scenic lookouts should be designed to safely cater for the vehicles entering and leaving and also allow through vehicles to safely pass turning traffic.

The identification of scenic lookouts and key vistas is best undertaken by experienced natural area planners or landscape architects. Factors to be considered include:

- available vistas;
- naturalness of view;
- built form, water and pattern in the view;
- contributing factors to scenic quality;
- detracting features to scenic quality; and
- suitability in terms of ease of access and traffic engineering considerations.

Table 14 Scenic Lookout Arrangements

Lookout & Type	Application/ Function	Limitations	Advantages	Disadvantages
Highway Layby/ Two Way	For 100km/hr highway situation where the view and space permit.	The length and width required to develop this type of access.	Good sight distance. Ample parking. Dual entry and exit points. Buses can use this type of lookout.	Multiple points of conflicts on high speed road. Large area is required for this type.
Highway Layby/ Single Direction	For 100km/hr highway situation for single direction.	Only caters for traffic flow in one direction.	Deceleration lane reduces sight distance considerably. Buses can use this type of lookout.	Single entry and exit points. Larger longitudinal area required.
Highway/ Local Roads - Park	For 80km/hr highway situation where the view and space permit.	Requires passing lanes on higher volume roads.	Good sight distance. Ample parking. Single entry and exist points. Buses can use this type of lookout.	Used by some Local Governments in Wet Tropics region.
Local Roads Unsealed Layby/ Single Direction	For 60km/hr local roads single direction.	Only caters for traffic flow in one direction needs to be on the same side as the view.	Deceleration lane shortens sight distance. Good position on outside of curve gives extra sight distance safety.	Single direction.
Highway Layby	For 60km/hr highway situation single direction.	Only caters for traffic flow in one direction needs to be on the same side as the view.		Single direction.
Local Roads Unsealed and Sealed - Park	For 40km/hr local dual direction.	Single entry/exit with high volumes may cause conflicts.	Ample parking. Single entry and exit. Buses can use this type of lookout if large enough.	Large area is required.

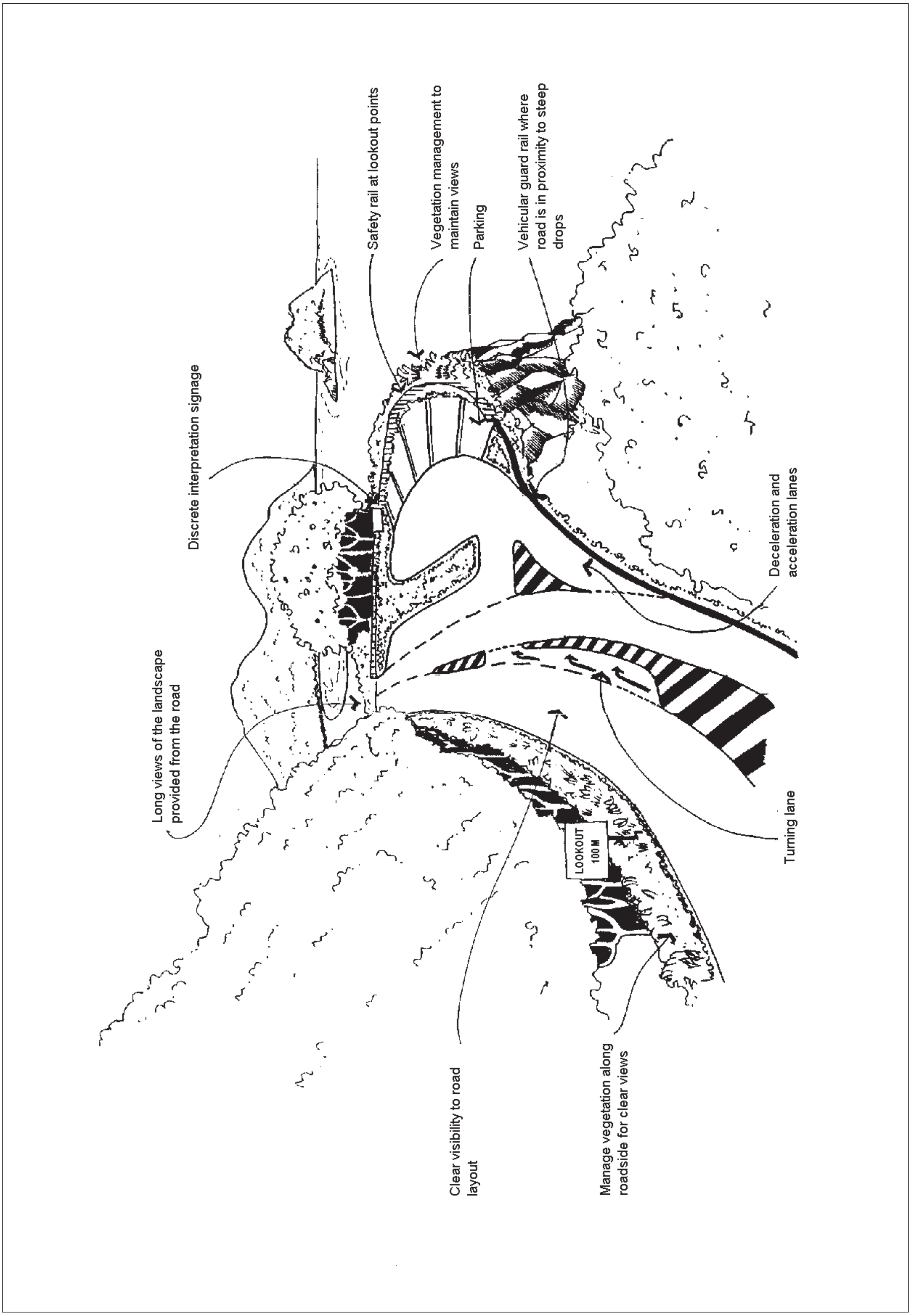

Figure 34   Design for Presentation

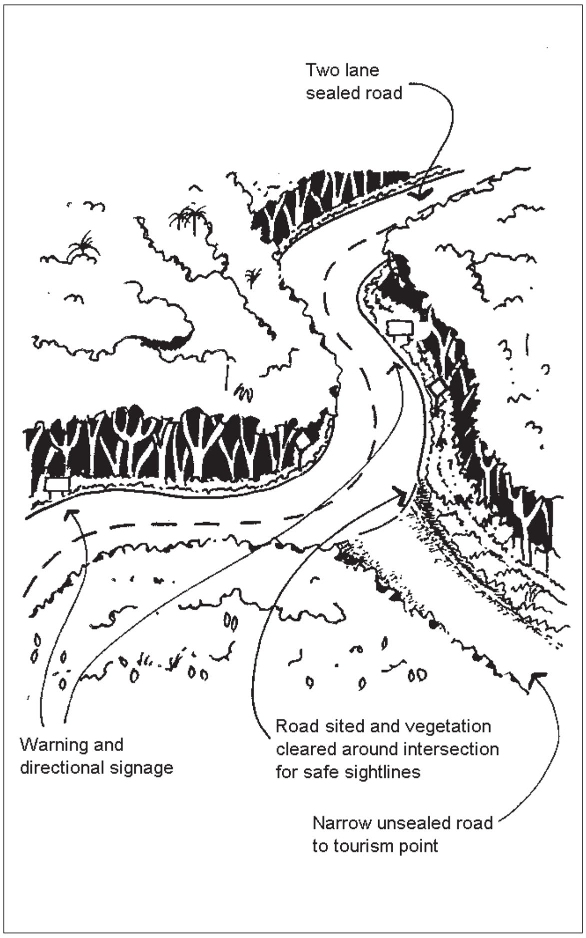

Figure 35 Access for Presentation

Consider relocating the site to a safe entry/exit location and develop the site clear of the existing road possibly down an adjacent ridge. Developing off road facilities with parking and perhaps a short walk to the scenic location also enables development of interpretation signage to enhance and educate the tourists on the regions attributes.

