APPENDIX P: LAND-BASED PIPELINE CONSTRUCTION

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It must be read in conjunction with that document.

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Appendix P

Land-based pipeline construction

This appendix provides specific guidelines on the application of best practice erosion and sediment control to the construction of land-based pipelines, and pipeline crossings of waterways, but not offshore pipelines. Its purpose is to describe the various temporary drainage, erosion and sediment control measures that are available for use during the construction of land-based pipelines, and where possible, outline the circumstances in which their use is likely to be warranted.

It is not the intent of this appendix to over-rule the ESC standards set by regulatory authorities for pipeline construction. The intent is to define, from an industry perspective, what is considered 'reasonable and practicable' with regards to temporary erosion and sediment control measures applied during the construction of pipelines.

As such, the appendix is not intended to be used as a prescriptive regulatory tool. It is acknowledged that unique site conditions often require site-specific solutions that may fall outside the generic recommendations presented within this appendix. The appendix also does not contain complete and comprehensive details on all aspects of erosion and sediment control (ESC) relating to pipeline construction; and thus cannot be used in isolation from other industry based publications.

The information presented in this appendix is intended to 'supplement' the recommendations provided within the pipeline industry's Code of Environmental Practice. This appendix specifically refers to the 2013 edition of this Code (APIA, 2013) however readers should always refer to the latest edition of this Code.

The primary focus of this appendix is on major, land-based pipeline construction projects. In general it is not applicable to the installation of minor sewer, water and stormwater pipe connections within residential areas, or the construction of offshore pipelines; however, part of the appendix can reasonably be applied to major projects associated with domestic pipeline installation. Similarly, only parts of this appendix may be applicable to the installation of cables and rural irrigation systems.

It is assumed that readers have an understanding of the principles of erosion and sediment control outlined in Chapter 2, and the contents of the Code of Environmental Practice.

As in all sections of this document, ESC techniques that are presented within the text in italics and with capitals are those techniques on which the reader can find further information within the Book 4 Fact Sheets.

P1 Introduction

In Australia, pipelines are used for a range of purposes including:

- domestic, agricultural, mining and industrial water supply
- stormwater, sewage and wastewater transportation, including recycled water
- gas transmission and petrochemical liquids transmission
- slurry transportation
- powerline, telecommunication and cable conduits.

'Strip' or 'linear' construction, which includes pipeline, road and railway construction, represents one of the most difficult site environments for achieving effective erosion and sediment control. What is considered reasonable and feasible on an open construction site (broad-acre construction) is often significantly different from what is considered reasonable and feasible in strip construction.

Independent of the varying environments, type and size of these construction projects, all pipeline construction activities are likely to experience some common erosion and sediment control issues, including:

- Construction activities are typically restricted to a narrow easement or Right of Way (RoW) where it is not possible to locate erosion and sediment control (ESC) measures outside of the RoW.
- The narrow RoW typically prevents the construction of Type 1 sediment control measures, such as *Sediment Basins*, which means that potential environmental harm is best managed through enhanced erosion and drainage control measures. Thus the key to effective hazard reduction is not to focus on sediment control, but to focus on the 'timing' of construction activities, such as land clearing and site stabilisation, with the aim of minimising the duration soils are exposed to the erosive forces of wind, rain and overland flow.
- Pipeline construction is typically a rapid form of 'strip construction'. The environmental risks associated with such works are often significantly less than slower forms of strip construction such as road construction, or static 'broadacre construction' such as urban development. The most notable exception to this rule is when several pipe and cable services are intended to be installed along a common RoW by different contractors. In such cases it can become impractical to coordinate the activities of all contractors, especially on large projects. Similar problems exist when the concept of 'common trenching' is applied to urban development.
- During the construction phase, RoWs can effectively become drainage channels collecting local rainfall and feeding it along the RoW. This problem is often amplified by the fact that the working surface of the RoW is usually lower (after the stripping of topsoil) than the adjacent land surface, making it difficult to release this water from the RoW at regular intervals, consequently increasing the quantity and velocity of surface water passing down the RoW.
- Pipeline RoWs often cover long distances and cross multiple drainage lines of varying topography, plant communities and soil types. The ESC measures applicable to one drainage catchment may not be appropriate for the adjoining catchment. Consequently, construction personnel need clear guidance on when a generic ESC treatment process is acceptable, and when a site-specific treatment process is required.
- Pipeline crossings of waterways can be a high-risk construction activity, largely dependent on the type of waterway and flow conditions at the time of construction. However, flow conditions within any given waterway will generally not be known at the time of construction tendering, or during the development of the project's generic or primary Erosion and Sediment Control Plans; thus site-specific plans will usually be required for each waterway crossing.
- Pipeline trenches are frequently excavated through problematic soils (dispersive, sodic, saline, or acidic) where soil properties can vary significantly with depth, typically becoming more problematic with increasing depth. It is usually impractical to excavate, stockpile and backfill the trench soil **without** causing some degree of soil mixing.
- Managing problematic soils on pipeline construction sites is complicated by the fact that the majority of the soil disturbance within the RoW is relatively shallow (i.e. just the temporary removal of topsoil) while the complex issues associated with deep subsoil disturbance are usually limited to the relatively narrow region of the actual pipe trench. This means that it can be difficult to assign generic industry-wide

solutions to soil management. Instead, the focus should be on site-based advice received from soil specialists contracted to individual projects.

The overall objectives of environmental protection within the pipeline industry are outlined within the pipeline industry's Code of Environmental Practice (APIA, 2013). With respect to the task of 'erosion and sediment control', the overall objectives may be defined as:

- to take all reasonable and practicable measures to minimise actual or potential environmental harm resulting from soil or water movement as a consequence of either the construction or operational phases (with regard to soil erosion and land rehabilitation) of pipeline installations
- to maintain, and where practical, enhance the land use capabilities of disturbed areas with respect to land's soil, water and vegetation attributes
- to ensure that permanent erosion control measures applied to pipeline and road crossings of waterways are compatible, to the maximum degree practical, to the geomorphological attributes of the waterway
- to ensure temporary ESC measures do not unreasonably impact upon the economic and safety-related attributes of an individual project.

This appendix aims to focus on those issues and site conditions that are unique to pipeline construction; however, there will be circumstances where designers and construction personnel will be required to refer to other chapters or appendices within this document. Table P1 outlines those circumstances where reference to other sections of this document is recommended.

Table P1 – Recommended referencing to other chapters of this IECA document

Chapter / appendix	Issues relating to erosion and sediment control
Chapter 2	• Generic guidance on the application of erosion and sediment control principles to construction sites.
Chapter 3	• Guidance on soil testing for broad-acre (i.e. non-RoW) construction works associated with pipelines, such as gas processing plants.
Chapter 4	• Guidance on ESC technique selection for broad-acre (i.e. non-RoW) construction works associated with pipelines, such as gas processing plants.
Chapter 5	• General guidance on the preparation of Erosion and Sediment Control Plans (ESCPs) for all works, and generic ESCP check list.
Chapter 6	• Guidance on the management of construction sites specifically relevant to site managers, on-site environmental officers, and regulators. • General guidance on the management of pipeline construction sites may be found in Section P3 of this appendix.
Chapter 7	• General guidance for environmental officers and regulators on conducting erosion and sediment based site inspections.
Appendix A	• Guideline on hydrology and hydraulic analysis of ESC measures.
Appendix B	• Design and construction of sediment basins.
Appendix C	• Educational material on the management of soil and vegetation.
Appendix E	• Guidance on the application of soil loss RUSLE calculations.
Appendix I	• Generic guidance on the management of instream works such as pipeline crossings of waterways. • Section P3.6 of this appendix directs the reader to Appendix I as required.
Appendix K	• Guidance on the construction of unsealed access track outside the pipeline RoW.
Book 4 Fact Sheets	• Design, installation and maintenance information on various drainage, erosion and sediment control measures.
Book 6 Standard Drawings	• Typical installation drawings and specifications for various drainage, erosion and sediment control measures.

It is not the intention of this appendix to reproduce issues or recommendations provided within the pipeline industry's Code of Environmental Practice. Table P2 outlines those site issues which are either addressed solely within the Code of Environmental Practice (APIA, 2013 edition) or are addressed collectively by the Code and this appendix.

Table P2 – Referencing to the Code of Environmental Practice (APIA, 2013)

Section	Issues relating to erosion and sediment control
5.0 Pipeline planning activities	• Appropriate integration of ESC issues (as raised within this appendix) into the planning of pipeline route selection.
6.1 Access to site	• Guidance on those issues that influence the planning of site access and the selection of appropriate access points.
6.2 Clearing	• Minimising the area of disturbance is a critical ESC objective. This section of the Code outlines those issues, in addition to ESC, that need to be considered when selecting the width of the RoW. • Guidance on selective clearing and clearing procedures adjacent to waterway crossings.
6.3 Grading	• Guidance on the stripping of topsoil. • The information provided in the Code shall be considered to 'supplement', not supersede, that presented within this appendix.
6.5 Trenching	• Guidance on the environmental management of acid sulfate soils. • Detailed guidance on the management of acid sulfate soils is neither provided in APIA (2013) or this appendix, but should be sought from local state guidelines.
6.7 Trenchless technology	• Guidance on the use of micro-tunnelling (closed-face boring), thrust boring, directional drilling, and plough-in pipe laying techniques.
6.9, Borrow pits, 6.10 Construction camps & work sites	• Guidance on issues associated with ancillary works associated with the pipeline, such as site office, lay-down areas, pipe-yards, and borrow pits.
6.11 Watercourse crossings	• Guidance on appropriate risk assessment procedures for selecting the preferred construction (pipe installation) technique. It is noted that the issues that need to be considered are beyond the scope of this appendix.
6.13 Reinstatement and Rehabilitation	• Guidance on the environmental management of site rehabilitation activities. • The information provided in the Code shall be considered to 'supplement', not supersede, that presented within this appendix.
9.1 Flora management	• Guidance on flora management during the construction and operational phases.
9.3 Biosecurity management	• Guidance on weed management with respect to imported soils.
9.6 Soil management	• Guidance on the environmental management of soils. • Guidance on the management of dispersive and slaking soils (9.6.2), acid sulfate soils (9.6.3), high shrink/swell soils (9.6.4), saline soils (9.6.5), soils in dry/desert environments (9.6.6), wetland soils (9.6.7), soils with pH extremes (9.6.8), and shallow rocky soils (9.6.9).
9.7 Drainage, erosion and sediment management	• Guidance on temporary erosion and sediment control requirements. • The information provided in the Code shall be considered to 'supplement', not supersede, that presented within this appendix.
9.8 Water management	• Guidance on the environmental management of natural water bodies and the discharge of site water.
9.11 Dust and other air emissions	• Guidance on dust control.

P2 Planning and design phase

There are numerous environmental, technical, social and economic factors that need to be considered when selecting a pipeline easement route. Readers are directed to the pipeline industry's Code of Environmental Practice (APIA, 2013) for guidance on the various factors that need to be considered, and how best to select an easement route. As in all cases throughout this appendix, reference to APIA (2013) implies that readers should refer to the latest version of this Code

The following discussion summarises those issues that relate directly to the practices of erosion and sediment control (ESC). The intent of this discussion is to 'supplement' the discussion already contained within the Code. It is of course recognised that ESC issues will rarely be the defining factor that determines the preferred pipeline route.

P2.1 Erosion and sediment control issues that may influence pipeline planning

The factors that typically influence soil erosion are discussed in Appendix M – *Erosion processes*. With respect to pipeline construction, these factors include:

- rainfall erosivity
- soil erodibility
- topography
- degree of surface cover
- layout of surface drainage (i.e. the division of 'sheet' and 'concentrated' flow)
- area and duration of soil exposure to wind, rain and surface flow.

The geological factors that should be considered when selecting the pipeline route, include:

- local topography associated with small hillsides where alternative routes are available across the hillside
- existence, depth, nature and hardness of bed rock
- existence of unstable or unfavourable land surfaces, including slopes subject to mass movement, areas of rock outcrops and areas of existing erosion
- possible waterway crossings, including alternative route options that minimises the number of waterway crossings, and/or minimise the disturbance of unstable or highly mobile reaches of a waterway.

Rainfall erosivity is normally independent of route selection. Rainfall erosivity is more likely to influence the timing of works relative to a 'wet season', the desirable extent (area) of soil exposure at any given time, and the timing and method of site rehabilitation.

Topography is only likely to influence route selection if the route options allow alternative passage over or around a hill, such as passing over a hill perpendicular to the contours, across the contours, or passing around the hill. Passing over a hill perpendicular to the contours will usually result in the pipeline ascending the steepest gradient, which increases the potential for high velocity surface flows passing down the RoW. However, this option can also reduce the potential up-slope catchment area feeding run-on water into the RoW.

Passing over a hill along an alignment that crosses the contours will usually result in lower pipeline gradients, and thus reduced surface flow velocities; however, this option will likely increase the potential up-slope catchment area feeding run-on water into the

RoW, and this option can present safety issues associated with the operation of heavy machinery on cross slopes.

Passing around a hill can significantly reduce pipeline gradients, but can increase the easement length and the up-slope catchment area feeding run-on water into the RoW.

Rock outcrops can occur when either bedrock or large fragments of dissected bedrock occur at or near the ground surface. The combination of bare rock surfaces and shallow soils can result in reduced infiltration, increased runoff rates, and an increased erosion hazard.

Common examples of existing erosion that may present a hazard to pipelines include active gully erosion, head-cut erosion migrating up drainage lines, slopes subject to mass movement (land slips) and larger areas of exposed subsoil (e.g. scalds). Head-cuts, gully erosion and landslips can not only expose a previously buried pipeline, but can also cause some pipelines to fracture.

P2.2 Waterway crossings

Constructing pipelines across waterways is expensive and is usually subject to a high environmental risk. Minimising the number of waterway crossings provides obvious financial benefits during the construction phase; however, this should not be the only consideration. Crossing waterways at suitably stable locations can **significantly** reduce ongoing maintenance expenditure.

During the planning phase, designers can seek guidance on the selection of suitably stable waterway reaches in the following ways:

- seek the advice of waterway experts, such as a river morphologist, or geologist specialising in waterways; however, it is noted that there can be numerous subtle differences between the behaviour of rivers and creeks, and while some professionals may have experience with a wide range of waterway types, others may specialise in only one type of waterway
- obtain historical aerial photographs of the waterway for the purpose of assessing the past movement history of the waterway
- obtain the advice of local authorities and/or long-term land owners.

Waterway rehabilitation is a specialist industry in terms of both the choice of armouring materials and plant selection. Selecting appropriate bank vegetation that is compatible with the waterway morphology, the required fauna passage, and the requirements for maintenance access to the pipeline, is a specialist task that often requires reference to state codes and guidelines.

Planners and designers need to be aware of the fact that there are many different types of waterways, from creeks to rivers, saline to freshwater, fixed-bed to alluvial. The same rules do not apply to all waterways. Therefore, it is important to ensure that the planners and designers of pipelines receive appropriate advice from waterway experts that have experience in the types of waterways being crossed by the pipeline.

If the proponents of a pipeline project are concerned about a possible environmentally, politically, or socially sensitive waterway crossing, then consideration should be given to highlighting these issues within the tender process, and/or issuing the waterway crossing as a separate contract or cost item.

P2.3 Soil hazards and soil testing

If soil properties are expected to vary significantly along a pipeline corridor, then the construction project will either need to employ a resident soil scientist, or have ready access to the consulting services of a soil scientist. In such cases, any advice or recommendations presented in the following text should be considered subservient to the advice of the resident soil scientist.

It is noted that engineering-based geotechnical advice is usually required in addition to, and **not** in replacement of, soil science. Geotechnical advice is often critical in determining the trenching method (e.g. degree of benching) and the post-works stabilisation of steep slopes.

Readers that wish to expand their knowledge of soil issues are encouraged to review Appendix C – *Soils and revegetation*, which is an educational appendix provided for the benefit of non soil scientists.

The soil properties that are most likely to present hazards to pipeline construction are:

- soil acidity
- potential acid sulfate soils
- hydrophobic soils
- expansive and reactive soils
- hardsetting soils
- sodic soils
- non-cohesive soils
- low water-holding capacity
- soils of low fertility
- saline soils

Of most concern to pipeline projects is the management of dispersive and slaking soils. Considerations in determining clay dispersion hazard are outlined in Table P3.

Table P3 – Clay dispersion hazard [1]

Dispersion hazard rating	Emerson class number	ESP	Ca:Mg ratio	ESI [2]	Typical clay content	Cation:clay ratio
Low	4–8	< 6%	> 0.5	> 0.1	< 10%	< 0.2
Moderate	3	6 to 15%	0.5	< 0.05	10–30%	> 0.2
High	1–2	> 15%	< 0.5	< 0.05	> 30%	> 0.2

Notes:

[1] Each of these parameters are an ‘indicator’ of dispersion potential. The preferred indicator is the exchangeable sodium percentage (ESP). A common indicator used in civil construction is the Emerson class; however, it is not considered as reliable as ESP.

[2] Electrochemical Stability Index (ESI) = (EC1:5 in dS/m)/ESP.

General guidance on soil testing is provided in Appendix C – *Soils and revegetation*. It is strongly recommended that the services of a soil expert and the resident land operator are consulted in regards to soil testing and amelioration in any circumstance where pipeline construction crosses active agricultural land.

Soil sampling and testing is recommended to determine those soil characteristics that might influence revegetation outcomes (e.g. soil fertility, pH, depth, structure, particle size distribution) and asset stability/safety (e.g. soil dispersion, bulk density).

Wherever possible, soil sampling and testing should be conducted by a suitably qualified person (e.g. a CPSS or CPESC). If this occurs, the frequency of sampling can be determined by the suitably qualified person, based on the likely distribution and variation of 'soil landscapes' (i.e. areas containing a relatively consistent suite of soils) along the right-of-way. These 'soil landscapes' can be determined based on existing soil mapping, land topography, geology changes, vegetation changes or landscape position.

By determining 'soil landscapes', the number of soil samples and tests undertaken can be reduced because only representative or typical soil samples need to be sampled and tested from each 'soil landscape' along the right-of-way. In addition to sampling and testing these representative or typical soil profiles, additional soil observations should be made at other locations within each 'soil landscape' to confirm the sampled soils are indeed representative of that 'soil landscape'.

If the above method of sampling only representative samples from 'soil landscapes' is not used, soil sampling is recommended at minimum intervals along the right-of-way equivalent to $3 \times \sqrt{d}$, where d is the length (in km) of the proposed right-of-way. For example, on a 64 km long right-of-way, a minimum of 24 samples should be collected and tested ($3 \times \sqrt{64} = 24$).

Chapter 3 – *Site planning*, provides guidance on the density of soil sampling in broad-acre (i.e. non-RoW) construction areas, such as the larger ancillary works often associated with pipeline projects.

P2.4 Erosion hazard and risk assessment

Regulatory standards as they relate to the assessment of environmental impact of pipeline projects are highly variable across Australia. In the absence of state-specific requirements, APIA (2013) provides guidance on the type of documents that need to be prepared, plus broad guidance on the issues that should be addressed.

Data collection and interpretation is the key to understanding the erosion hazards and designing appropriate management systems for these hazards. The extent of data collected about soils, vegetation, hydrology and river morphology (if waterway crossings are involved) must be commensurate with the potential environmental risk, and the extent and complexity of the proposed soil disturbance.

Project characteristics and constraints that should be investigated and evaluated during project planning include:

- existing and likely areas of soil disturbance
- existing vegetation and land use
- land slopes and contours
- location of drainage lines, waterways, creeks and rivers
- soil constraints, such as erodibility, dispersibility, sodicity, salinity, texture, pH, depth, fertility, areas susceptible to tunnel erosion, expansive or reactive soils, potential acid sulfate and contaminated soils
- landscape constraints, such as mass movement, flood hazard, water logging, high watertable and rock outcrops
- the expected variation in rainfall erosivity across the construction period, or throughout the full year if the construction period is unknown.

Chapter 3 – *Site planning* provides guidance on data collection and the possible impacts of a range of site constraints, as well as introducing the concept of erosion hazard assessment.

Erosion hazard assessment is a procedure for undertaking a 'preliminary' assessment of the erosion hazards associated with a construction project. For pipelines, this assessment is typically carried out on a corridor segment (hilltop to hilltop) but may also be performed on individual sub-catchments (refer to discussion in Section P2.5).

Erosion Risk Mapping may be derived from a combination of the various parameters presented in Table P4 depending on available information.

Table P4 – Erosion risk parameters and suggested ratings [1]

Site conditions during soil disturbance	Erosion risk rating [2]				
	Very low	**Low**	**Moderate**	**High**	**Extreme**
Average gradient of disturbed area (%)	≤ 3	> 3 & ≤ 5	> 5 & ≤ 10	> 10 & ≤ 15	> 15
Clay dispersion hazard [3]	Low	Low	Moderate	Moderate	High
Average monthly erosivity (RUSLE R-factor) [4]	0–60	61–100	101–285	286–1500	> 1500
Average monthly rainfall depth (mm) [4]	0–30	31–45	46–100	101–225	> 225

Notes:

[1] This table is derived from tables 4.4.1, 4.4.2, F4 and P3 (refer to Chapter 4 and Appendix F).

[2] The erosion risk rating for any given corridor segment or sub-catchment is taken as the highest rating of: the land slope rating, clay dispersion hazard, and either the average monthly R-factor or average monthly rainfall classification.

[3] Clay dispersion hazard is determined from Table P3, and is based on the properties of dominant subsoil exposed across the RoW (not the subsoils exposed within the pipe trench).

[4] Both the 'average monthly erosivity' and the 'average monthly rainfall depth' (which ever is adopted) should be determined as an average of the months during which soil disturbance is occurring, or scheduled to occur, whenever this time period is known; otherwise the annual average value shall be adopted.

At the discretion of the asset owner or regulatory authority, the erosion hazard can be used to provide guidance on:

- assessing the attributes of alternative pipeline routes (along with other factors)
- the spacing of trench breakers (more likely linked to just the dispersion hazard)
- the need for special treatment of trench backfill
- when it is necessary to engage specialists in the fields of soil, vegetation, hydrology, or erosion and sediment control
- areas where soil disturbances should be avoided during certain periods of the year
- the required erosion and sediment control design standards and techniques to be adopted in regions of a given erosion risk and/or specific periods of the year.

Each erosion hazard should be assessed individually to determine appropriate management strategies and techniques to address the specific erosion risk. There are no specific outcomes that apply to all sites and all circumstances. The adopted solutions must consider the parameters that contribute to the erosion risk, potential environmental impacts, the mechanics of the erosion, the availability of suitable materials, required performance outcomes, lifespan and cost.

The erodibility of soil is typically influenced by particle size distribution, organic matter content, clay type and the percentage of sodium or magnesium ions in relation to the other soil cations. Expansive/reactive soils, hardsetting soils, sodic soils and non-cohesive soils all potentially have high erosion risk when disturbed. Although it can be technically possible to ameliorate such soils to reduce their erosion potential, the cost and practicality of doing so along a pipeline RoW is unlikely to be feasible.

Details on the application of erosion hazard assessment to broad-acre (i.e. non-RoW) construction sites (i.e. large scale disturbances associated with ancillary works) are provided in Appendix F – *Erosion hazard assessment*.

P2.5 Drainage catchment and sub-catchment boundaries

Large-scale pipeline corridors can cross several drainage catchments, each of which can be divided into several sub-catchments by temporary drainage control measures. To avoid confusion, it is important for the pipeline industry to have a clear definition of these two terms, 'catchment' and 'sub-catchment'.

Traditionally, the term 'catchment' referred to any land that contributed surface runoff to a specific waterway or receiving water. As such, it could be claimed that any pipeline being constructed in the south-western region of NSW would exist within the single drainage catchment of the Darling River. Clearly, such a broad definition would have little meaning within erosion risk mapping. Consequently, for the purposes of erosion risk mapping, the following definitions have been adopted.

Catchment: That part of a drainage catchment, including the land up-slope of a pipeline corridor, that would naturally drain to a single waterway or drainage line passing through the pipeline corridor. The expression 'naturally drain' means the natural topographic drainage of a catchment excluding the effects of permanent or temporary drainage diversions such as roads and flow diversion banks. Typically the 'catchment' includes the full surface area of the pipeline corridor from ridge-top to ridge-top.

It is noted than in parts of this document, the term 'catchment' may be used in a generic sense to simply imply the drainage catchment contributing flow to a given structure.

Corridor segment: That part of an individual 'catchment' that is contained within the pipeline corridor or Right-of-Way. In effect, this is the full surface area of the pipeline corridor from ridge-top to ridge-top. Typically this means that a 'segment' would include only one waterway or drainage line crossing; however, some drainage lines may be considered too minor to be considered as an individual catchment. Professional judgement is therefore required to select meaningful corridor segments.

Sub-catchment: Any sub-section of a drainage catchment, whether temporary or permanent, that drains to an individual drainage control measure, sediment trap, or flow release point from the pipeline corridor. A 'sub-catchment' is typically the drainage area considered when designing an individual flow diversion system or sediment trap.

Figure P1 demonstrates the three drainage terms diagrammatically.

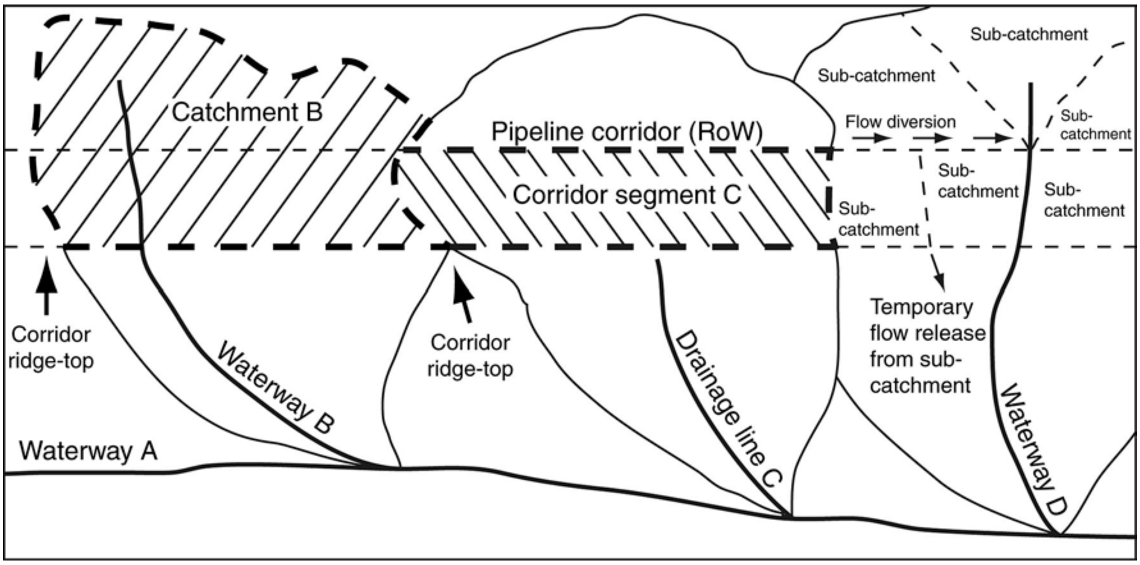

Figure P1 – Definition of a catchment, corridor segment and sub-catchment

P2.6 Erosion and Sediment Control Plans

The minimum standard of documentation that should be prepared for pipeline construction is Erosion and Sediment Control Plans (ESCPs). Due to the unique, often fast moving nature of pipeline construction, a two-tier ESCP process is **recommended** (but not mandatory). The first ESCP is termed the ‘Primary ESCP’. The Primary ESCP is an overarching ESCP that demonstrates general drainage, erosion and sediment control practices for the whole construction project. Typically these plans would be produced during the planning and design phase.

In some cases these plans will need to document actual site conditions along the full length of the pipeline. In other cases, such as irrigation and cable installation, these plans may only need to provide generic solutions that can be applied to a wide range of topographic conditions. The extent and complexity of these plans needs to be commensurate with the potential environmental risk, the project scale, and the extent and complexity of the proposed soil disturbance.

The second level of ESCPs is termed the ‘Progressive ESCP’. Progressive ESCPs are developed as the project progresses, as site conditions evolve, and as flow paths change. These plans provide up-to-date details on the location and installation of the required control measures, and are usually prepared at the expense of the contractor.

The two-tier ESCP approach has been proven to work well on linear construction projects such as roads, rail and pipelines. It reduces unnecessary repetition of information as projects progress, and allows timely updating of ESCPs to reflect actual site conditions and to demonstrate ongoing compliance.

Progressive ESCPs should be presented as a series of drawings and associated tables and report outlining temporary drainage, erosion and sediment control procedures to address a given sub-catchment, corridor segment, or high-risk area (e.g. waterway crossings). In most cases, individual plans will be needed for each waterway crossing, but not necessarily for each drainage line crossing.

Table P5 outlines the recommended production of Primary and Progressive Erosion and Sediment Control Plans. Table P5 also outlines those conditions when generic (non site-specific) plans are considered a suitable replacement for Primary ESCPs.

Table P5 – Recommended development of ESCPs for pipeline construction

Activity or installation type	Primary ESCPs	Progressive ESCPs
Timing of plan development	Prior to site establishment	Prior to soil disturbance at the specified location or within a specific corridor segment
All cases	All ESCPs provide guidance on variations in ESC measures required for different seasonal weather conditions	Revised ESCP in the event that the Primary ESCP no longer addresses actual site conditions (e.g. variable soil conditions, or construction site layout)
Width of soil disturbance along the RoW is less than 6 metres	Generic ESCPs [1] showing typical ESC layouts (content as discussed below)	Individual plans required for corridor segments or sub-catchments with a high or extreme erosion risk rating [2] and all waterway crossings [3]
Width of soil disturbance along the RoW is greater than 6 metres but less than 20 metres	Generic ESCPs showing typical ESC layouts (content as discussed below)	Individual plans required for corridor segments or sub-catchments with a moderate or higher erosion risk rating [2] and all waterway crossings [3] Progressive ESCPs may be required at some road crossing, depending on the degree of complexity
Width of soil disturbance along the RoW is greater than 20 metres	Large-scale, site-specific ESCPs (content as discussed below)	Individual plans required for corridor segments or sub-catchments with a moderate or higher erosion risk rating [2] and all road, drainage line and waterway crossings [3]

Notes:

[1] A 'generic' Primary ESCP is a plan that is not specific to any given project or location.

[2] Erosion risk rating as derived from Table P4.

[3] Refers to waterways that have a reasonable possibility of carrying surface flow during the period from initial soil disturbance below top-of-bank to a time when a stable surface has been achieved on the channel banks. Does not refer to drainage lines or overland flow paths. If multiple waterway crossings exists of a similar nature (i.e. not a mixture of clay, sand, gravel and rock-based waterways), then these individual plans can be linked back to a single generic plan. Also, refer to the discussion below on the development of Progressive ESCPs for drainage line and waterway crossings.

A key difference between Primary and Progressive ESCPs is that the time of year, and thus the likely flow conditions within drainage lines and waterways, should be known during development of the Progressive ESCP. This allows ESC issues at drainage line and waterway crossings to be more appropriately addressed for the expected flow conditions.

Table P5 (above) recommends that Progressive ESCPs should be developed for all individual drainage line and waterway crossings if the RoW width exceeds 20 metres. The 'intent' here is to ensure that the detail of information provided within the ESCP is appropriate for the local topography and expected flow conditions. Given this 'intent', if on a particular pipeline project, the site conditions (including local topography and likely flow conditions) are similar for a number of drainage line or waterway crossings, then the Progressive ESCPs may revert back to a generic form for each crossing type so long as the 'intent' is always satisfied.

Recommended contents of a ‘generic’ **Primary ESCP** are:

- document control information
- generic ESC layout for: trench spoil stockpiled up-slope of trench, trench spoil stockpiled down-slope of trench, drainage line crossings, site entry and exit points, and vehicle crossings of drainage lines and waterways
- standard drawings of all ESC measures likely to be used
- materials, operation, maintenance and removal procedures of the of the ESC measures, including procedures for site stabilisation and revegetation.

Recommended contents of a ‘site-specific’ **Primary ESCP** are:

- document control information
- project description outlining the nature and scale of the works
- location of primary receiving waters, soil sampling and site entry/exit points
- location of non disturbance areas, areas of restricted clearing, and protected vegetation
- primary sub-catchment boundaries and erosion risk mapping
- management strategies for:
  - minimising the extent and duration of soil disturbance
  - controlling water movement through disturbed areas
  - minimising risk of ongoing tunnel erosion within the backfilled pipe trench
  - ESC procedures adopted for wet weather and temporary site shut down
  - proposed staging of site rehabilitation relative to anticipated weather conditions and time of year
  - site monitoring and inspecting procedures
  - procedures for revising ESCPs and the production of Progressive ESCPs
- standard drawings of all ESC measures likely to be used
- materials, operation, maintenance and removal procedures of the of the ESC measures, including procedures for site stabilisation and revegetation
- calculations and work sheets.

Recommended contents of a **Progressive ESCP** are:

- pre and post disturbance/shaping contours
- description of specific works covered by the plan
- clean and dirty water drainage paths
- local soil, water and landscape issues (if not included in Primary ESCP)
- location of sensitive features and non disturbance areas
- limits of disturbance
- erosion Risk assessment (if sub-divisions exist within plan’s coverage area)
- installation sequence for ESC measures
- location and identification coding/numbering of control measures
- directions for controlling water movement along and across the RoW
- location of local monitoring sites (if specific location have been identified)
- specific installation details, notes and calculations for ESC measures
- specific operating procedures
- relevant standard drawings (if not already included within the Primary ESCP).

Erosion and Sediment Control Plans should be prepared and certified by a suitably experienced and qualified erosion and sediment control professional. Some states and territories in Australia nominate the minimum training requirements for those certifying ESCPs.

It is also important to note that some states (e.g. Queensland) and some organisations, require hydraulic or hydrologic calculations and designs associated with engineering structures (such as sediment basin spillways) to be reviewed and certified by an appropriately qualified/certified engineer.

However, it is not the intent of this appendix to imply that **all** persons involved in the development of ESCPs should be trained in the field of erosion and sediment control. The key to the development of appropriate ESCPs is to engage a team of people with varying expertise (soil, water, vegetation, construction, ecology and waterway experts) that are guided by a suitably experienced and qualified ESC professional, who ultimately signs off on the plan.

It is difficult to clearly define the 'measure' of a suitably experienced and qualified ESC professional, because it varies with the complexity and erosion risk of the project. In the absence of local requirements, Table P6 provides a **guide** to the level of training likely to be required to sign off on an ESCP for different project conditions.

Table P6 – Recommended minimum training of a 'suitably qualified and experienced ESC professional'

<table>
<tr><th>Project type</th><th>Erosion risk [1]</th><th>Primary ESCPs</th><th>Progressive ESCPs</th></tr>
<tr><td rowspan="2">Width of soil disturbance along the RoW is less than 6 m</td><td>Very low to high</td><td colspan="2">Introductory (1-day) ESC training</td></tr>
<tr><td>Extreme</td><td colspan="2">Advanced (2-day) ESC training</td></tr>
<tr><td rowspan="2">Width of soil disturbance along the RoW is greater than 6 metres but less than 20 metres</td><td>Very low to moderate</td><td>Introductory (1-day) ESC training</td><td>Advanced (2-day) ESC training</td></tr>
<tr><td>High to extreme</td><td>Advanced (2-day) ESC training</td><td>Comprehensive (4-day) ESC training</td></tr>
<tr><td rowspan="3">Width of soil disturbance along the RoW is greater than 20 metres</td><td>Very low to moderate</td><td colspan="2">Advanced (2-day) ESC training</td></tr>
<tr><td>High</td><td colspan="2">Comprehensive (4-day) ESC training</td></tr>
<tr><td>Extreme</td><td>Comprehensive (4-day) ESC training</td><td>Certified Professional in Erosion and Sediment Control (CPESC)</td></tr>
</table>

Note:

[1] Erosion risk rating as derived from Table P4.

P2.7 Developing project-specific targets and responses

Numerous aspects of pipeline construction can be site, regional or project-specific. As such, many of these issues either, cannot reasonable be addressed in detail within this national guideline, or if address, could benefit from further refinement based on regional considerations. The following discussion outlines some of the ESC-related issues that are possibly best addressed on a regional or project basis.

Planners and designers of major pipeline projects are encouraged to expand upon the generic recommendations presented within this appendix, and develop appropriate regional or project-based targets and/or responses to local soil and erosion issues. However, all regional or project-based targets should at least achieve the environmental protection established by the generic responses, unless appropriately justified to the satisfaction of the regulating authority. Typical examples of issues that can benefit from a regional adjustment are provided below.

(i) Erosion risk rating

The default 'erosion risk rating' is provided in Table P4. This table may be refined to a project level based on the following:

- Refinement of the land slope divisions based on the range of land slopes expected on a given project. Noting also, that in some regions of Australia, such as arid areas, only very minor changes in land slope can cause significant increases in the erosion risk.
- Refinement of the range of monthly rainfall depths.