Local Government, DoE and WTMA should be consulted as they may be able to assist funding presentation facilities.

Consider a strategy to develop scenic spots but limit along road corridors to a specific number.

Design Vehicle

The desired outcome is road designs which provide for appropriate vehicle types whilst minimising environmental impacts.

The road needs to be designed to allow for the various vehicle types to use the road safely.

The percentage and type of heavy vehicles using the road will influence the turning radii at intersections and in steep winding country curve widening may be required to cater for the larger vehicles. The layout and access to scenic areas will also be influenced by the size of tourist vehicles entering the site.

Clearance to the overhead canopy will also be affected by the sizes of vehicles using the road.

Best Practice Guidelines:

Design the road and intersection for the anticipated vehicles using the route.

For local and tourist roads the maximum vehicle size may be determined. Smaller vehicles only require narrower roads and clearing and have less wear, particularly on unsealed roads.

Where large or heavy vehicles are to be accommodated in the design, the regional context of the need for them should be addressed (usually in the planning stage, but as part of design if not).

Design Speed

The desired outcome is roads with appropriate design speeds whilst minimising environmental impacts.

The Austroads "Guide to the Geometric Design of Rural Roads", provides guidance on the selection of appropriate design speeds.

Best Practice Guidelines:

For tourist roads travelling through hilly and scenic terrain adopt a lower speed environment.

For the major commuter/freight routes in flat terrain a higher design speed will be required.

On mixed function roads containing both commuter and tourist traffic in areas of steep terrain with high scenic values it may be desirable to adopt a design speed compatible with the slower moving tourist traffic.

here there are significant ongoing environmental impacts directly attributable to vehicle speeds (eg. roadkills of an endangered species), consider reducing design speed and using traffic calming measures.

Horizontal and Vertical Alignment

The desired outcome is a horizontal and vertical alignment of roads which are consistent with design speed and minimise environmental impacts.

The vertical and horizontal alignment chosen may impact significantly on the landscape through which it passes. In general the horizontal and vertical alignment should be coordinated to provide a consistent alignment. However, in open areas increased sight distance may be required to provide for overtaking opportunities.

Best Practice Guidelines:

Develop a curvilinear alignment in hilly and mountainous terrain.

On steep sections used by long heavy vehicles with or without trailers (eg B doubles and road trains) try not to adopt the maximum grade. However where required to reduce environmental impact short stretches of maximum grade are acceptable.

Provide truck runoff and pull-off areas on steep grades with a high volume of heavy vehicles.

On gravel roads avoid grades over 10% or consider sealing steep sections of the road to prevent erosion. Short sections of steeper grades can be utilised where drainage minimises erosion potential (eg. use of whoa-boys).

Provide curve widening for design vehicles where required. However, recognise that this can involve greater impact and loss of canopy connectivity in specific habitats (eg. gullies and ridges) and reconsider whether particular vehicles need to be catered for.

Provide appropriate sight distances at entrances/exits and intersections.

Where possible provide stopping sight distance to cut/fill transition zones (for safe fauna crossing).

Consider providing for manoeuvring sight distance (rather than the longer stopping sight distance) to minimise the depth of cuts.

Minimise canopy vegetation trimming required around the inside of corners.

Road Formation/Batters

The desired outcome is for road formation and batters to be designed to meet road engineering requirements and minimise environmental impacts.

Road formation and associated earthworks provides support to the pavement and traffic lanes. By designing roads which minimise the area to be cleared, the height and slope of batters and the volume of earthworks, the resultant road alignment will generally be a safe, cost effective and an environmentally sound project that requires minimal ongoing maintenance.

Best Practice Guidelines:

In order to reduce the width of clearing and disturbance, design batters to be as steep as possible in sensitive areas. Obviously, all batters have geotechnical stability considerations, particularly fill batters. Note that steep batters require erosion protection and adequate drainage.

Consider rounding of batters and using constant batter line in less sensitive areas to provide a more natural cut/fill batter.

Consider benches on batters over 3 m high to facilitate planting.

On cuts, it is as important to ensure long term stability as it is to minimise construction disturbance. A steep cut which fails and collapses will result in more disturbance and environmental impacts over time than a wider, less steep cut which (although it has a greater area of disturbance during construction) is revegetated with surrounding vegetation species and regains its habitat values.