(ii) Development of Erosion and Sediment Control Plans

Table P5 provides recommendations on the development of Primary ESCPs and Progressive ESCPs. This table may be refined to a project level based on the following:

- The definitions of, and environmental risks associated with, drainage lines and waterways can vary significantly across Australia. Where appropriate, this table may be refined to ensure Progressive ESCPs are only developed where the environmental risks warrant such refinement.
- The need for Progressive ESCPs also depends on the degree of refinement of any generic ESCPs developed for the project. The more effort that is applied to the development of the generic ESCPs such that they address a range of common site issues or conditions, then the less reliance need be placed on Progressive ESCPs.

(iii) Temporary stabilisation of topsoil windrows and flow diversion banks

The need for the temporary stabilisation of topsoil windows and other flow diversion banks is a complex issue. Unlike subsoils, topsoils can be highly resistant to erosion by raindrop impact, and what erosion does occur is unlikely to cause environmental harm. Of course, exceptions do exist, and if the land that has a long history of pastoral activity, then the stripped topsoil may be heavily degraded from its original condition.

Recommendations for the temporary stabilisation of topsoil windows and other flow diversion banks can be refined to a project level based on the following site variables:

- The erosion potential of the topsoil.
- The risk of the eroded soil causing adverse impacts on down-slope environments.
- The expected velocity of concentrated flows passing along the up-slope face of the windrow.
- The expected working life of the window prior to site rehabilitation.

(iv) Construction details for trafficable cross banks (berms)

The typical profile of trafficable drainage berms is provided in Section P3.3.1. The specification for these drainage berms can be refined to a project level based on the following site variables:

- The risk of exposure of highly dispersive subsoils.
- The existence of soils on the RoW that are highly unstable when wet, thus requiring the inclusion of rock or geotextiles to improve the berm's wet weather trafficability.
- The speed of vehicles travelling along the RoW.

(v) Temporary soil stabilisation (erosion control) of RoW at drainage line crossings

The temporary stabilisation of soils exposed at drainage line crossings is discussed in sections P3.3.2, P3.5 & P6.8, and tables P23, P32 & P33. Given the high variability of drainage lines conditions across the country, and the number of drainage lines that a single project can cross, the treatment of drainage line crossings may need to be refined for a specific project or region. Ideally, a simple technique/treatment selection table could be produced that would typically be based on:

- The likelihood of flows within the drainage line—possibly related to the time of year of the construction, and the expected duration of the exposure.
- The catchment area—it is noted that catchment area influences the possible discharge, and that subdivision of catchment areas into various categories can vary significantly across different climatic regions.
- The gradient of the drainage line—which influences the likely flow velocity.
- The duration of exposure—this may or may not have been considered in regards to the likelihood of flow occurring.
- The staging of works—it is noted that if a project has a long lead time between land clearing and the opening of the pipe trench across a drainage line, then a temporary soil treatment may be required at this early stage, followed by a secondary treatment after pipe installation and equipment disturbance of the crossing has largely been completed.
- The occurrence of unexpected site shut-downs.

An example of a 'regional' treatment of drainage line crossings is provided in Table P7 for demonstration purposes only. This example is provided for the Western Downs region of Queensland, and would not be appropriate in other regions.

Table P7 – Example of the treatment of drainage line crossing in the Western Downs region of Queensland

Catchment area	Pre open trench	Post pipe installation [1]
Less than 5 hectares with gradient less than 4%	*Soil binder* [2]	*Jute blanket* or *Jute mesh* securely pinned over seeded loose mulch
Less than 5 hectares with gradient more than 4%	Filter cloth [3]	*Bonded Fibre Matrix* or *Flexible growth media* with a suitable velocity-control *Check Dam* placed along the down-slope edge of the RoW to control flow velocities
5 to 25 hectares	Filter cloth [3]	*Jute mesh* over *Bonded Fibre Matrix* or *Flexible growth media*
Greater than 25 hectares	Filter cloth [3]	Filter cloth prior to placement of site revegetation measures *Jute or coir mesh* over *Bonded Fibre Matrix* or *Flexible growth media* as part of site revegetation measures

Notes:

[1] Treatment may be altered by the nominated revegetation measures.

[2] Appropriate only if rainfall is possible during this period, and the exposure period prior to pipe installation exceeds two weeks.

[3] Placement of filter cloth depends on the expected duration of exposure prior to active pipe installation activities (i.e. works that are likely to heavily disturb the soil in the region of the drainage line).

(vi) Temporary soil stabilisation (erosion control) of RoW at waterway crossings

The temporary stabilisation of soils exposed at waterway crossings is discussed in sections P3.3.2, P3.6, P3.9 & P6.9, and tables P23, P27, P28 & P33. Given the high variability of waterways across the country, the treatment of waterway crossings may need to be refined for a specific waterway, region or project. If the waterway conditions are highly variable, then it may be necessary to treat each waterway on a case-by-case basis. If waterway conditions are not highly variable throughout the project, then it may be possible to develop a simple treatment selection table similar to that discussed above for drainage line crossing.

(vii) Stabilisation of vehicle crossings of drainage lines and waterways

The stabilisation of vehicle crossing of drainage lines and waterway is discussed in sections P3.5, P3.6 & P5.1, and Table P24. Given the high variability of drainage lines and waterways across the country, the treatment of these vehicle crossings may need to be refined to a regional or project level based on the following site variables:

- The type of drainage line or waterway (e.g. clay-based, sand or gravel-based, rock-based, ephemeral, continuous flow).
- The type of soils over which vehicles will travel.
- The likelihood of stream flows—possibly related to the time of year.
- The catchment area— it is noted that catchment area influences the possible discharge, and that subdivision of catchment areas into various categories can vary significantly across different climatic regions.
- The duration of exposure and/or degree of vehicle traffic.

(viii) Sediment control standard

The suggested sediment control standard is discussed in sections P3.3.3, P3.3.4 & P3.6, and Table P24. On large pipeline projects it would be appropriate for a regional or project-specific version of Table P24 to be developed. Such a revised table would need to take into account the allowable flexibility in the RoW width, and the type of equipment used in the project to excavate and backfill the pipe trench.

(ix) Site rehabilitation

Site rehabilitation issues are discussed in sections P3.8, P3.9 & P6.6. Given the high variability of climatic conditions across the country, and the variability from season to season, it is appropriate for site-specific soil conditioning and site rehabilitation procedures to be established, including the fine-tuning of tables P16 and P17.

P3 Construction and stabilisation phase

P3.1 Introduction

Pipeline construction is a unique form of civil construction practice that warrants its own approach to erosion and sediment control (ESC) practices. General ESC practices, as outlined in other chapters of this publication, may not be not considered 'fair and reasonable' or even 'practicable' in pipeline construction due to:

- the relatively short duration of soil disturbance
- the narrow width of allowable soil disturbance (as defined by the RoW).

Due to the relatively narrow width of the pipeline RoW, the adopted ESC practices are usually required to interact closely with other construction practices within the RoW. This means that the selection and layout of ESC measures cannot be done in isolation from the many other construction issues that exist within the RoW. Specifically, the adopted ESC practices must be sited in a manner that does not unnecessarily interfere with other construction activities, including material and pipe deliveries.

All erosion and sediment control measures have design and durability limitations, for example, ESC measure can fail due to the occurrence of excessive rainfall; however, it is not acceptable for such failures to occur due to:

- failure to install the measures correctly
- failure to install all the specified ESC measures
- failure to use appropriate ESC measures for the site, soil and weather conditions
- failure to regularly inspect, monitor and maintain ESC measures in proper working order
- failure to report to those in authority any information about an ESC measure that would identify the measure as being either inappropriate or otherwise not fit-for-purpose.

P3.2 Right of ways (RoW)

RoWs generally range in width from 6 to 40 m, and can extend for hundreds of metres to hundreds of kilometres. APIA (2013) provides guidance on the factors to be considered when determining the required corridor width. Flexibility in RoW width is desirable or necessary at critical locations (e.g. creek crossings); however changes to the ROW width must comply with environmental constraints and approval conditions. Variations in the RoW width may be desirable to allow for the construction of appropriate sediment traps that:

- may not fit within the normal RoW width, or
- to allow the formation of a sediment trap that best allows the formation of a continuous or near-continuous topsoil or trench spoil windrow.

It is inevitable that the pipeline construction will intercept overland flows (run-on water) from up-slope catchments. In most cases this run-on water will consist of shallow, low-velocity sheet flow that, in its undisturbed condition, has a low erosive potential. However, while passing through the RoW these overland flows can quickly convert to highly-erosive concentrated flows if not appropriately managed.

Erosion and sediment control strategies for RoWs should therefore aim to maintain sheet flow conditions for as long as possible, restore sheet flow conditions once the flows pass through the construction site, and aim to re-establish the original sheet flow conditions as quickly as possible upon completion of the construction activities.

Recommended ESC strategies within the RoW include:

- minimise forward clearing
- maximise the retention of soil surface cover, especially where dispersive soils are present (this can be achieved, for example, by optimising the width of the RoW in areas of dispersive soils, and modifying construction practices to further reduce the duration that such soils are exposed during those times when rainfall is likely)
- control water movement through the RoW
- divert clean run-on water away from soil disturbances (if practical), or ensure this water passes through the RoW in a controlled manner (water should only be diverted if it can be achieved without causing environmental harm or nuisance, including public safety and flood risk)
- identify and preserve site materials for use in erosion control
- strip topsoil in two layers where possible to preserve the seed bank (not always practical or necessary depending on the depth of topsoil)
- stockpile topsoils and subsoils (trench spoil) separately
- ameliorate problematic topsoils during the stripping process (this is best achieved by applying the ameliorants to the soil surface before stripping)
- ameliorate problematic trench soil during the excavation process (if possible), otherwise ameliorants can be placed onto the trench spoil and mixed in with the padding machine during backfill
- aim to place subsoil layers back in the trench in the same order as excavated where dispersive and/or saline soils are present (this action is not always practical, or even possible in cases where the RoW is narrow)
- suitably compact, and where necessary, gypsum treat trench spoil to minimise the risk of tunnel erosion (asset owners and contractors should ensure that the management of dispersive soils is outlined and costed within construction contracts)
- early installation of control measures and site preparation for wet weather and holiday shutdown periods
- inspect and maintain control measures in proper working order
- progressively rehabilitate the RoW to minimise the extent and duration of soil disturbance.

Figures P2 and P3 show typical layouts of a pipeline RoW with the access track either up-slope or down-slope of the pipe trench.

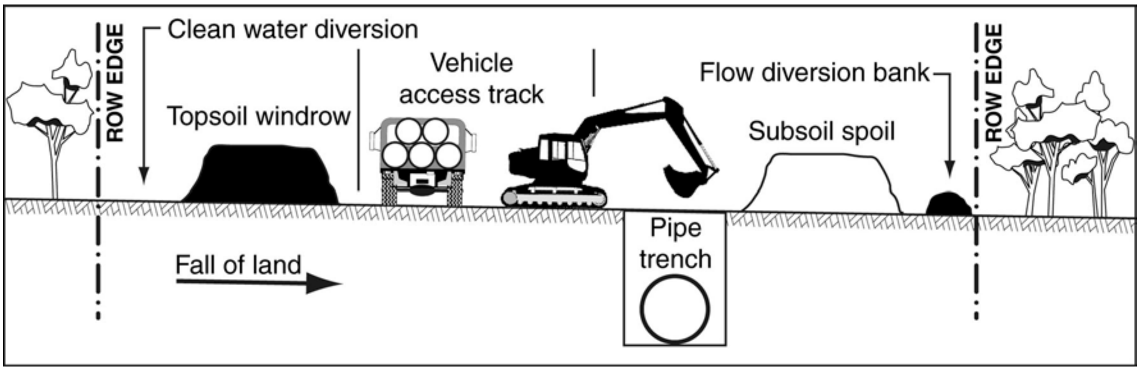

Figure P2 – Typical RoW with trench down-slope of the vehicle access track

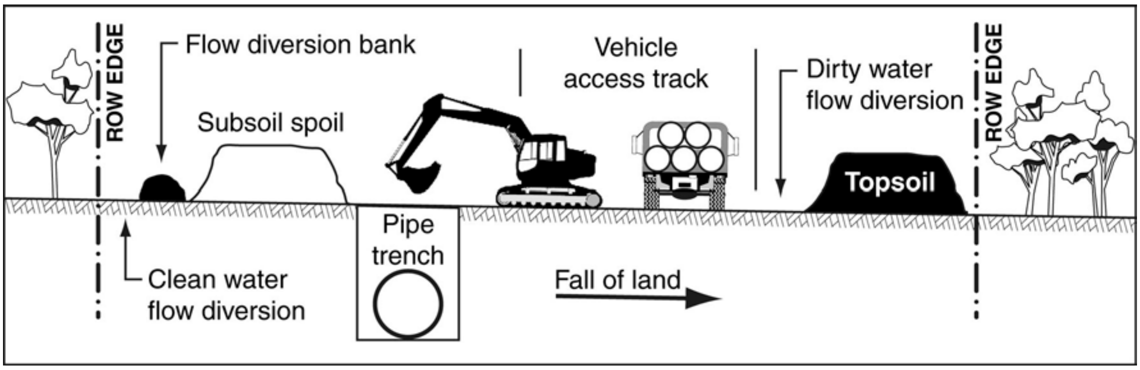

Figure P3 – Typical RoW with trench up-slope of the vehicle access track

P3.3 Erosion and sediment control practices

In most cases, erosion and sediment control practices within pipeline construction can be reduced to the tasks outlined in Table P8.

Table P8 – Typical ESC practices within pipeline construction

Category	Key tasks
Drainage control	• Diversion of 'clean' up-slope run-on water either around or through the construction site. • Collection of 'dirty' runoff generated within the RoW and the delivery of this water to an appropriate sediment trap. • Minimising the risk of soil erosion caused by site-generated flows passing along the RoW through the use of 'intermediate' flow treatment and release points. • Control of the flow velocity of water passing through the RoW at drainage line and waterway crossings.
Erosion control	• Appropriate management of work programming and the scheduling of forward works with the aim of minimising the erosion risk. • Control soil erosion at drainage line and waterway crossings caused by run-on water passing through (across) the RoW (this task is closely linked to the 'drainage control' task listed above). • Control of soil erosion at vehicle crossings of drainage line and waterway crossings • Minimising the extent of vegetation and soil disturbance at drainage line and waterway crossings. • Erosion control practices during site rehabilitation.
Sediment control	• Treatment of 'dirty' water runoff generated within the RoW. • Sediment control at vehicle exit points from the pipeline RoW. • Integration of sediment control attributes into the drainage/erosion control practices installed at drainage line and waterway crossings.

In many instances, the drainage and erosion control practices utilised on a particular pipeline project will be strongly influenced by the choice of sediment control practices. For this season, the ESCP designer will first be required to answer the following questions:

- What sediment control layout is warranted at a given location?
- Are flow releases and/or sediment controls required at intermediate locations (i.e. at locations other than roadway, drainage line and waterway crossings?

- What sediment control layout is required at intermediate locations (i.e. at locations other than roadway, drainage line and waterway crossings?

P3.3.1 Drainage control practices

In order to perform the drainage control tasks listed in Table P8 it is necessary for the ESC designer to perform the following actions:

- assess if the up-slope topsoil windrow has sufficient hydraulic capacity (i.e. height) and scour-resistance to divert the expected quantity of run-on water
- determine if it will be necessary for the up-slope run-on water to be diverted across (through) the RoW at intermediate locations between a given ridge-top and drainage line crossing
- nominate appropriate locations for the installation of flow control berms along the RoW (typically associated with intermediate flow release points, and drainage lines and waterway crossings)
- determine the best way to release both ‘clean’ and treated water from the RoW (i.e. as ‘sheet’ flow or ‘concentrated’ flow)
- assess the risk of soil erosion at drainage line and waterway crossings, and determine the need for, and suitability of, placing a velocity control device, such as a temporary *Check Dam*, along the downstream edge of the RoW (refer to Figure P14), or the use of *Erosion Control Mats* (Figure P9).

Unfortunately there is no simple way to determine the answer to the first task. A response is either achieved through the hydrologic analysis of the up-slope drainage catchment (i.e using Appendix A of this document), or is assessed based on local experience.

‘Drainage control option D1’ involves diverting all up-slope run-on water to the adjacent drainage line and waterway crossing without the use of intermediate release points. Site conditions where drainage control option D1 may be considered appropriate include:

- the up-slope catchment area is small and only minor quantities of run-on water are expected during the construction period
- the length of the pipeline segment from ridge-top to drainage line is short
- the countryside down-slope of the pipeline corridor is highly susceptible to gully erosion resulting from the un-natural concentration of surface flows (meaning that intermediate flow releases from the pipeline corridor are considered undesirable).

‘Drainage control option D2’ (Figure P4) involves diverting up-slope run-on water through the RoW at intermediate locations between the adjacent ridgeline and the drainage line or waterway crossing. This drainage option is usually linked to the ‘sediment control option’ of capturing and treatment of site runoff at intermediate locations (as per Section P3.3.4).

Site conditions where drainage control option D2 may be considered appropriate include:

- the up-slope catchment area is relatively large and/or the quantity of run-on water during the construction period is expected to exceed the hydraulic capacity of the up-slope flow diversion system
- the length of the pipeline segment from ridge-top to drainage line is significant

- the countryside down-slope of the pipeline corridor is **not** susceptible to gully erosion resulting from the release of these surface flows.

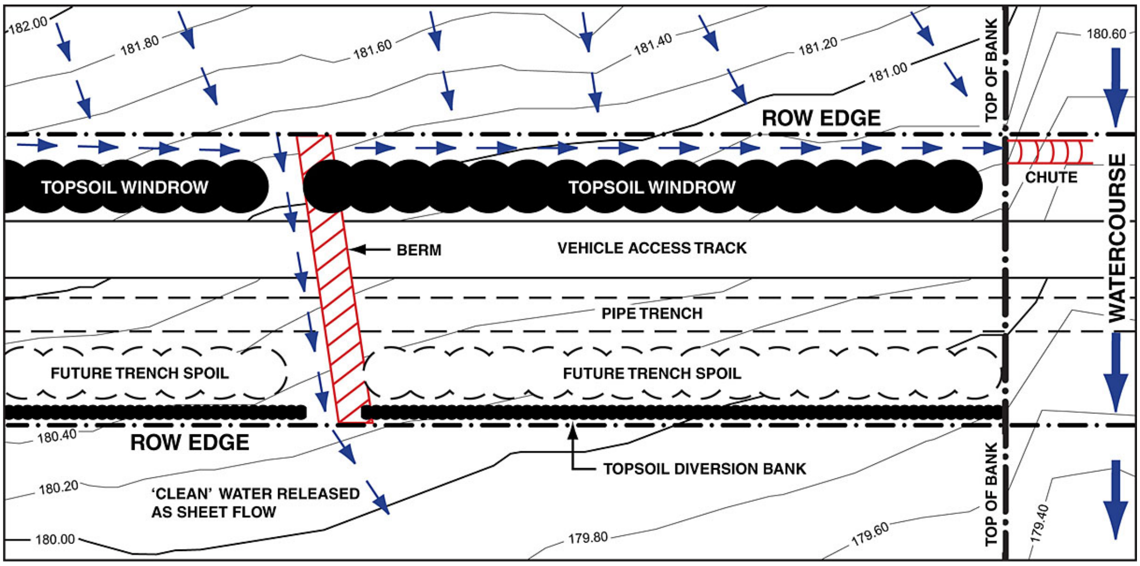

Figure P4 – Drainage control option D2 (intermediate flow release point)

Surface flows are captured and directed across the RoW through the use of cross drainage structures such as flow control berms (cross banks). Figures P5 and P6 shows construction details for two cross banks formed from materials excavated from the up-slope face. The wider the berm the smoother the travel path over the berm, and thus the faster vehicles can travel. Narrower berms may be desirable on steeper gradient tracks.