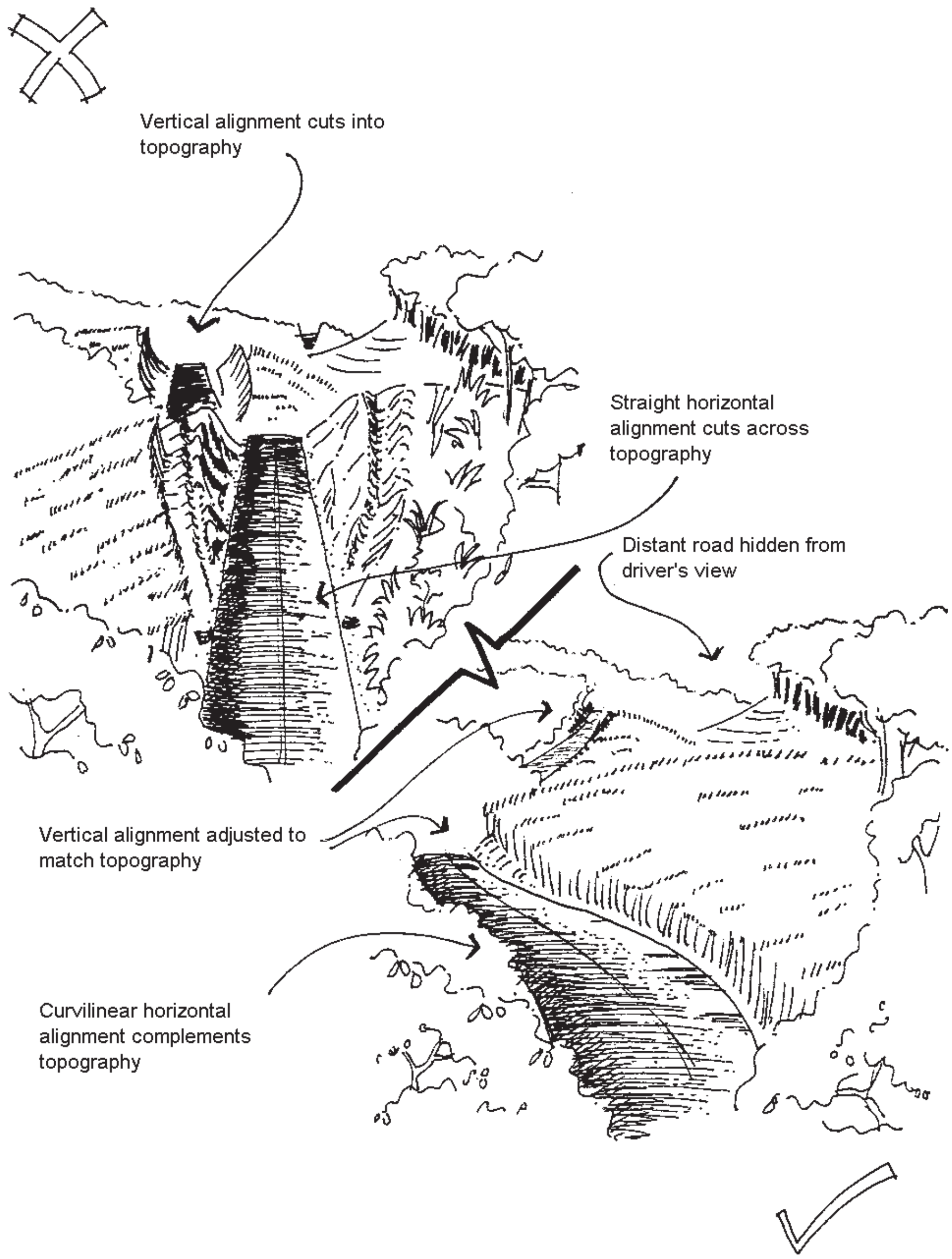

Figure 36   Avoid Landform Modification

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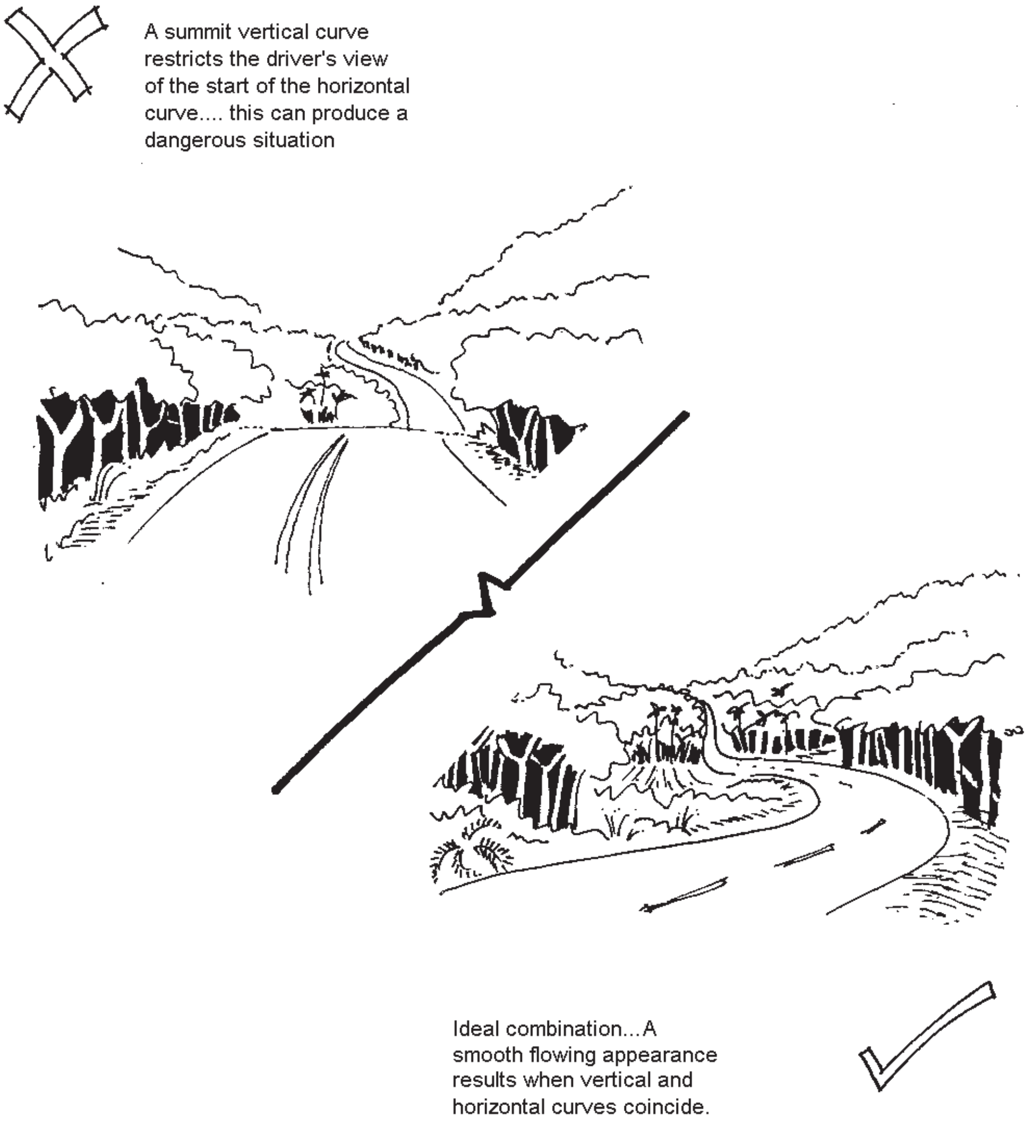

Figure 37 Coincidence Of Vertical And Horizontal Curves

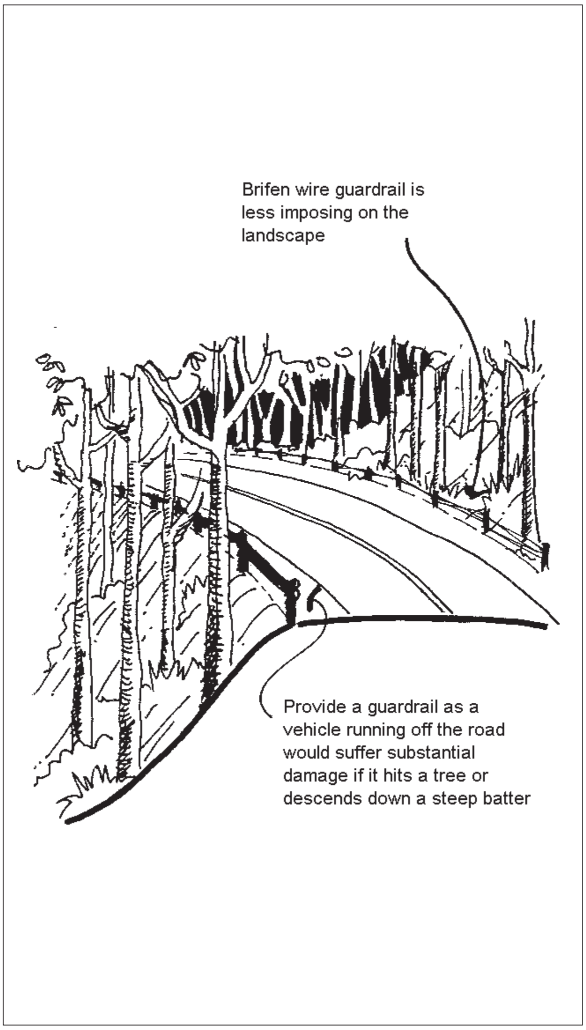

Figure 38 Clearing Widths (High Volume High Speed Roads in Closed Forest)

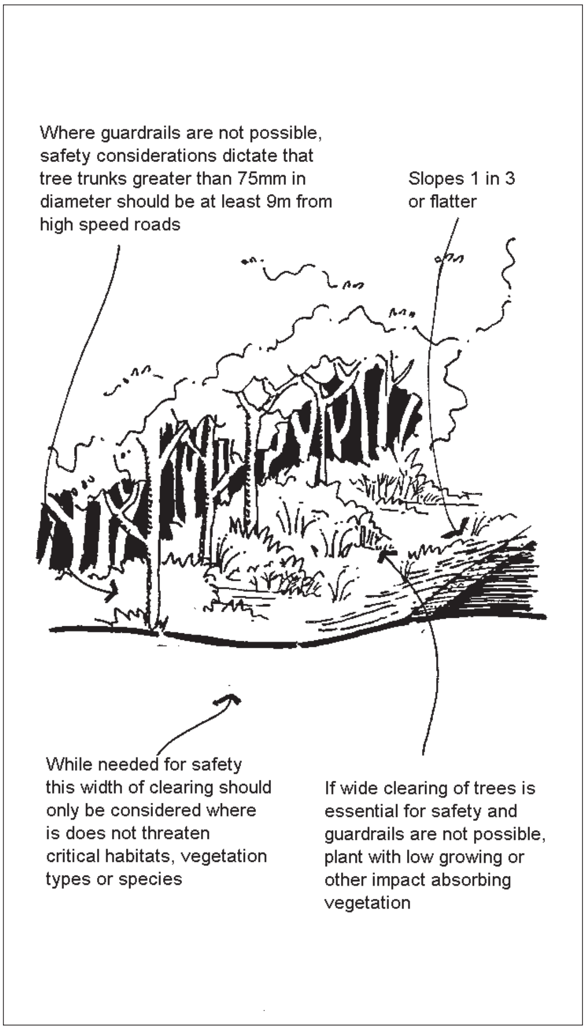

Figure 39 Clearing Widths (Low Volume-High Speed)

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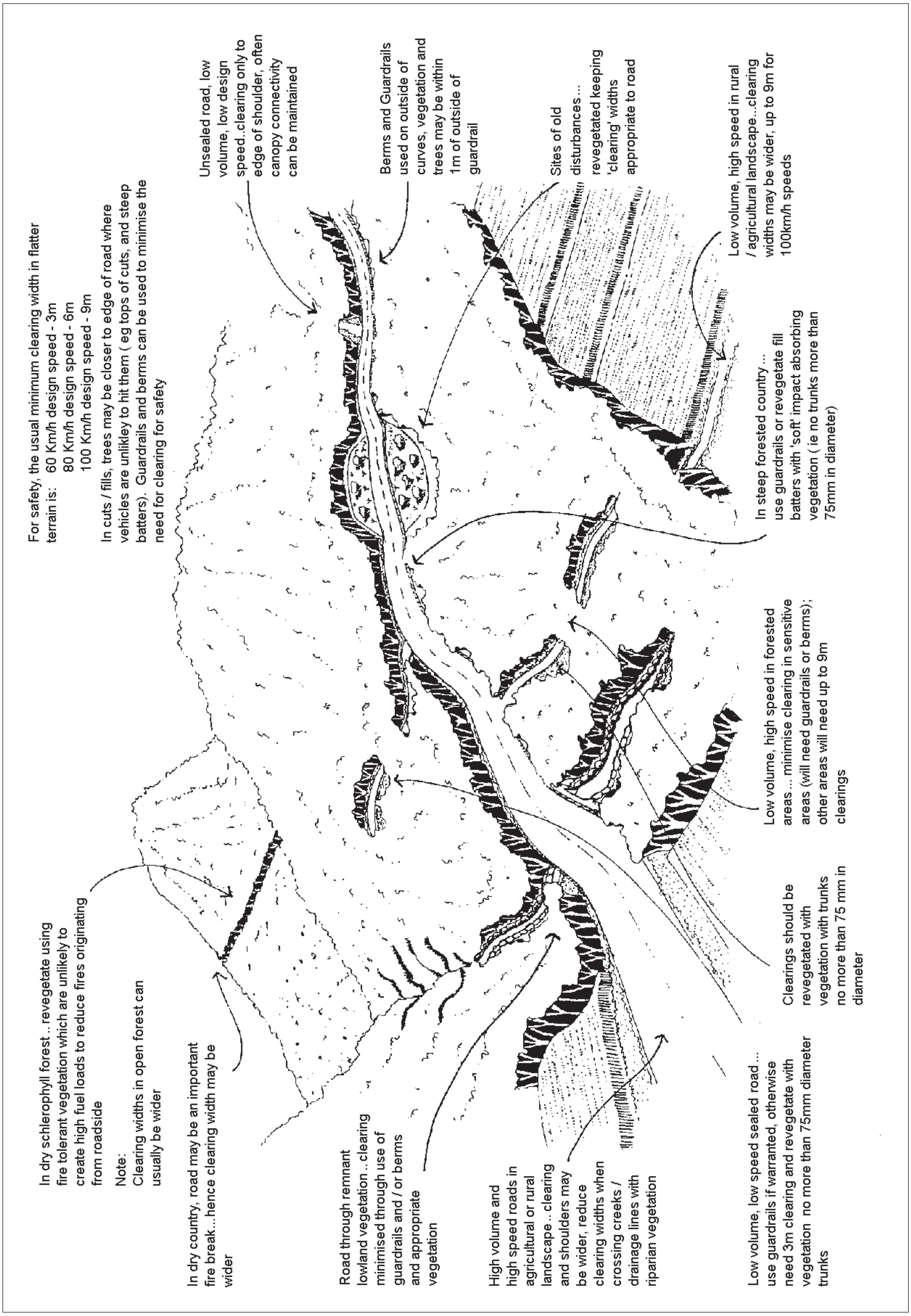