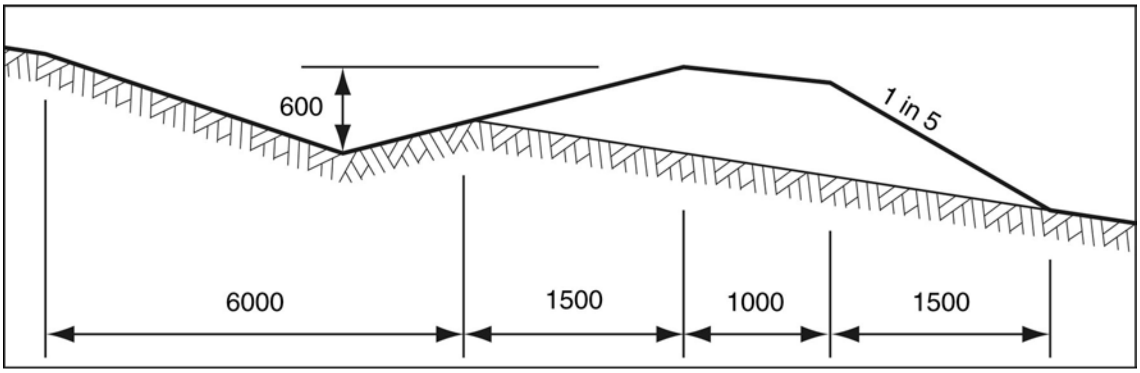

Figure P5 – Trafficable cross bank (berm) construction (10 width)

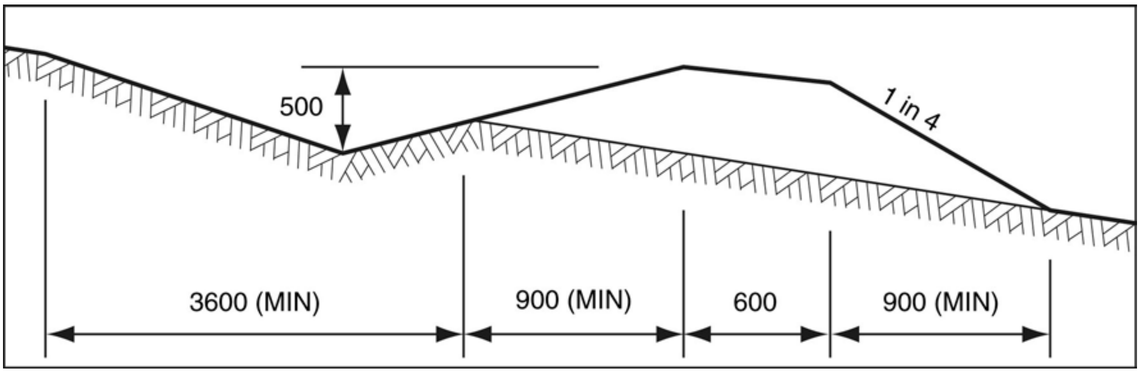

Figure P6 – Trafficable cross bank (berm) construction (6 width)

In some cases it may be desirable not to cut deep into the subsoils up-slope of cross banks. In such cases the cross bank details provided in figures P7 and P8 may be more desirable. The advantages and disadvantages of both design options are listed in Table P9. It is noted that in most cases these cross banks will be constructed after topsoil has been stripped from the RoW; therefore both options can result in the exposure of dispersive subsoils.

Table P9 – Advantages of the alternative cross bank design options

Earth excavated up-slope of berm (Figures P5 and P6)	Earth excavated from down-slope of berm (Figures P7 and P8)
• Greater drainage capacity. • Likely to require less maintenance in order to maintain sufficient drainage capacity as the berm is slowly compressed in height.	• Invert of the up-slope drainage diversion has a high elevation, thus increasing its ability to freely drain from the RoW. • Reduced risk of the exposure of dispersive subsoils up-slope of the berm

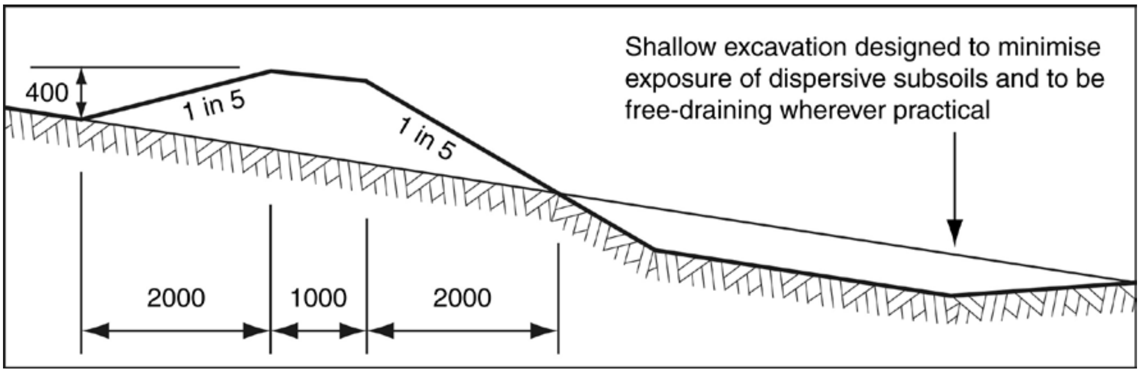

Figure P7 – Alternative trafficable cross bank (berm) construction (wide)

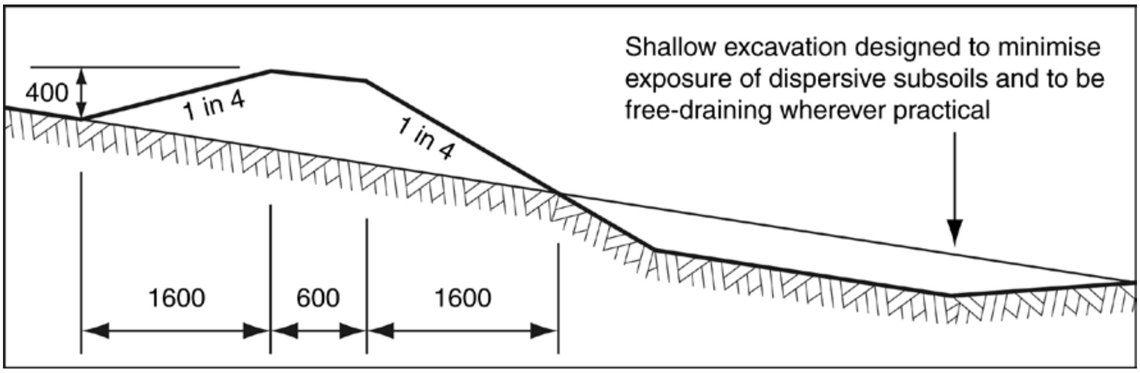

Figure P8 – Alternative trafficable cross bank (berm) construction (narrow)

P3.3.2 Erosion control practices

In order to perform the erosion control tasks listed in Table P8 it is necessary for the ESC designer to perform the following actions:

- determine the 'erosion risk' for each corridor segment (refer to Table P4 and Figure P1) and use this information to determine an appropriate construction program and the scheduling of forward works
- analyse the soil erosion risk at drainage line and waterway crossings, and access the need for (i) drainage control devices to control flow velocities, and/or (ii) *Erosion Control Matting* placed over the expected flow path (Figure P9)

- assess the need for rock stabilisation of vehicle crossing of drainage line and waterway crossings
- analyse each individual waterway crossing and assess the net benefit of minimising the extent of vegetation and soil disturbance at the crossings (refer to Section P3.6 – *Waterway crossings*), and determine the minimum set-back of soil stockpiles from the drainage line or waterway
- assess the need for erosion control measures during the site rehabilitation phase.

In pipeline construction, erosion control practices are most commonly restricted to the site rehabilitation phase, and during construction and cycle breaks. Given the narrow width of the pipeline RoW it is usually impractical to employ general erosion control practices during the construction phase.

The key to effective 'erosion control' is to:

- minimise the extent and duration of soil disturbance during periods when significant rainfall is possible, and
- promptly cover exposed soils once the construction phase has been completed.

Stabilising any exposed or disturbed soil at drainage line and waterway crossing can be viewed as a combined task of erosion control and drainage control. If site conditions warrant the use of *Soil Binders* or *Erosion Control Mats*, then the ESC designer should refer to tables P32 and P33 (Section P5.3) for guidance on the selection of an appropriate type of material.

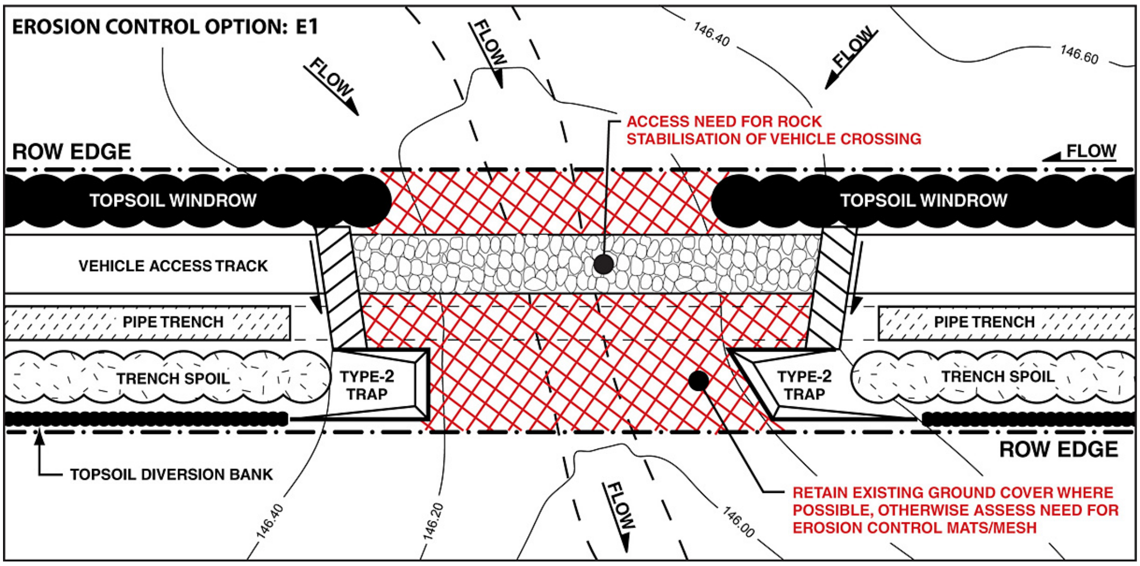

Figure P9 – Typical layout of erosion control option E1

P3.3.3 Sediment control practices at drainage line and waterway crossings

In order to perform the sediment control tasks listed in Table P8 it is necessary for the ESC designer to perform the following actions:

- determination of the sediment control system (e.g. sediment control options S1 to S7) at each 'dirty' water release point
- determine if 'intermediate' sediment collection and treatment points will be required between each ridge-top and valley floor (refer to Section P3.3.4). This analysis is usually based on an assessment of the maximum allowable/desirable RoW sub-

catchment area for the treatment of 'dirty' water within a nominated sediment control system (e.g. Type-2 or Type-3)

- determine the need (value) of integrating sediment control attributes into the drainage/erosion control practices installed along the downstream edge of the RoW at drainage line and waterway crossings.

Figures P10 to P25 show seven different approaches (options S1 to S7) to the management of sediment control at drainage line and waterway crossings. Similar approaches can be applied to roadway crossings where the open table drains of the roadway are treated as 'drainage lines'.

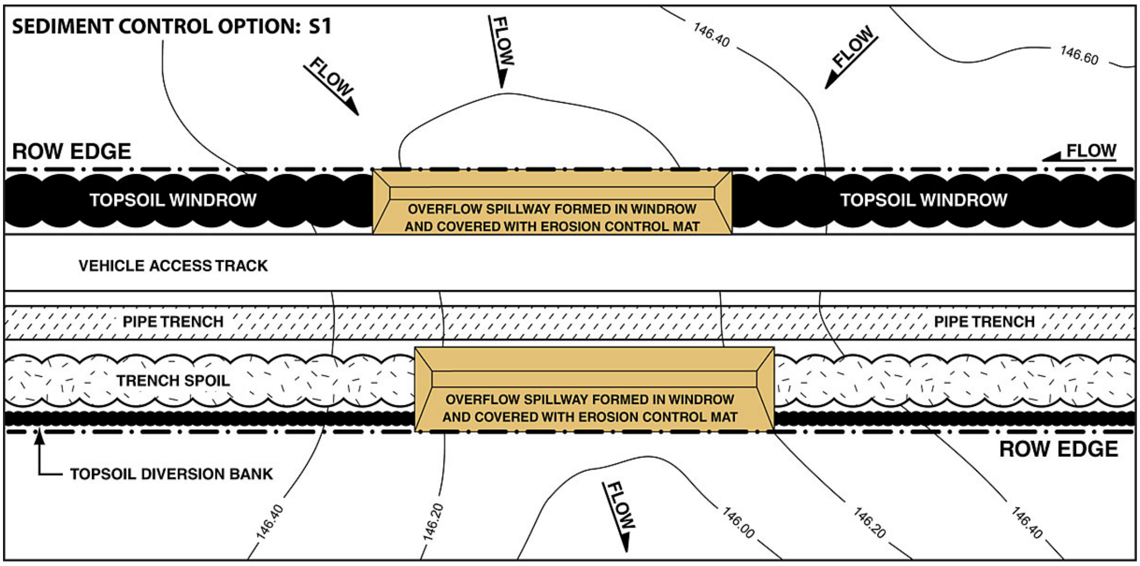

Figure P10 – Sediment control option S1

Figure P10 shows the layout of **sediment control option S1** where sediment trapping is primarily provided by water pooling up-slope of continuous topsoil and/or trench spoil windrows. The features of this treatment option are:

- Generally only considered suitable for those periods when flows within the drainage line or ephemeral waterway are either not expected, or anticipated to be very minor in both duration and peak discharge.
- Typically the topsoil and trench spoil windrows need to be suitably profiled (i.e. lowered and shaped to form a level overflow weir as per figures P11 and P12) at locations where flows are expected to overtop the windrows. This profiling is usually required even if overtopping flows are unexpected.
- If flows along the drainage line or waterway are possible during the construction period, then the overflow weirs should be protection from scour with suitable erosion control mats, or more commonly, filter cloth.
- Only minor changes need to be made to the above sediment control layout if the pipe trench is located up-slope of the vehicle access track.
- The need for rock stabilisation of the vehicle crossing will depend on the soil conditions at the crossing, the expected frequency of vehicle movement, and the risk of flows passing down the drainage line.