Figure 40 Clearing Widths

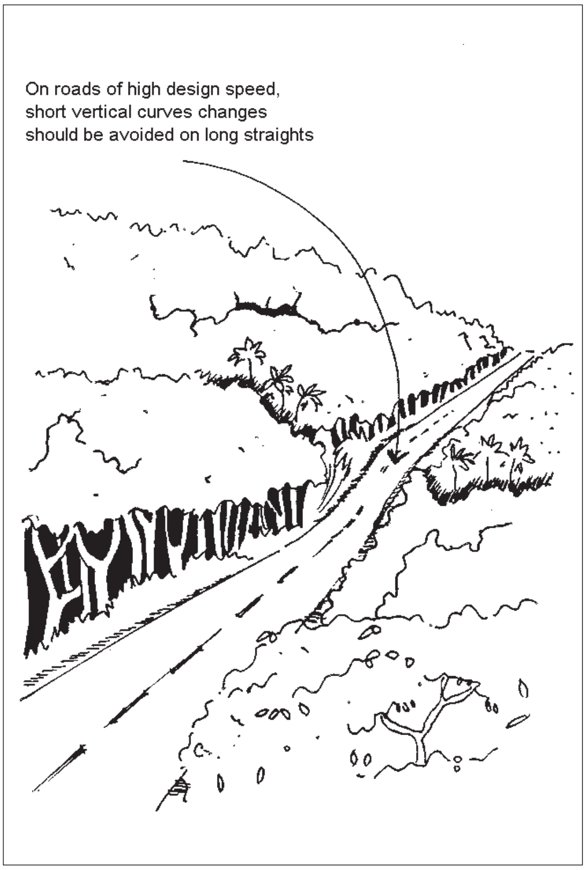

Figure 41 Avoid Vertical Curves

Safety

The desired outcome is safe roads.

To provide a safe and reliable road network is an essential part of the road design process. Road designers need to take into account accident patterns, particularly where they can be traced to existing design problems.

The road design should also take into account the speed of the traffic volumes, intersections and accesses.

Best Practice Guidelines:

Ensure an appropriate design speed is adopted and is relatively consistent throughout the route. Where changes in design speed are required they should be undertaken gradually.

Consider using Brifen Wire Rope in preference to guard rail or large clearings.

Ensure appropriate clear widths or recovery zones are provided (where environmental impacts are acceptable) based on the volume and speed of the traffic. Ensure design identifies appropriate revegetation in any cleared recovery zones and notes in Environmental Design Report for inclusion in Corridor Management Plan.

Provide safe access to scenic viewing areas consistent with the speed of the traffic and the traffic volume and sighting distance.

Ensure that intersection and stopping sight distance is maintained.

Ensure that end posts on structures are adequately protected.

Weeds

The desired outcome is to ensure that no weeds, pathogens or exotic animals are introduced to areas.

The importation of road making materials should be free of contaminants, from weeds and plant pathogens (eg., phytophthora the root rot fungus).

Crushed rock from quarries are unlikely to contain contaminants. However, material occurring in natural gravel deposits may be contaminated.

Road plant and equipment coming from other sites should be washed down to remove any dirt prior to entering the construction site. Washdown areas must have appropriate bunding and sediment control, and in natural areas must have mechanisms to ensure weeds and pathogens washed off vehicles are not introduced into new areas.

Any stockpiles created should be treated as though they are earthworks and be revegetated and topsoiled. Provision should be made to collect any sediment eroded from the stockpile.

Note that in the Wet Tropics World Heritage Area, apart from the cut and fill associated with the earthworks, obtaining additional material from borrow pits or dumping material over the edge of batters is prohibited unless specific approval has been obtained from the Wet Tropics Management Authority.

Best Practice Guidelines:

The existing rainforest topsoil and humus should be retained and respread on batters.

Dumping of any excess road making materials within the Wet Tropics World Heritage Area requires the approval of the Wet Tropics Management Authority.

The supply of gravel sources should be tested for pathogens if the materials are being imported from areas known to contain plant pathogens.

Retain topsoil and respread in the locations from which it was stripped.

Topsoil should not be transported from other areas due to the possibility of importing exotic weeds and/or plant pathogens.

Develop disposal points for material cleared out of sediment traps and revegetate the disposal areas as quickly as possible.

Consider surfacing materials with colours, textures which blend in with natural surroundings (other than roads safety markers and signage).

Consider special marker paint colours to delineate areas of conservation significance (eg. green edge lines).

Road furniture should be designed to be compatible with the surrounding environment.

Cut and Fill

The desired outcome is to minimise earthworks and disturbance.

Cut and fill can have a major visual impact. The area exposed during earthwork operations also can lead to erosion and sedimentation of watercourses.

The cut and fill can dominate the landscape and it is desirable to minimise the earthworks as far as practicable.

The cut and fill transition zones should be designed so that they do not obstruct escape routes for any fauna.

The distant view of the road alignment should be assessed and if major cuttings or fills will be visible then consideration may need to be given to altering the alignment to avoid the cut being viewed from distant vantage points. Where the cut and fill cannot be avoided then revegetation of the batter should be given a high priority.

Various revegetation techniques are available from Hydromulching to planting with viro cells and spraying of freshly exposed rock with an activator that promotes moss and algae growth.

Water running over steep batters will develop a high velocity and resulting erosion of any unprotected batter. Prevention of runoff water running over batters is essential to prevent erosion. In earth fill and cuts consideration should be given to adopting a constant batter offset to achieve a rolling cut and fill batter that better matches the natural terrain profile.

Best Practice Guidelines:

Consider the use of gabions or other retaining devices in steep sidelong country (especially in sensitive rainforest areas).

Batters should be designed to a stable slope based on consideration of topography, soil type, vegetation and rock formations for revegetation. Note, this must also consider needs to minimise erosion.

Incorporate in design surface relief on batter faces, this provides far greater microhabitat. This can be achieved by roughening cut slopes to provide horizontal steps along the batter or even small (300 mm) benching to enable topsoil to be retained and assist revegetation.

Provision should be made to prevent surface runoff damaging cut and fill batters. Catch drains, diversions banks and channels above and below batters, and benches within them, will intercept surface runoff and conduct it to safe disposal points. This will reduce the hazard of sheet erosion and batter slumps.

Berms or benches are recommended on batters with a vertical height greater than 5 metres. The bench should be at least 1 metre wide, but additional width may be necessary to allow for the movement of equipment used to establish and maintain vegetation on the batters. However, this may be avoided by progressively revegetating the cut (hydromulching and seeding) at the level of each bench as the cut is excavated to avoid the need for wide benches. If the batter is relatively steep (and it is unlikely to grow trees) a bench of 2-3m may allow trees to be established, this will effectively stabilise and screen the batter.

Benches should have a minimum longitudinal grade of 1% if vegetated or 0.5% if paved. The maximum grades should be restricted to a level consistent with the maximum permissible velocity for the type of lining used. A maximum lateral slope of 10% (10:1) towards the toe of the upper batter should apply.

With cut batters, a catch drain or diversion bank should be constructed above the top of the cut before excavation commences. Temporary toe drainage should be maintained as the work progresses, with permanent toe drainage installed when the final depth is reached. To prevent erosion, this catch drain may require concrete lining.

For small cuts, as the batter is excavated, serrated cuts are desirable to hold topsoil placement and assist with the establishment of vegetation.

For fill batters, permanent toe drainage should be installed at an early stage and should discharge to a suitable outlet. At the completion of each work period during the construction of the bank, or at the onset of rain, a windrow of suitably compacted soil material should be constructed along the recently completed fill slope. Permanent top drainage measures should be installed on completion of the filling operation.

Early stabilisation of exposed batters is essential. They should be adequately protected from erosion by vegetation, or other means, within 7 days of their construction. Best practice is to revegetate all exposed areas immediately.

Grass filter strips can be used to control sheet flow and sediment runoff on small, steep embankments. Typically these turf strips (minimum 300 mm wide) are placed in continuous rows along the contour, and at a spacing of 1 to 2 metres. Note: these should only be used in natural areas when the turf has been determined to have no potential to become a weed.

Creeks and streams are the principal corridors for fauna movement in rainforest areas therefore ensure that the road is high enough above the stream to enable suitable fauna crossing to be installed in culverts or under bridges.

Consider using a constant batter offset in earth cuts and fills to better match the earthworks into the terrain.

E3

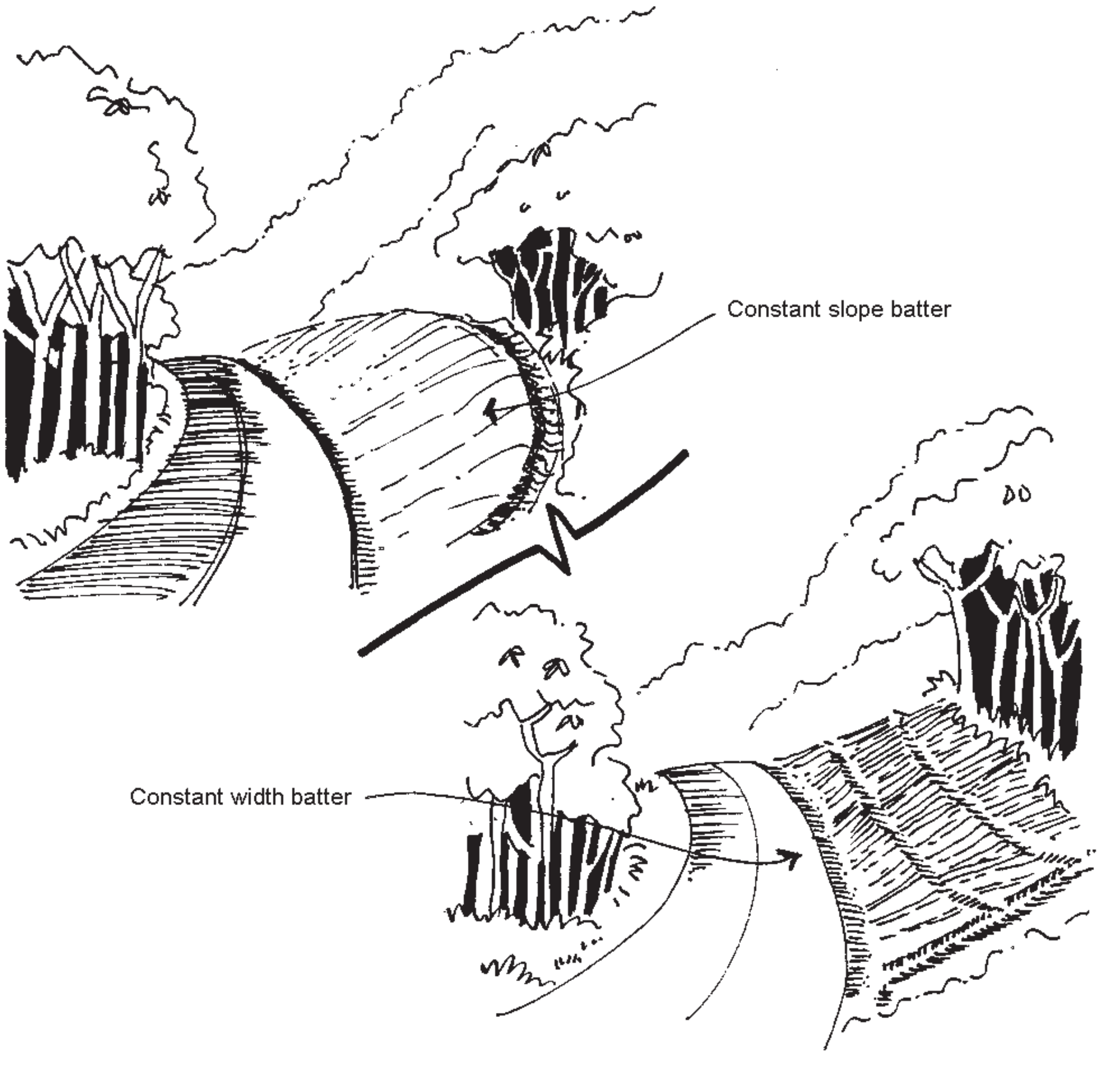

Figure 42 Batter Options

The cut/fill transition zone provides areas for fauna crossings and barriers across these sections should be avoided.

Consider use of temporary retaining structures on fill (downhill slopes) to prevent downslope contamination by spoil.

Intersection Design

The desired outcome is to provide safe access onto and off the road to other roads and access points.

The anticipated traffic on the major and minor road should be determined so that the appropriate intersection layout can be adopted. The design of intersections should be undertaken in accordance with the Guide to Traffic Engineering Practice Part 5 - Intersections at Grade 4 AustRoads 1988.

The design should consider any flora that will need to be cleared to obtain sight distance and to provide for earthworks. Any services that will require relocation should also be considered and the effect of the service relocations on the flora.

If the intersection will provide access to a scenic location appropriate advance signage and junction signage should be provided.

Best Practice Guidelines:

Ensure that intersections cater for the design vehicles especially for turning movements.

Ensure that junctions are located to provide intersection sight distance.

Ensure that the appropriate junction type is designed to cater for the anticipated traffic volumes.

Locate intersections to avoid clearing of native vegetation at significant sites.

Signage

The desired outcome is to provide safety, directional, orientation and interpretive signage.

In addition to the safety signage, additional signage in the Wet Tropics World Heritage Area and other natural areas of the wet tropics region may include:

- Wet Tropics Advisory Signs; sign advising that you are now entering the Wet Tropics World Heritage Area and to drive slowly and enjoy the experience. entry point to the wet tropics region.
- Information Signs; advisory signs of particular features of interest to tourists - eg. scenic spots, geological features etc.
- Warning Signs; warning signs used to advise motorists of fauna crossings etc. They may be temporary or permanent depending on the fauna movements. If species only cross the road for a limited time each year then temporary signs should be considered possibly with flashing yellow lamps if crossings occur at night.

Best Practice Guidelines:

Provide signage in accordance with the Manual of Uniform Traffic Control Devices by the DMR.

Consider additional information and interpretation signage to present the unique values of the Wet Tropics bioregion.

Install advisory signage along all relevant sealed and unsealed road corridors advising motorists that endangered species may be present eg. Cassowaries.