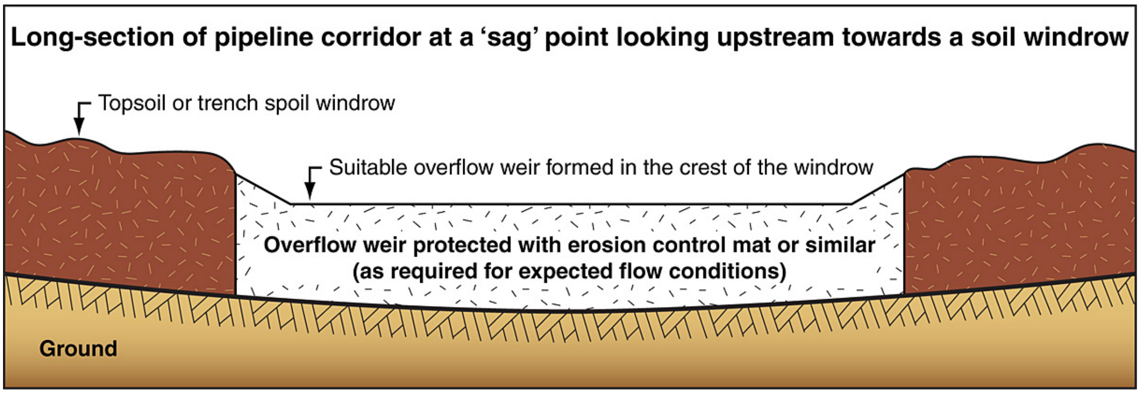

Figure P11 – Long-section of typical overflow weir formed into soil windrow

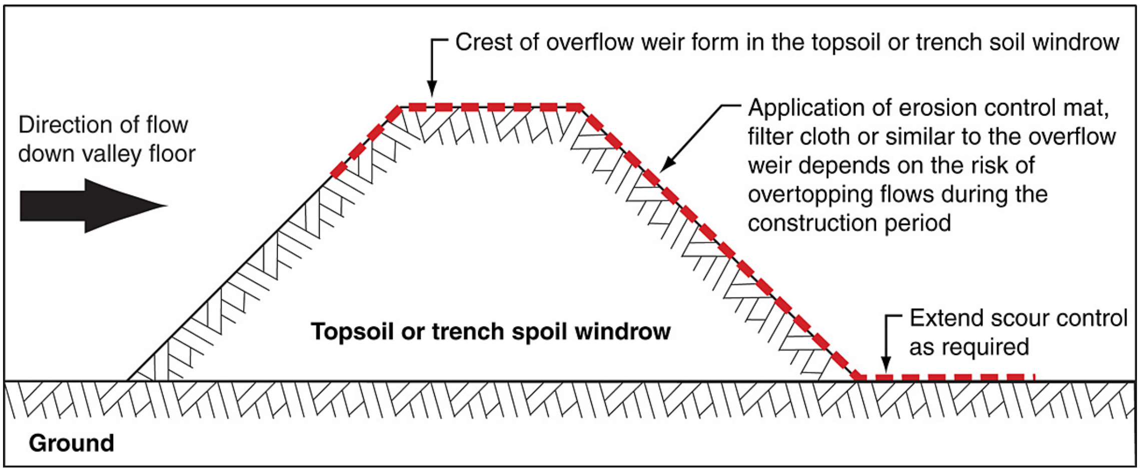

Figure P12 – Cross-section of typical overflow weir formed into soil windrow

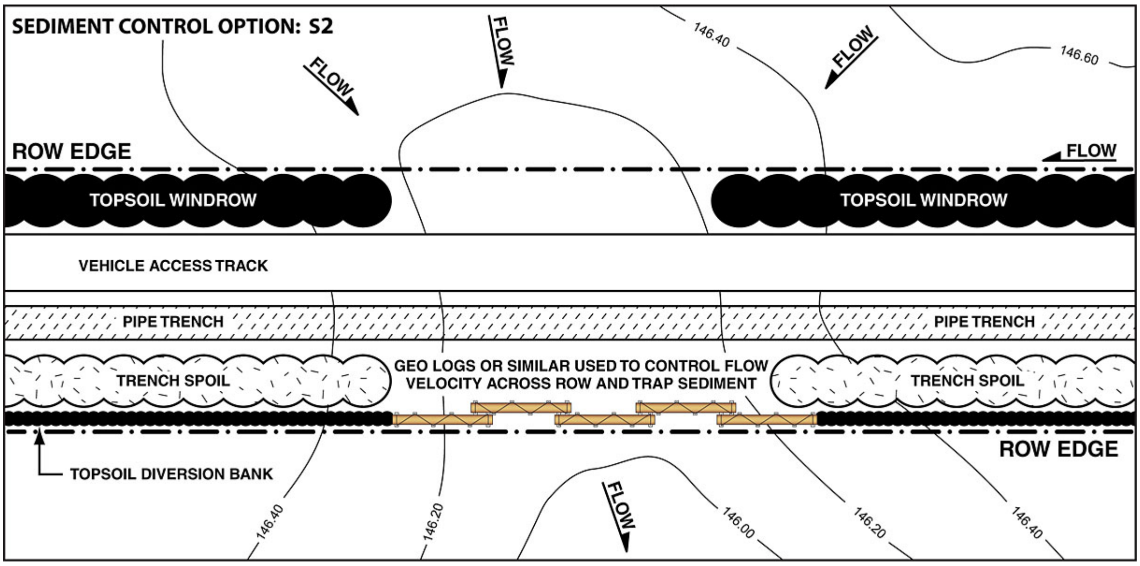

Figure P13 – Sediment control option S2

Figure P13 shows the layout of **sediment control option S2** where sediment trapping is primarily achieved as a by-product of installing an appropriate scour control *Check Dam* along the down-slope edge of the RoW. The primary purpose of the *Check Dam* is to minimise the risk of soil scour as concentrated run-on water passes across (through) the RoW.

Figure P14 shows a typical RoW profile with a *Geo Log* check dam/sediment trap. The types of *Check Dam* flow control structures that can be used include, large diameter *Geo Logs, Rock Check Dams*, and in extreme cases, *Sediment Weirs*.

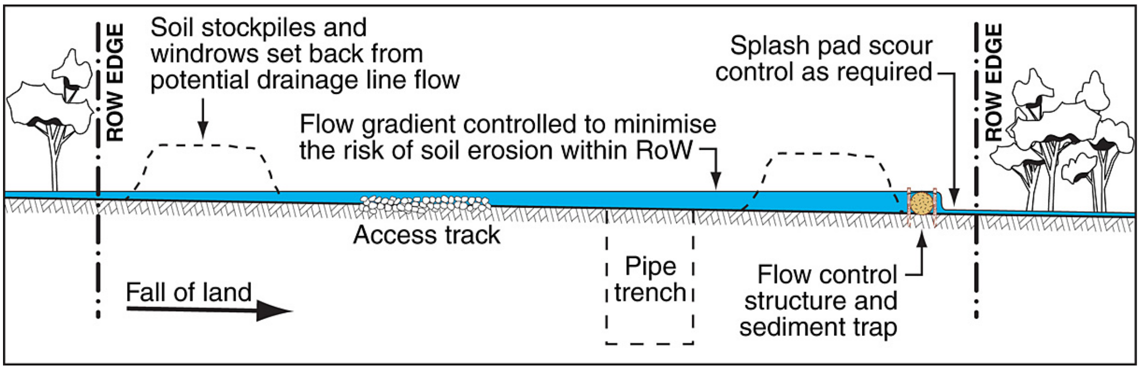

Figure P14 – Cross-section of RoW based on sediment control option S2

The features of sediment control option S2 are:

- Generally only considered suitable for those periods when flows within the drainage line or ephemeral waterway are either not expected, or anticipated to be very minor in both duration and peak discharge.
- Only minor changes need to be made to the above sediment control layout if the pipe trench is located up-slope of the vehicle access track.
- The need for rock stabilisation of the vehicle crossing will depend on the soil conditions at the crossing, the expected frequency of vehicle movement, and the risk of flows passing down the drainage line.

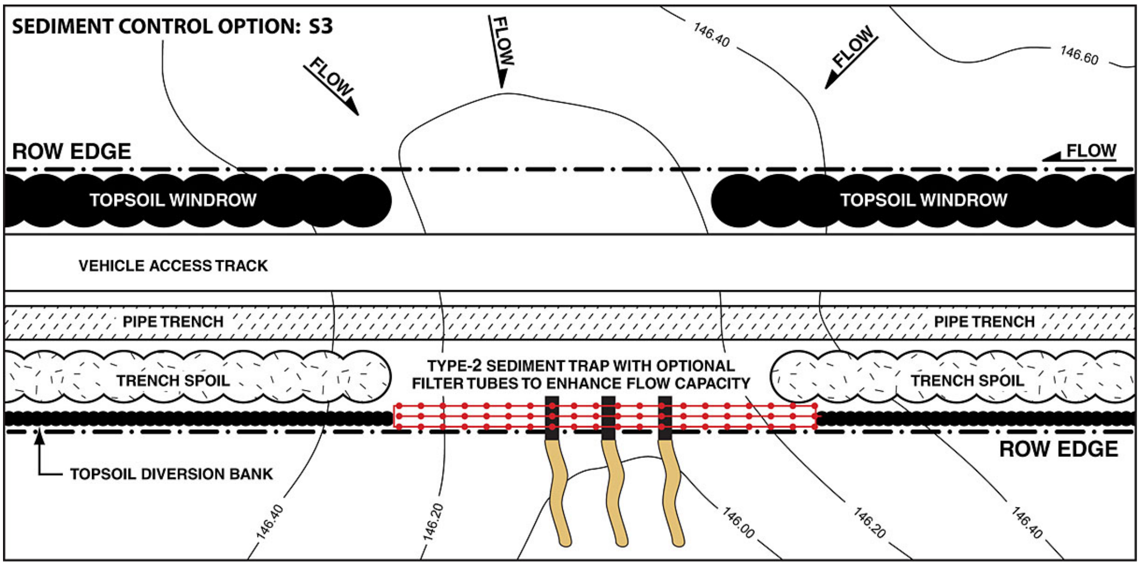

Figure P15 – Sediment control option S3

Figure P15 shows the layout of **sediment control option S3** where sediment trapping is provided by an 'instream' Type-2 sediment trap, such as a *Sediment Weir*. The features of this treatment option are:

- Generally only considered suitable for those periods when flows within the drainage line or ephemeral waterway are either not expected, or anticipated to be very minor in both duration and peak discharge.
- The hydraulic capacity and sediment trapping ability of the sediment trap can be enhanced by integrating one or more *Filter Tubes* into the structures. Permission

will be required from the down-slope property owner for the *Filter Tubes* to extend beyond the edge of the RoW.

- Only minor changes need to be made to the above sediment control layout if the pipe trench is located up-slope of the vehicle access track.
- The need for rock stabilisation of the vehicle crossing will depend on the soil conditions at the crossing, the expected frequency of vehicle movement, and the risk of flows passing down the drainage line.

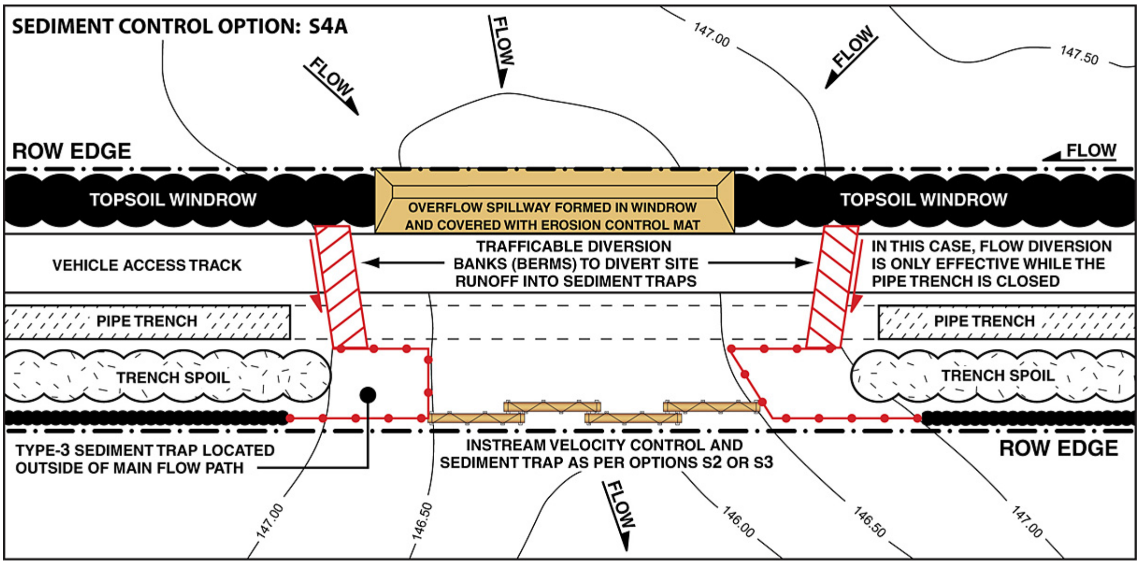

Figure P16 – Sediment control option S4A (pipe trench down-slope of track)

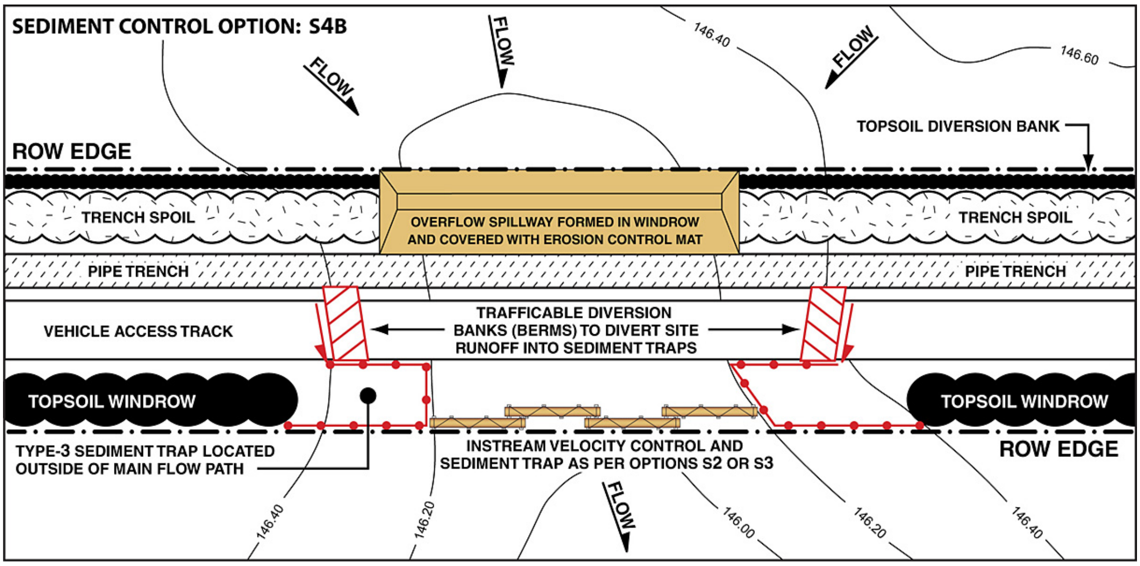

Figure P17 – Sediment control option S4B (pipe trench up-slope of track)

Figures P16 and P17 show the layout of **sediment control options S4A and S4B** where sediment trapping is primarily provided by ‘off-stream’ Type-3 sediment traps. The features of these treatment options are:

- Generally only considered suitable for those periods when flows within the drainage line or ephemeral waterway are either not expected, or anticipated to be very minor in both duration and peak discharge.
- Typically the up-slope topsoil or trench spoil windrow will need to be suitably profiled (i.e. lowered and shaped to form a level overflow weir) at the location where

flows are expected to overtop the windrow. This profiling is usually required even if overtopping flows are unexpected.

- If flows along the drainage line or waterway are possible during the construction period, then the overflow weir should be protection from scour with suitable erosion control mats, or more commonly, filter cloth.
- The inclusion of an **optional** instream scour control *Check Dam* system (e.g. *Geo Logs*) is dependent on the expected flow conditions along the drainage line as per sediment control options S2 and S3.
- The need for rock stabilisation of the vehicle crossing will depend on the soil conditions at the crossing, the expected frequency of vehicle movement, and the risk of flows passing down the drainage line.

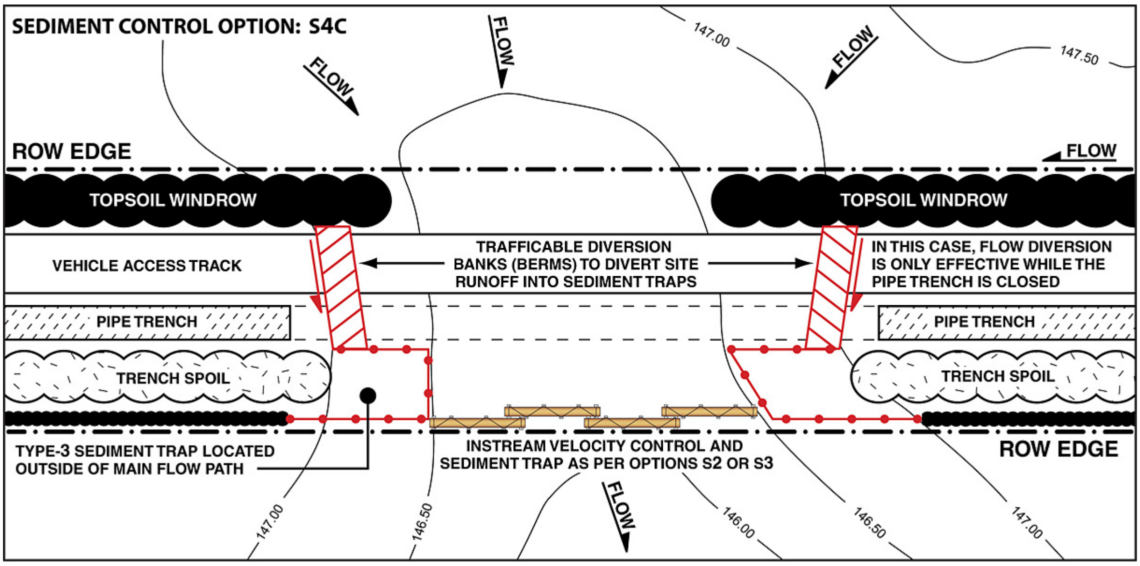

Figure P18 – Sediment control option S4C (pipe trench down-slope of track)

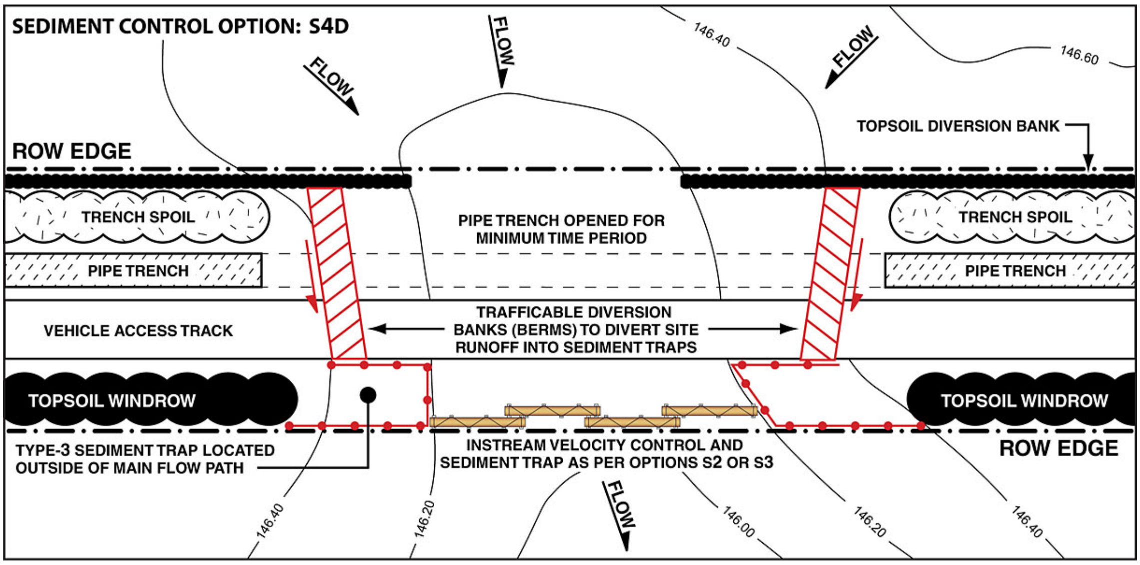

Figure P19 – Sediment control option S4D (showing site conditions while the pipe trench remains closed across the drainage line)

Figures P18 and P19 show the layout of **sediment control options S4C and S4D** where sediment trapping is provided by ‘off-stream’ Type-3 sediment traps. The features of these treatment options are:

- Generally considered appropriate when flows within the drainage line or ephemeral waterway are expected to be either continuous or significant in peak discharge.
- The inclusion of an **optional** instream scour control *Check Dam* system (e.g. *Geo Logs*) is dependent on the expected flow conditions along the drainage line as per sediment control options S2 and S3.
- The need for rock stabilisation of the vehicle crossing will depend on the soil conditions at the crossing, the expected frequency of vehicle movement, and the risk of flows passing down the drainage line.

Figure P20 shows one possible layout of **sediment control option S5** where sediment trapping is primarily provided by 'off-stream' Type-2 sediment traps. Sediment control options S5A, S5B, S5C & S5D mimic the four variations of sediment control option S4 (S4A, S4B, S4C & S4D) except the Type-3 sediment trap is replaced with a Type-2 sediment trap. The features of sediment control option S5 are:

- This elevated (Type-2) treatment standard is generally preferred over option S4 when crossing waterways, as opposed to drainage lines, or when significant sediment runoff is expected from the RoW during the construction period.
- The inclusion of an **optional** instream scour control *Check Dam* system (e.g. *Geo Logs*) is dependent on the expected flow conditions along the drainage line as per sediment control options S2 and S3.
- The need for rock stabilisation of the vehicle crossing will depend on the soil conditions at the crossing, the expected frequency of vehicle movement, and the risk of flows passing down the drainage line.

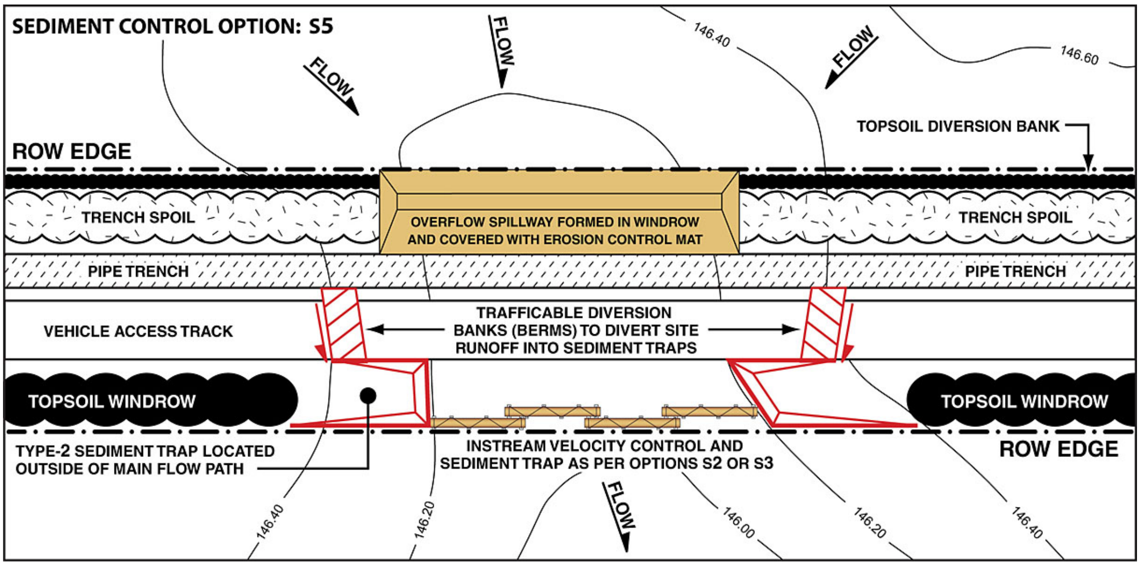

Figure P20 – Sediment control option S5 (this layout mimics option S4B)

Figures P21 and P22 show two possible layouts of **sediment control option S6** where sediment trapping is primarily provided by 'off-stream' Type-3 sediment traps that are located within an expanded RoW. The features of this treatment option are:

- Expanding the width of the RoW at key locations can allow construction practices to utilise near continuous topsoil and trench soil windrows. This option is generally only required when the utilised construction equipment (e.g. 'padders') require a near-continuous windrow.
- This treatment option is only considered suitable for those periods when flows within the drainage line or ephemeral waterway are either not expected, or anticipated to be very minor in both duration and peak discharge.

- Typically the topsoil and/or trench spoil windrows need to be suitably profiled (i.e. lowered and shaped to form a level overflow weir) at locations where flows are expected to overtop the windrows. This profiling is usually required even if overtopping flows are unexpected.
- If flows along the drainage line or waterway are possible during the construction period, then the overflow weirs should be protection from erosion with suitable erosion control mats, or more commonly, filter cloth.
- The inclusion of an **optional** instream scour control *Check Dam* system (e.g. *Geo Logs*) is dependent on the expected flow conditions along the drainage line as per sediment control options S2 and S3.
- The need for rock stabilisation of the vehicle crossing will depend on the soil conditions at the crossing, the expected frequency of vehicle movement, and the risk of flows passing down the drainage line.

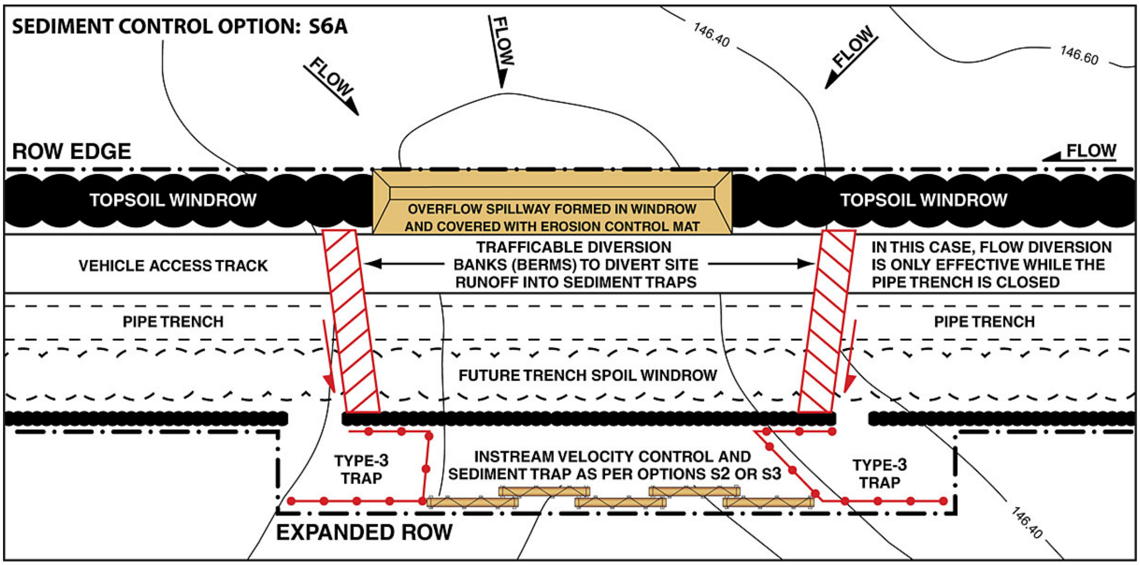

Figure P21 – Sediment control option S6A (pipe trench down-slope of track)

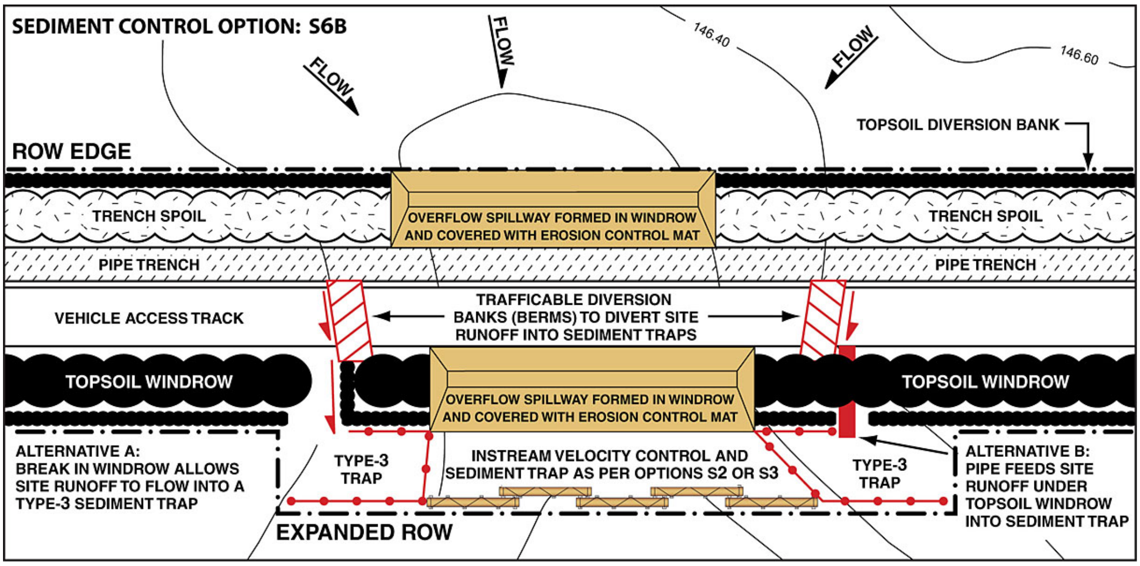

Figure P22 – Sediment control option S6B (pipe trench up-slope of track)

Figures P23 and P24 show two alternative layouts of sediment control option S6 where sediment trapping is primarily provided by 'off-stream' Type-3 sediment traps that are located within an expanded RoW. The features of this treatment option are:

- Generally considered appropriate when flows within the drainage line or ephemeral waterway are expected to be either continuous or significant in peak discharge.
- The inclusion of an **optional** instream scour control *Check Dam* system (e.g. *Geo Logs*) is dependent on the expected flow conditions along the drainage line as per sediment control options S2 and S3.
- The need for rock stabilisation of the vehicle crossing will depend on the soil conditions at the crossing, the expected frequency of vehicle movement, and the risk of flows passing down the drainage line.

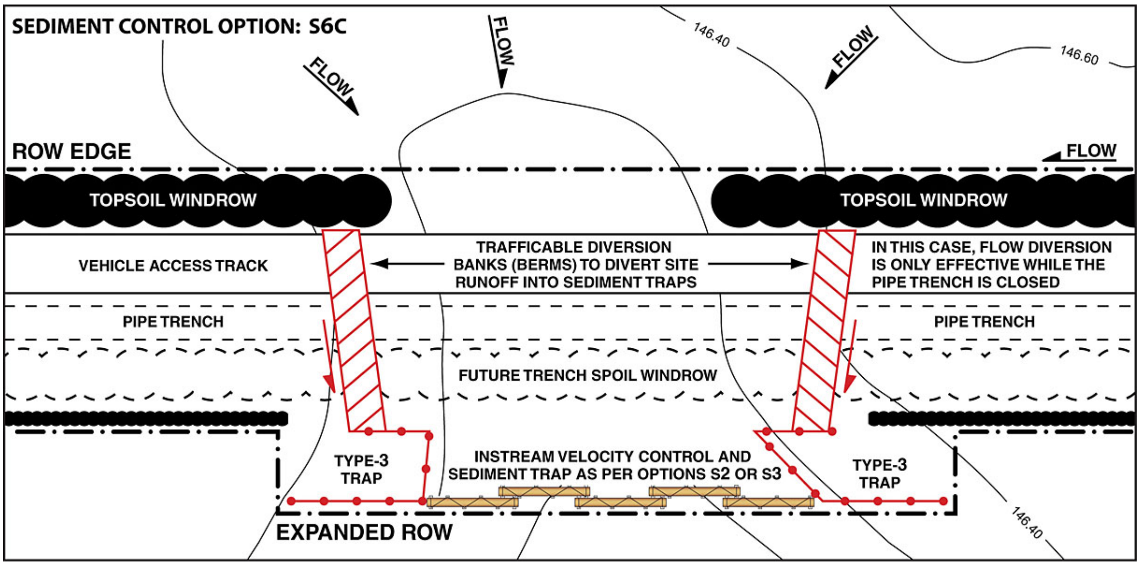

Figure P23 – Sediment control option S6C (pipe trench down-slope of track)

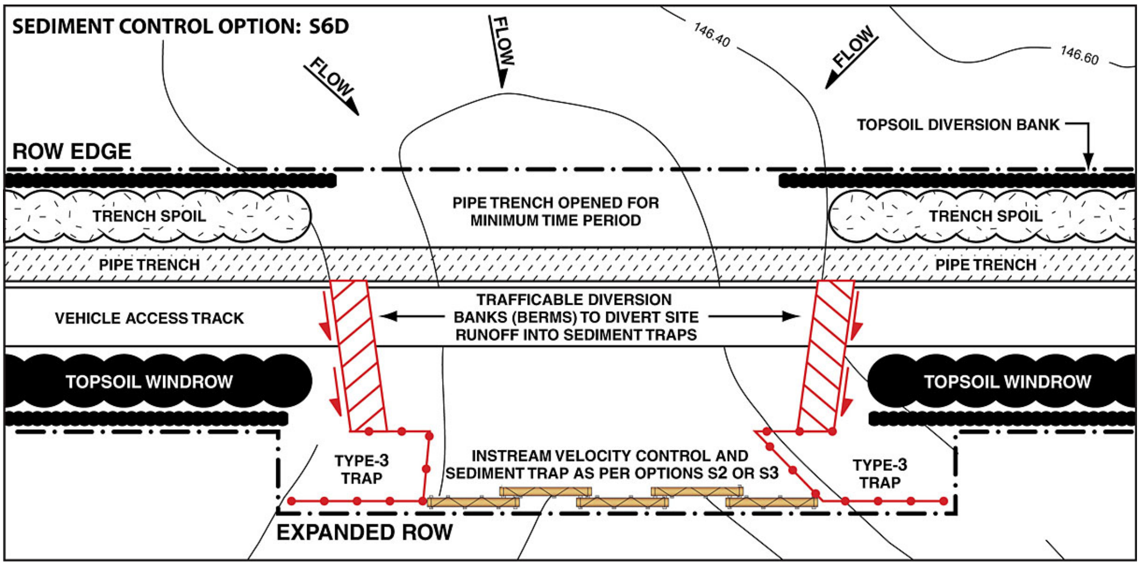

Figure P24 – Sediment control option S6D (showing site conditions while the pipe trench across the drainage line is open)

Figure P25 shows one possible layout of **sediment control option S7** where sediment trapping is primarily provided by 'off-stream' Type-2 sediment traps that are located within an expanded RoW. Sediment control options S7A, S7B, S7C & S7D mimic the four variations of sediment control option S6 (S6A, S6B, S6C & S6D) except the Type-3 sediment trap is replaced with a Type-2 sediment trap. The features of sediment control option S5 are:

- This elevated (Type-2) treatment standard is generally preferred over option S6 when crossing waterways, as opposed to drainage lines, or when significant sediment runoff is expected from the RoW during the construction period.
- The inclusion of an **optional** instream scour control *Check Dam* system (e.g. *Geo Logs*) is dependent on the expected flow conditions along the drainage line as per sediment control options S2 and S3.
- The need for rock stabilisation of the vehicle crossing will depend on the soil conditions at the crossing, the expected frequency of vehicle movement, and the risk of flows passing down the drainage line.

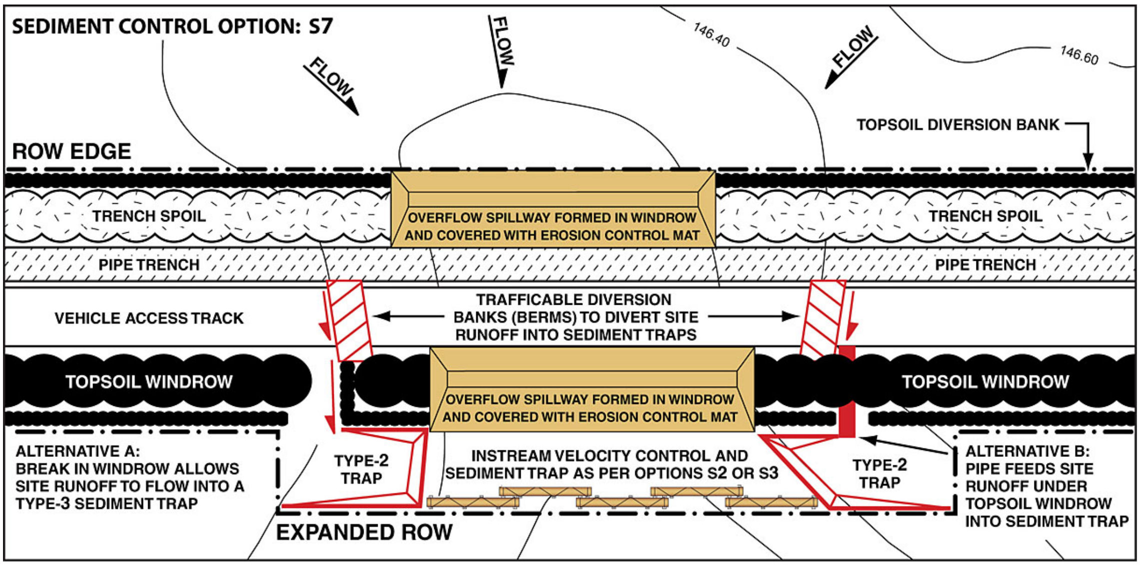

Figure P25 – Sediment control option S7 (this layout mimics option S6B)

P3.3.4 Sediment control practices at 'on-grade' locations along the RoW

Figures P26 to P29 show two possible approaches (options SO1 and SO2) to the management of sediment control at 'intermediate' (on-grade) flow release points located between the ridge-top and valley floor.

Figures P26 and P27 show the layout of **sediment control options SO1A and SO1B** where sediment trapping is typically provided by a Type-3 sediment trap. Site conditions that may trigger the need for this treatment option include:

- Site conditions exist where it is necessary for up-slope 'clean' run-on water is required to be diverted through (across) the RoW.
- The RoW sub-catchment area exceeds the maximum desirable catchment area for the nominated sediment control system (e.g. Type-2 or Type-3).