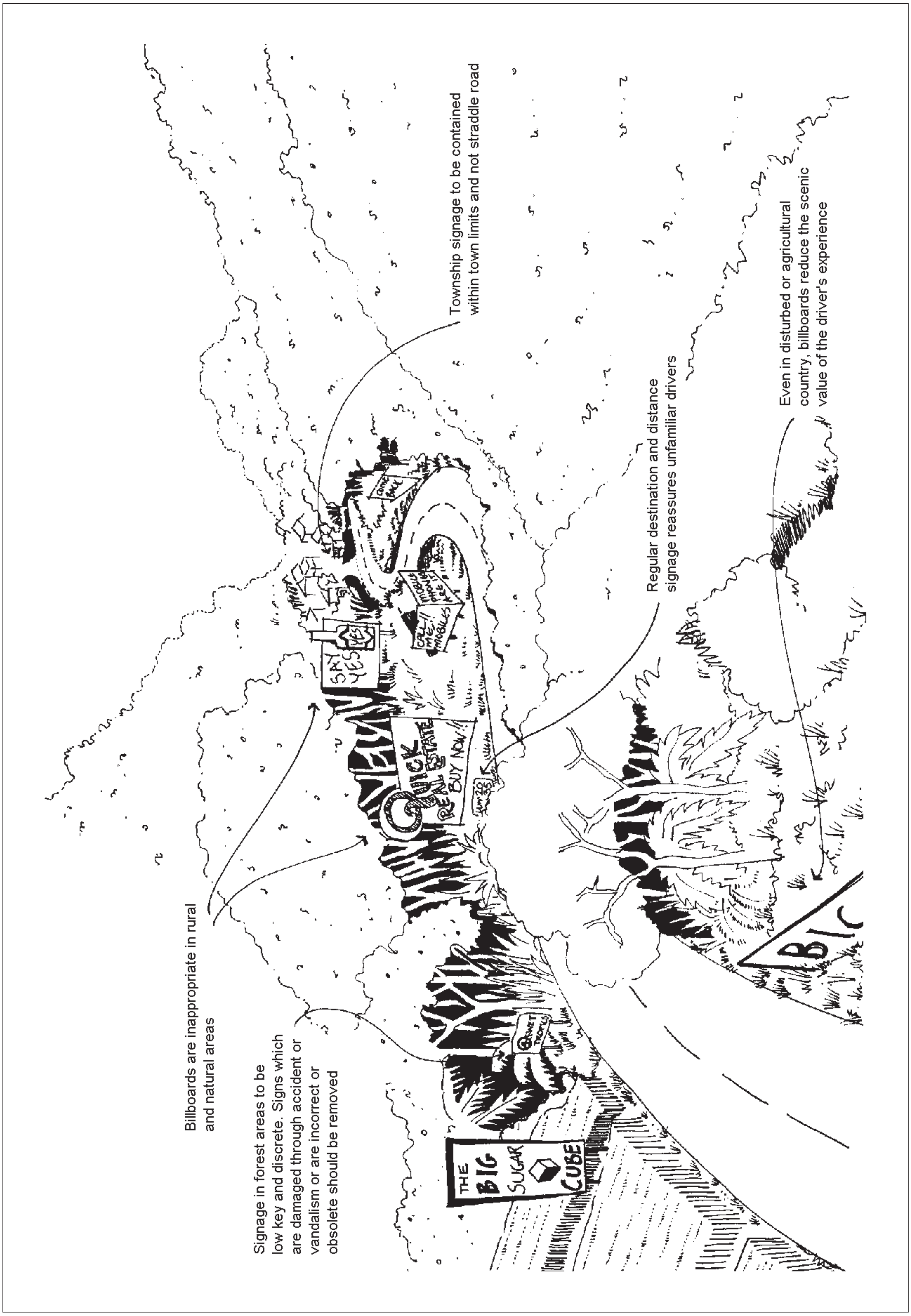

Figure 43 Roadside Signage

Provide additional signage containing contact numbers of a local animal welfare authority or wildlife reserve authority to promote increased reporting of injured fauna by motorists.

Position signs to mark the location of a specific site or turn-off.

Provide advisory signage for specific points of interest for tourists eg., scenic lookouts, landforms (geological), tourist parks etc.

Erect warning signage to advise motorists of likely fauna crossings in the area or an endangered species zone eg. warning signs followed by rumble strip in dedicated endangered fauna areas such as Cassowary habitat.

Provide advance signage to motorists advising of Wet Tropics World Heritage Area, national parks and state forests.

Billboards and commercial advertising reduce scenic values.

Promote the adoption of design codes/standards for signage in the World Heritage Area: presently signs of all shapes, sizes and colours exist.

E4 Design for Construction

Construction Impacts

The desired outcome is to design to minimise environmental impacts from construction activities.

Construction activities can impact the natural environment in a number of ways. Influx and outbreak of undesirable plant and exotic weed species is enhanced during clearing for road corridor construction. Light penetrates the canopy and encourages exotic plant growth, altering the integrity of the natural environment.

Environmental impacts arising from construction activities include segregation of habitats, reduced ecological integrity, promotion of soil erosion and scouring (stream and bank), increased suspension densities in nearby drainage lines, alteration of flow regimes and channel dimensions of streams and infiltration of dust, noise and light.

The potential to impact the surrounding environment is minimised by containing impacts within the construction zone or in areas previously disturbed, eg felling of trees, land clearing.

Staging of Construction

Construction activities are to be staged in accordance with the agreed contract and in a fashion that minimises the amount of exposed and erodable area. This requires the submission of an EMP (Construction) and certification of a stormwater management plan that has been developed and approved by Main Roads. The staging of construction activities is to be as per the provisions of the contract’s stormwater management plan.

Temporary and permanent erosion and sediment control measures are to be established prior to commencing construction activities. It is preferable to conduct all construction activities, particularly vegetation clearance and topsoil removal, in the dry season to minimise the impact of rainfall and storm events as the intensities of flow velocities, volume of runoff and infiltration of stormwater into natural catchments are substantially less.

Introduce where possible median and table drains prior to earthworks to provide a more permanent drainage system. Once temporary and permanent drainage structures have been installed, remove topsoil in areas ready for excavation. Maintenance and repair of erosion and sediment control devices are to be ongoing as development proceeds.

Progressively revegetate and stabilise exposed areas during the construction phase. Once the site is stabilised, all temporary erosion and sediment control structures should be removed. Stabilisation of the site should be within 14 days of completing earthworks.

Storage of fuel, chemicals, machinery and topsoil is to be located in disturbed areas away from drainage lines that are clearly marked and signed, with appropriate erosion and sediment control measures in place.

The EMP (Construction) must address waste management and waste minimisation issues in order to reduce the generation of waste and its impact on the surrounding environment.

Temporary watercourse crossings, traffic detour alternatives and site access provisions are to be installed progressively as development proceeds.

Temporary Watercourse Crossings

Temporary watercourse crossings need to be practical and cause minimal disturbance. Construction of these crossings is to commence before earthworks and excavation on opposite banks.

Siting of temporary crossings should be away from permanent culverts and provide for easy access and movement of construction vehicles.

Cellular confinement (a three dimensional matting material) should be placed on the banks and bed of watercourses providing traction for construction vehicles.

Temporary Erosion and Sediment Control Measures

During construction, sediment and erosion control measures must satisfy appropriate standards. Adequate drainage should ensure that all runoff over the construction zone is collected and disposed of in a suitable manner. Clean stormwater entering the site should be diverted away in an appropriate manner. Topsoil stockpiles, road cuttings, batters and benches, embankments, spoil and borrow should all require appropriate erosion and sediment control measures.