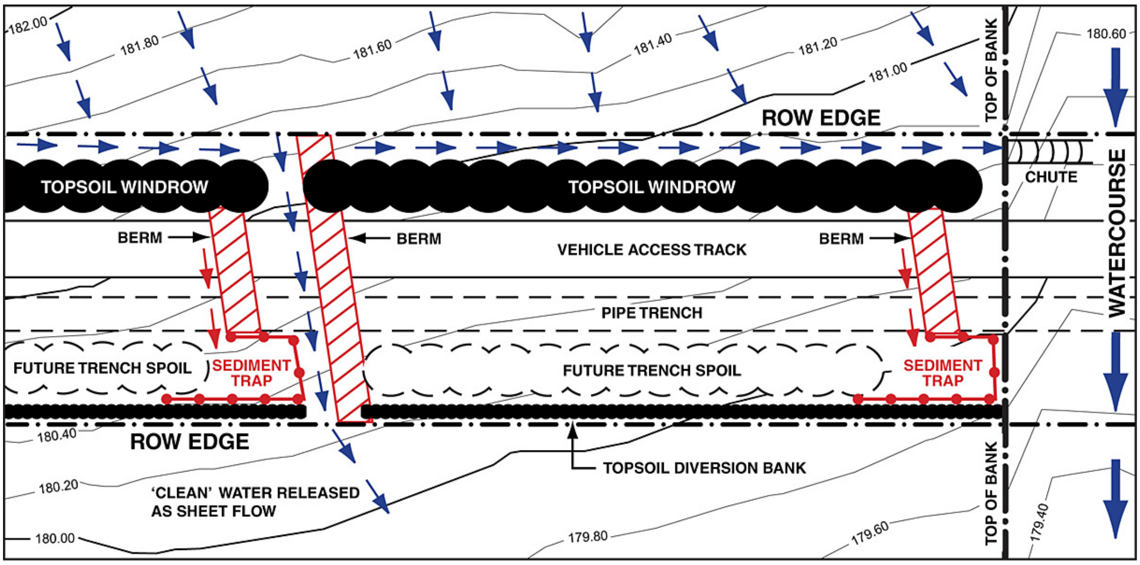

Figure P26 – Sediment control option SO1A: pipe trench down-slope of vehicle access track

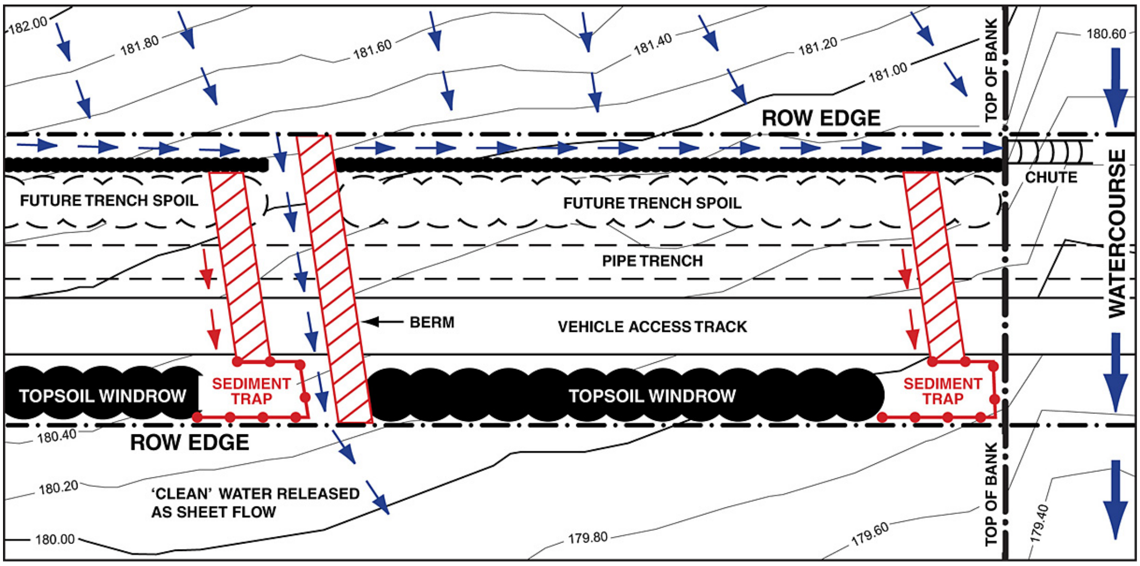

Figure P27 – Sediment control option SO1B: pipe trench up-slope of vehicle access track

Figures P28 and P29 show the layout of **sediment control options SO2A and SO2B** where sediment trapping is typically provided by a Type-3 sediment trap which is located within an expanded RoW. Site conditions that may trigger the need for this treatment option include:

- Site conditions exist where it is necessary for up-slope 'clean' run-on water is required to be diverted through (across) the RoW.
- The RoW sub-catchment area exceeds the maximum desirable catchment area for the nominated sediment control system (e.g. Type-2 or Type-3).
- The utilised construction equipment (e.g. 'padders') require a near-continuous windrow.

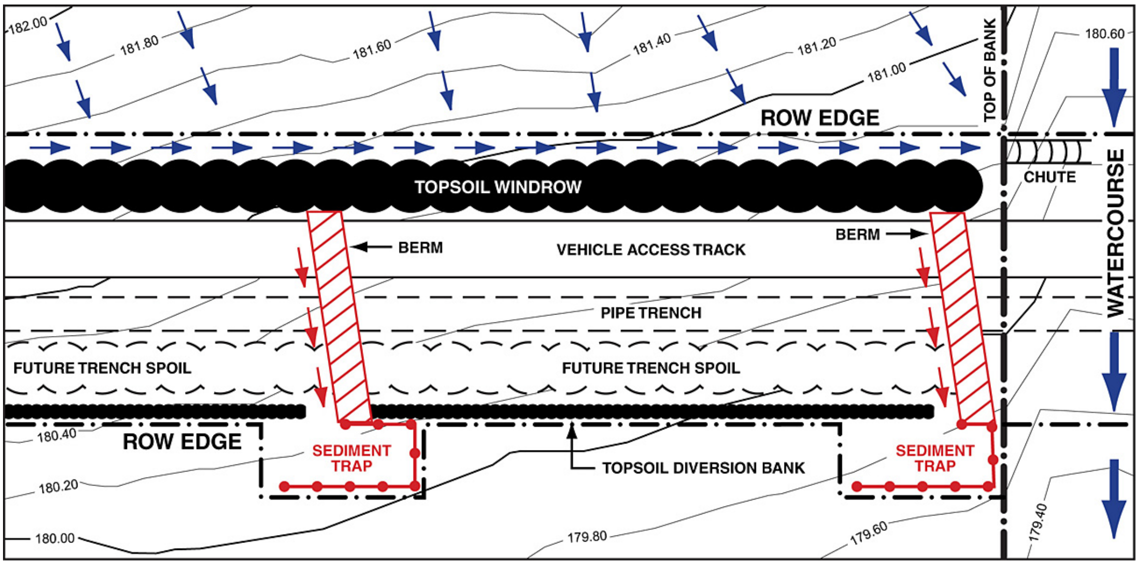

Figure P28 – Sediment control option SO2A: pipe trench down-slope of vehicle access track

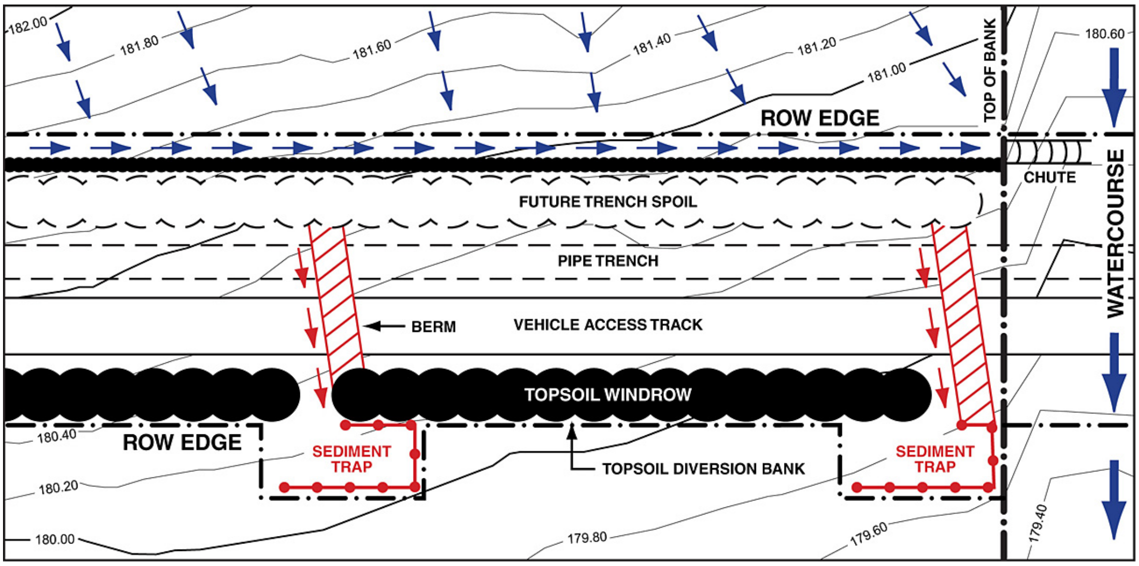

Figure P29 – Sediment control option SO2B: pipe trench up-slope of vehicle access track

P3.4 Steep slopes

Many pipeline projects intersect steep slopes during their construction. The Revised Universal Soil Loss equation (RUSLE) demonstrates that slope gradient and slope length are significant factors when determining erosion risk on sloping sites. The longer and steeper the slope, the greater the erosion risk, and the more sophisticated the control techniques typically required to stabilise the slope.

In addition to the risk of soil scour, disturbances to naturally-steep slopes during the construction of pipelines may result in geotechnical instability due to changes in topography, groundwater flows, loss of soil strength, stress changes and weathering.

Table P4 indicates that slopes greater than 10% but less than 15% have a high erosion risk, while slopes steeper than 15% have an extreme erosion risk. Conventional flow diversion techniques such as *Cross Banks* (berms) should not be used on slopes steeper than 18% without expert advice due to:

- the increased erosion and slope stability risk associated with cutting the back batter
- likely inability to source sufficient material to build the bank
- likely difficulty in sourcing a safe and stable discharge point.

Sediment control measures typically rely on the pooling of water in order to allow the settlement of coarse sediments. However, on steep slopes, the pooling of water can significantly increase the risk of hydraulic failures and soil scour. Therefore, on steep slopes the focus should primarily be on the utilisation of drainage and erosion control measures, with sediment control measures generally only used at the base of steep slopes where it is safe to pool water.

The following erosion and sediment controls should be considered when constructing works in steep areas:

- minimise forward clearing
- avoid soil disturbance during periods of high rainfall risk
- maintain soil surface cover particularly where dispersive soils are present
- minimise erosion on travel roads and other exposed areas
- divert clean run-on water away from, or in a non erosive manner through the RoW
- identify and preserve site materials that can aid erosion control and site stabilisation
- divert stormwater off the RoW as regularly as possible if it can help to maintain sheet flow conditions down-slope of the RoW
- install regular trench breakers keyed into the bottom and side of the trench to minimise tunnel erosion (in cases where the pipe trench is formed along a steep slope)
- compact, and where necessary treat with gypsum, trench spoil to minimise the risk of tunnel erosion
- progressively rehabilitate the RoW to minimise the extent and duration of disturbance
- re-establish sheet flow conditions where possible.

P3.5 Drainage line and roadway crossings

A drainage line is a natural or constructed stormwater drainage path that:

- carries 'concentrated' rather than 'sheet' flow
- is likely to flow only during periods of rainfall, and for short periods (hours rather than days) after rain has stopped
- is a drainage path that cannot be classified as a 'watercourse' based on a locally or regionally-adopted classification system (e.g. state policies).

Drainage lines may also be referred to under other names, such as 'overland flow paths' or dry-land gullies. However, a 'gully' is generally more physically defined by steep banks than a traditional drainage line. In most cases, pipelines can cross gullies following the same procedures outlined below for drainage lines. However, discretion is required by the designer/civil contractor as to when a deep, well-formed or active gully should be treated as an ephemeral waterway.

It is noted that most roadway crossings can be treated in a manner similar to drainage line crossings. In effect, the table drains located each side of the roadway are just another form of drainage line. Typically the differences are only in regards to the detail of the site entry/exit points, which do not occur at normal drainage line crossings.

In cases where there is the risk of accelerated soil erosion occurring within the drainage line during the construction phase, then the management options include:

- stabilise the soil within the RoW with *Erosion Control Mats* (Figure P9), and/or
- install a velocity control structure (e.g. *Geo Log* or *Check Dam*) along the downstream edge of the RoW (Figure P14).

Typically these velocity control structures are looked upon by regulators as 'sediment control' systems; however, in reality their ability to capture sediment is highly limited. Instead these devices should be viewed as a form of 'drainage control' that **primarily** aims to reduce the velocity of water flowing across the RoW, with sediment control being a secondary by-product.

Figure P30 shows the profile of a typical vehicle crossing at an ephemeral drainage line. The need for rock stabilisation (or other treatment options) of the vehicle crossing will depend on the soil conditions at the crossing, the expected frequency of vehicle movement, and the risk of flows passing down the drainage line.

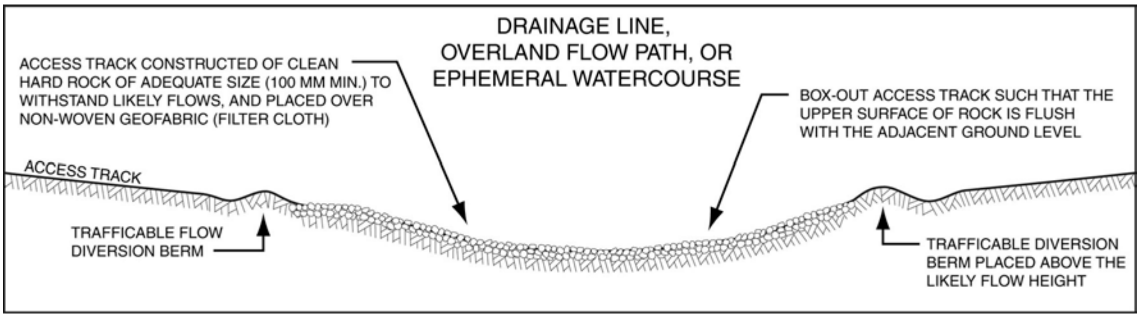

Figure P30 – Typical profile of bed-level vehicle crossing of a drainage line

P3.6 Waterway crossings

As discussed in Section P2.2, there are significant environmental risks associated with open trenching through waterways including:

- increased quantity and frequency of suspended sediment within stream flows during the construction phase
- erosion of stream banks and subsequent sedimentation issues that can harm aquatic fauna, smother aquatic habitats, increase instream turbidity, and decrease light transmission in the water body (this issue can be linked to both the construction phase and rehabilitation phase)
- unnatural alteration of bed and bank stability, thereby increasing the likelihood of scouring of the backfilled pipeline trench (some soils become less stable once disturbed, even if compacted to a pre-disturbance condition and vegetated)
- contamination of surface water and groundwater by construction-related chemicals (associated with some trenchless construction processes)
- disruption and fragmentation of riparian ecosystems, including breaks in movement corridors for small terrestrial animals associated with a permanent change in type and density of riparian vegetation within the RoW (a post-work revegetation issue).

Guidance on the management of instream works is provided in Section P3.9 *'Waterway crossings'* and Appendix I – *'Instream works'*.

There are numerous methods for installing pipelines across waterways. Section 6.11 of APIA (2013) and the Canadian publication (CAPP, CEPA & CGA, 2005) provide discussion on various construction techniques, including:

Open trench techniques:

- Dozer or spider plough
- Open cut trench
- Dragline (excavation of open trench by a dragline)
- Dredging (excavation of open trench by a floating dredge)

Cofferdams and isolation barriers:

- Flume (cofferdam system with gravity bypass flow line)
- Cofferdam with pumped flow bypassing
- Two-stage open trenching behind impervious isolation barriers
- Channel diversion

Trenchless techniques:

- Horizontal bore, punching, or pipe jacking
- Horizontal directional drilling

Aerial techniques: (may not be appropriate for all types of pipeline, e.g. gas)

- Bridge attachment (attachment to existing bridge)
- Self-supporting bridge/truss

Consideration of trenchless or bridging techniques is recommended when the environmental or social risks associated with open trenching of waterways cannot be eliminated or adequately mitigated.

The method used to construct a pipeline across a waterway is largely dependent on the experience and capabilities of the construction company that wins the pipeline project. If the proponents of a pipeline project are concerned about a possible environmentally, politically, or socially sensitive waterway crossing, then consideration should be given to highlighting these issues within the tender process, and/or issuing the waterway crossing as a separate contract or cost item.

Factors that need to be considered when selecting a construction method include:

- cost of pipe installation and site rehabilitation
- environmental 'values' of the waterway and associated riparian zones
- required fish passage and navigation needs during the construction phase
- the width of the watercourse
- soil properties within the bed and banks
- base flow conditions within the watercourse, including the depth, flow rate and velocity of flow, and the risk of elevated flows
- stability and potential mobility of the waterway (this primarily impacts on the design of the pipe crossing)
- the type of bed material (which usually defines the type of waterway) and the stability, depth and potential mobility of any loose bed material (e.g. sand or gravel).

Wherever practical, the construction methodology should avoid the need for, and use of, instream sediment control systems. Instead, preference should be given to:

- procedures that isolate construction works and soil disturbances from stream flows
- procedures that treat sediment-laden water, including site runoff, lateral inflows and stream flows, within sediment control system located above the low bank, and preferably outside the critical riparian zone (the latter typically being defined as at least three times the bank height measured from the edge of the low-flow channel).

Figures P31 and P33 show typical stabilised waterway crossings prior to the opening of the pipe trench. Figure P34 shows typical ESC controls during open trenching of a waterway where clean upstream water is pumped around the active construction zone. The layout of each crossing would change depending on whether the vehicle access track is upstream or downstream of the pipe trench.

Figures P35 to P44 provide examples of various open trench installation procedures that aim to isolate construction activities from stream flows. These options are presented as a guide only, and should not imply that such methods will always be practical.

Technical note P1: Use of instream sediment traps

Instream sediment control systems were developed in response to a particular regulatory framework where the success of ESC measures was primarily based on water quality sampling upstream and downstream of the works. In cases where the waterway has only a minor trickle flow, a greater than 10% increase in turbidity or suspended solids would register as a 'failure' even though at such low flow rates the risk of causing environmental harm was potentially very low.

Thus in general construction practice, instream sediment traps generally aim to treat only those low flows that cannot otherwise be prevented or bypassed around the instream disturbance. In the case of pipeline construction, the primary purpose of these in-channel sediment traps is usually to act as a temporary, low-height, velocity-control check dam that reduces the risk of soil scour across the RoW. Any sediment control outcomes are just a secondary benefit.