Installation of temporary drainage structures, eg drop pipes, should drain the earthworks without causing erosion.

Drop pipe drainage structures should encourage water flow to enter and discharge at the natural surface. Installing energy dissipators with all of the above drainage structures as a general technique should reduce the flow velocity and energy of the water and thus minimise the potential for scouring and erosion.

Temporary catch drains installed upslope of exposed areas should minimise the potential for erosion and scouring during the wet season and other rainfall episodes throughout the year.

Traffic Access Requirements

Temporary access tracks provide temporary low flow construction roads for road corridor development. It is desirable that these tracks follow natural land contours or areas designated for future clearing and avoid steep grades, watercourses and dense forest to minimise erosion and vegetation disturbance. Cross drainage at regular intervals should reduce erosion effects.

These tracks usually require minimal earthworks and bridging, further reducing the potential for environmental impact. On completion of works, temporary access tracks and batters should be revegetated.

Traffic Detours

Traffic detours are required for maintenance and repair of drainage structures or land slips. Construction of detours is to be confined within the existing road formation as far as possible. Off road detours should be restricted to previously degraded and cleared areas and, in World Heritage Areas, approval of the Wet Tropics Management Authority will be required.

When no longer required, rehabilitate detours immediately to minimise environmental impacts such as soil erosion.

Best Practice Guidelines:

Design should consider all aspects of construction of the road project to ensure that impacts are minimised. It is important to consider:

- staging of works;
- progressive rehabilitation;
- location of storages and spoil disposal;
- need for temporary access or side tracks;
- need for temporary water course crossings;
- traffic control;
- the ultimate construction disturbance zone;
- early installation of permanent erosion and sediment controls to avoid the use of temporary controls; and
- temporary sediment and erosion control.

E5 Design for Maintenance

Revegetation

The desired outcome is to identify revegetation requirements (including staging and interim cover crop areas) in each road design.

The revegetation of disturbed areas is a factor in the prevention of sedimentation of water courses. High silt loads in streams may endanger species for some considerable distance downstream and have impacts on ecological and aesthetic values.

It is therefore important to minimise disturbance and for those areas that have been disturbed to ensure that revegetation is undertaken quickly. This may mean that with staged construction of earthworks temporary revegetation treatment may be required as work proceeds.

Revegetation is an integral part of soil and water management. It can be either temporary and/or permanent.

Standards for temporary revegetation works fall into either one of the following four categories:

- erosion control;
- aesthetic, ie., green cover;
- short term use; and
- stability, ie., geotechnical.

Erosion Control

The key criteria is based on percentage cover. Generally 60% surface cover is necessary to significantly reduce erosion. Percentage cover can be measured in a number of ways, either physically, photogrammatically or indexed, that is estimation based on known standards from previous measured photos/quadrant sampling, or mechanically with an Ellen Bank Pasture Meter.

Aesthetics

The key criteria is also based on percentage cover or density of green matter/leaf area. Some species are better than others for this work. Of importance is the timeframe, that is how long does the work need to be green for? Many cover crop type species will achieve this for up to 12 to 14 weeks.

After this, more permanent species would be needed. Aesthetics is equally measured by simple observation.

Short Term Use

The temporary use, for example during stage construction of earthworks or temporary stockpiles, until areas can be developed.

Geotechnical Stability

E5

The vegetation type chosen needs strong root structure to assist stability, that is hedge species and some legumes which all eventually fall out of the system when a more permanent, slower growing, revegetation species becomes dominant. Success is measured by the material type maintaining its form and structure until a more permanent species becomes established. Many cover crop species fit into this category.

The standards for permanent revegetation works fall into the following three categories:

- erosion control;
- sustainability of revegetation type; and
- ecological sustainability and compatibility.

Sustainability of Vegetation Type

The key issues are choice of vegetation type that will exist in the long term due to the sites existing environmental conditions and management/ maintenance of the area (ie., impacts from fire, grazing, periods of non-disturbance, periods of physical disturbance).

In natural areas it is desirable to always plant species which are native and naturally occurring in the location and are from local provenance. The only exception to this is the planting of short term cover crops for immediate soil stabilisation and introduced grasses which are not invasive weeds.

Ecological Sustainability and Compatibility

The key criteria is vegetation cover that can co-exist with the surrounding vegetation type. Co-existing implies that species will not disperse or be overtaken by the surrounding vegetation unless that is the desired result. Vegetation type may provide habitat or some other feature that is desired, for example a wildlife corridor.

Risk Management

All construction programs rely heavily on appropriate design. The responsibility of successful implementation is therefore associated with the designer. Designers are now faced with either detailing the list of revegetation procedures necessary to achieve an end point (eg. set hydromulch rates etc.) or alternatively stating an end point performance criteria to be achieved (60% cover of particular species after 6 and 12 months).

End point performance contracts relating to rehabilitation of the environment are extremely difficult to cost due to the range of factors and climatic conditions that may alter the approach or procedures chosen. Consequently, the contractor needs to allow for these possibilities and contract reflect this. The other issue associated with performance based environmental contracts is the difficulty a client has in choosing between contractors.

Alternatively, procedural based contracts rely on the designers expertise. In many instances the procedures proposed may be appropriate during a particular period ie., dry season, but inadequate or deficient during another period. This is often realised by client and contractor, but contractual obligations and budgets prevent alterations to the procedures and therefore the environmental success may not be achieved.

There are opportunities with appropriate contractual arrangements to undertake work on a procedural basis while having the opportunity to improve the performance due to climatic fluctuations or new information being made available as the development proceeds.

Mowing is expensive and can be a hazardous operation on roads with narrow shoulders and poor sight distance. The aim should be to design a road that minimises the amount of maintenance required.

Adjacent to the road pavement low height vegetation cover is required. Traditionally grasses have been sown in these areas that have high growth rates and require constant mowing.

Best Practice Guidelines:

Salvage topsoil and respread on batters as soon as earthworks are complete (batter slopes flatter than 1 on 2).

If topsoil contains exotic weeds provide a temporary hydromulch and water. After germination of the weeds spray with herbicide. Repeat the treatment after two weeks. The topsoil is then suitable for permanent planting.

Within 4 m to 6 m of the traffic lanes plant low growing native grasses to avoid the need for future mowing.

Steep rocky exposed batters should be treated to promote moss growth by spraying with an appropriate culture (ie yoghurt).

On sealed roads avoid unsealed shoulders to avoid maintenance grading.

Drains should be of asphalt, concrete or revegetated to minimise the need for grading of drains. Leaving the shoulders and table drains as gravel or earth can lead to erosion and siltation of streams.

Revegetate verges with low growing grasses to the table drain. Beyond the table drain plant only shrubs with trunks up to 75 mm within 6 m of the edge of the traffic lane (unless barriers or topography provide protection).

Check line of sight around the inside of curves and ensure planting does not encroach into the line of sight. At intersections and curves, to ensure sight distance triangles are provided plant only low growing species.

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