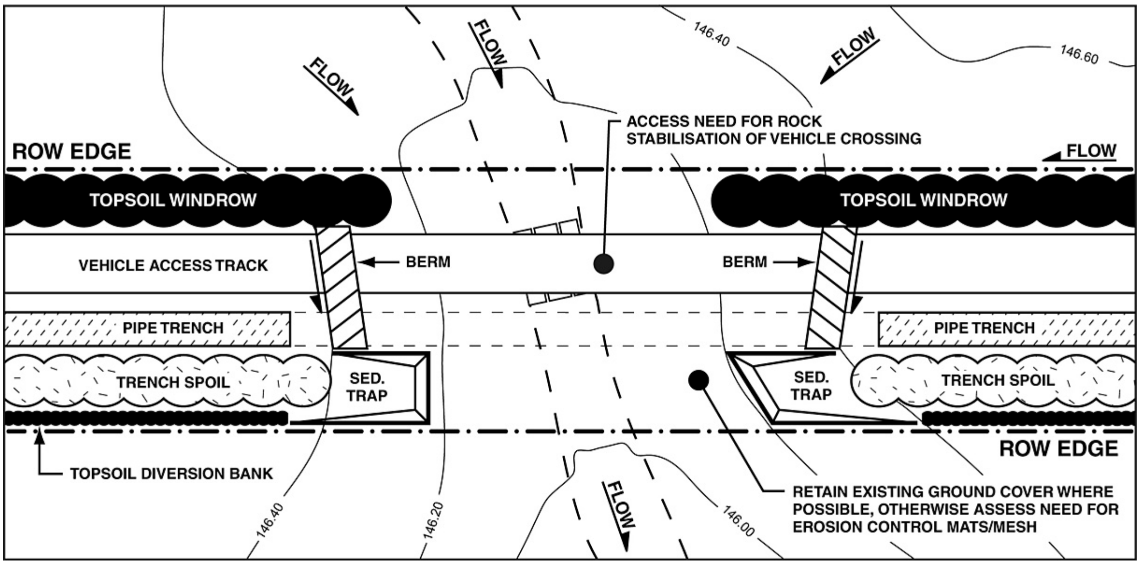

Figure P31 – Possible layout of pipe crossing of waterway with pipe trench located down-slope of the vehicle crossing

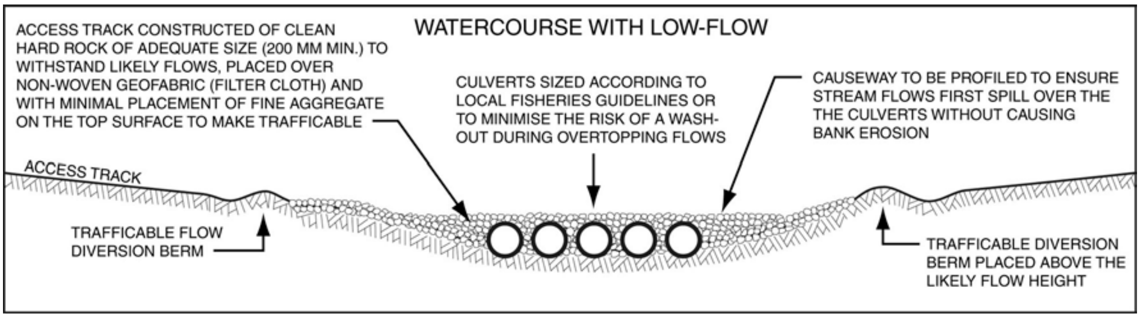

Figure P32 – Typical profile of temporary culvert crossing (cross-section)

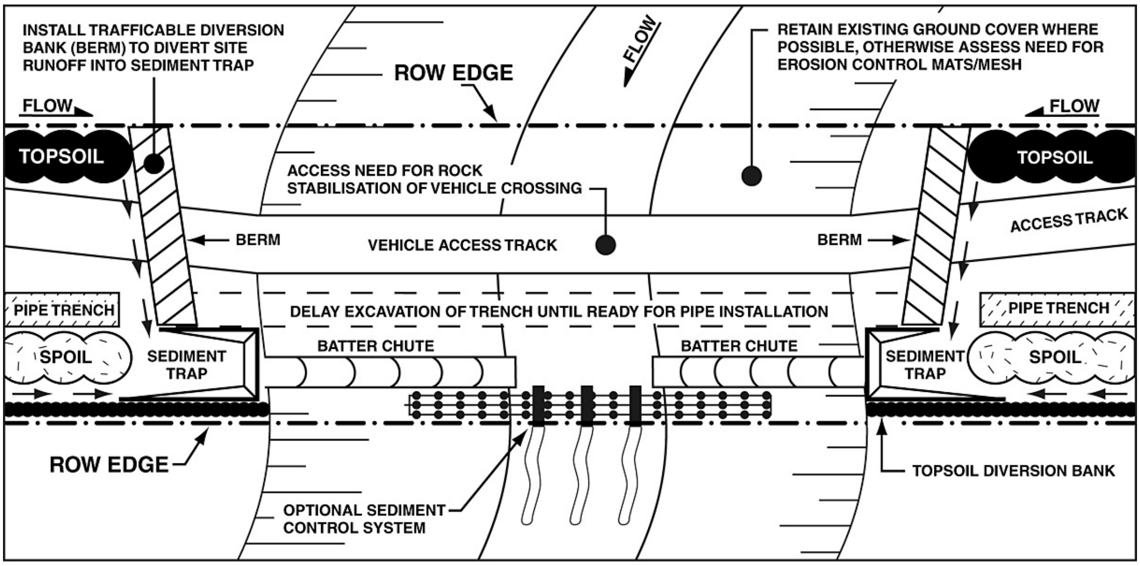

Figure P33 – Alternative layout of pipe crossing of waterway with pipe trench located down-slope of the vehicle crossing

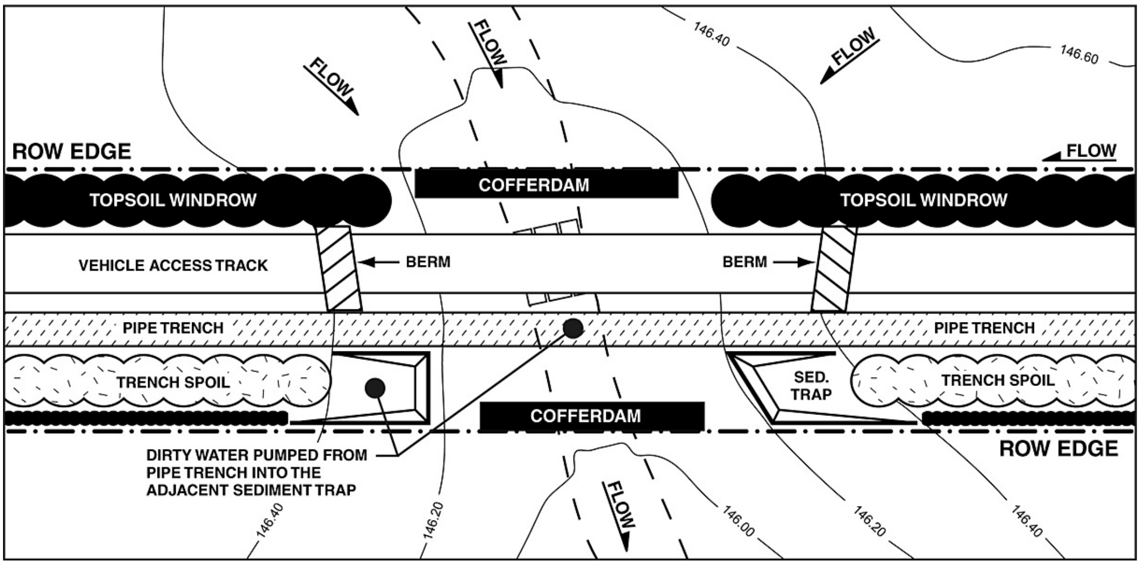

Figure P34 – Typical ESC control measures for a waterway crossing while the pipe trench is open

Example A: Pipeline installation across a narrow watercourse with all construction equipment operating from the channel banks

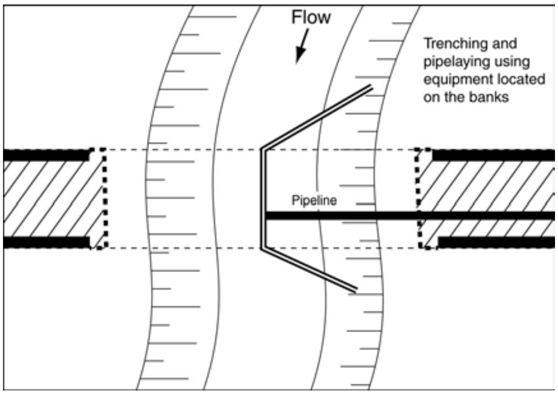

Figure P35 – Stage 1

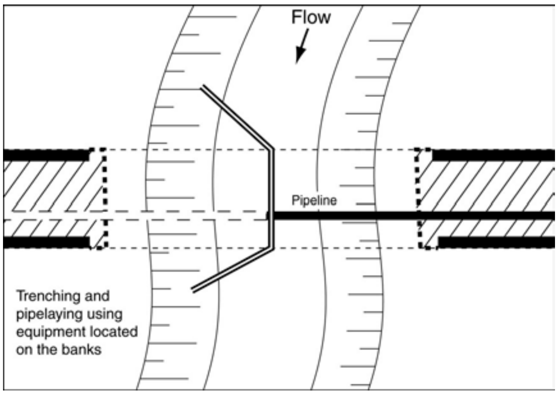

Figure P36 – Stage 2

Example B: Pipeline installation across a wide, dry-bed waterway where minor channel flows are possible

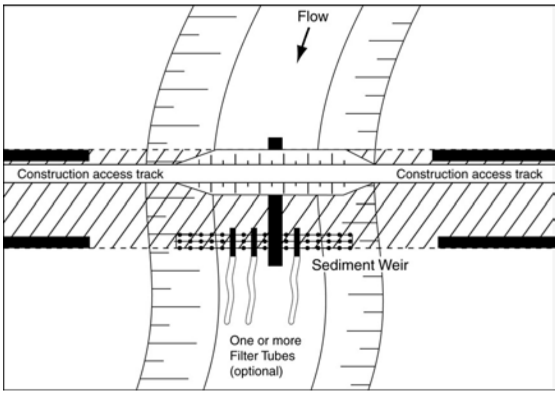

Figure P37 – Provision of vehicle access across the waterway

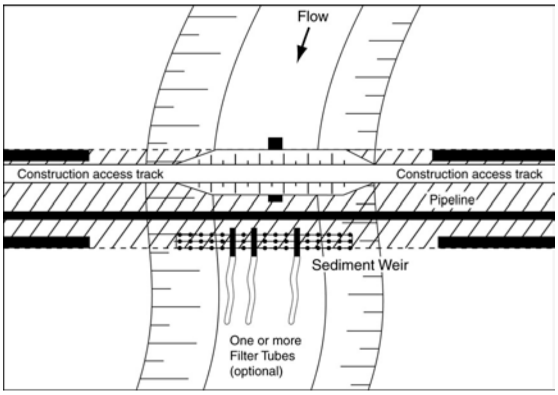

Figure P38 – Installation of pipeline (part of the bypass pipe may need to be removed to allow pipe installation)

Example C: Pipeline installation across a wide watercourse with constant dry-weather flow and where increased channel flows are possible

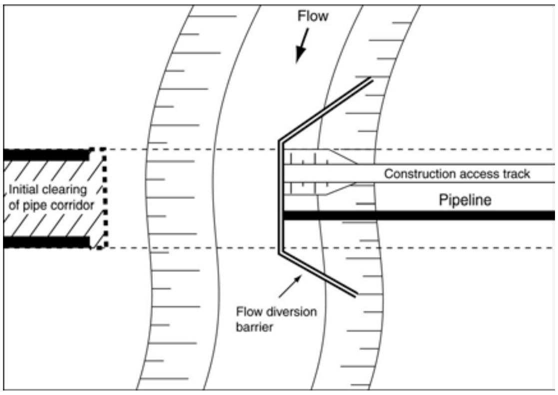

Figure P39 – Stage 1 of pipe installation using an isolation barrier

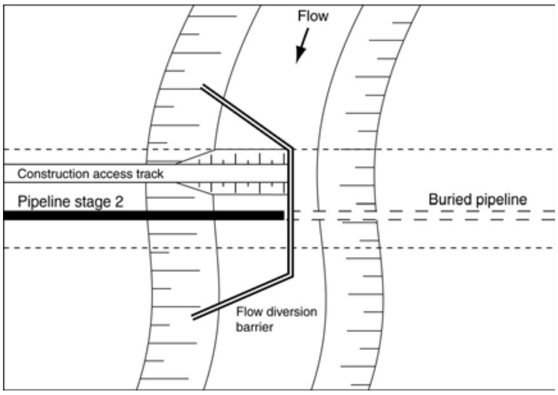

Figure P40 – Stage 2 of pipe installation

Example D: Alternative pipeline installation across a wide, watercourse with constant dry-weather flow and where increased channel flows are possible

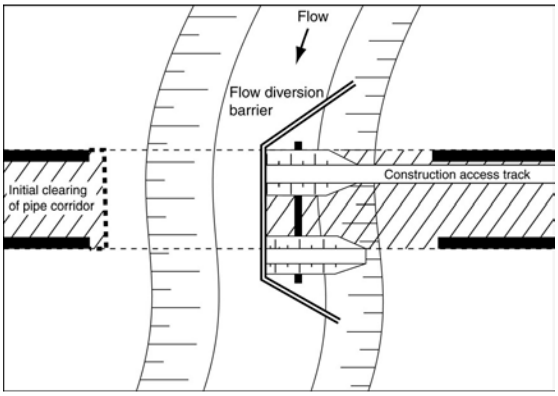

Figure P41 – Partial channel clearing and partial installation of cofferdam and construction access

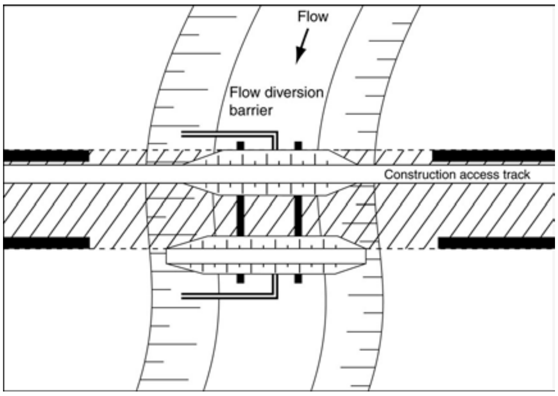

Figure P42 – Final channel clearing and final installation of cofferdam and construction access with full channel flow bypass

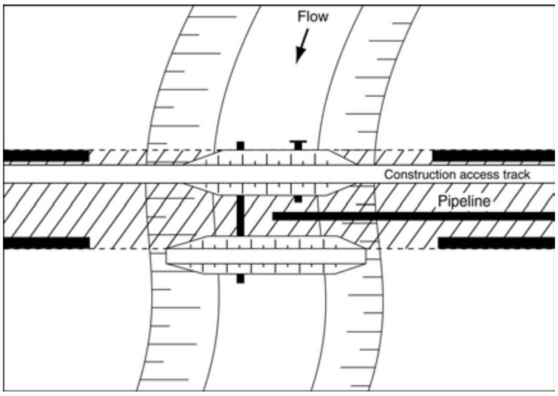

Figure P43 – Stage 1 of pipeline installation with one of the bypass pipes taken off-line to allow better access for pipe installation

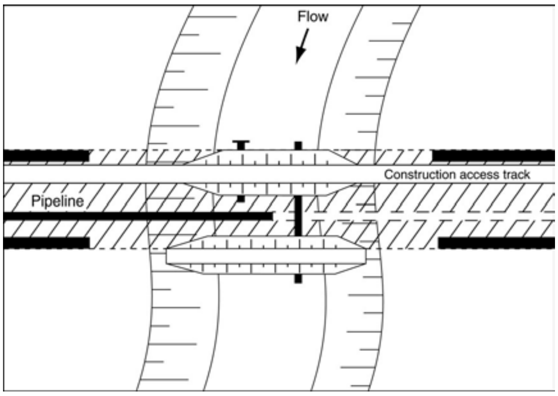

Figure P44 – Stage 2 of pipeline installation with the other bypass pipe taken off-line to allow better access for pipe installation

P3.7 Responding to adverse weather conditions

Although rain forecasting has improved in recent times, unexpected rainfall can still occur. Only in specific regions of Australia can construction works occur with a high degree of certainty that rainfall will not occur in the near future. As such, appropriate ESC measures will usually be required all year round on most pipeline projects.

In many instances, pipeline construction will occur with only Primary Erosion and Sediment Control Plans (ESCPs) as a guide to managing stormwater flows, soil erosion and sediment runoff. These Primary ESCPs will either consist of generic plans (i.e. plans that show the typical layout of ESC measures without specifically relating to a given project or location) or project-specific plans. In any case, these plans should describe (or list) information about the types of ‘temporary’ ESC measures that should be considered in the hours or days before the onset of adverse weather conditions.

What constitutes ‘adverse weather conditions’ will vary from location to location, and is at the discretion of the ESC designer. In some cases it may refer to any runoff-producing rainfall, in other cases it may only refer to rainfall that is expected to exceed a specified rainfall depth (or intensity). If the term ‘adverse weather conditions’ has not been defined within the ESCP, then the adoption of temporary control measures should be considered whenever the forecast rainfall is likely to approach, or exceed, the nominated ‘design’ storm.

It is noted that these ‘temporary’ ESC measures will only need to be operational while the adverse weather conditions are imminent or occurring, and that these measures are considered **additional** to those measures already detailed within the ESCP.

If suitable temporary control measures are not identified within the ESCP, then the following actions should be given **appropriate consideration** in the days prior to any forecast rainfall that is likely to approach or exceed the nominated design storm. It is noted that not all of the following measures will be appropriate in all circumstances.

- Formation of temporary flow diversion berms (e.g. earth windrows or geo-log diversion banks) up-slope of open trenches to minimise inflows, but only if suitable flow diversion systems do not already exist, and space is available within the RoW.
- Stabilisation of any potentially unstable flow diversion systems (including flow diversion windrows, drains and batter chutes) possibly through the use of filer cloth or a suitable spray-on channel lining or *Soil Binder*. If rainfall is imminent, then *Erosion Control Mats* (which includes filter cloth) will usually need to be secured with timber stakes, not metal pins. Alternatively, ensure the correct placement of *Check Dams* to prevent the occurrence of excessive flow velocities that may cause damage to these flow diversion systems.
- Stabilisation of ‘drainage line’ and ‘waterway’ crossings in a manner that suitably protects these surfaces from excessive scour.
- If strong winds are imminent, then secure recently pinned *Erosion Control Blankets* with rocks, logs, or timber stakes, if displacement of the blankets is a concern.
- Where appropriate, construct and stabilise suitable spill-through points along earth or mulch berms/banks to avoid such structures overtopping in a manner that may cause their structural failure.

P3.8 Reinstatement and rehabilitation

P3.8.1 Introduction

Section 6.13 of APIA (2013) details the environmental management considerations for the reinstatement and rehabilitation of areas disturbed by pipeline construction. The following section of this appendix details those aspects of this final stage of pipeline construction that relate directly to the activity of erosion and sediment control.

In these regards, the erosion and sediment control industry is not so much focused on the type of rehabilitation, or the selection of plant species, but on the following issues:

- how best to achieve the site revegetation (e.g. *Hydromuching*, *Bonded Fibre Matrix*) given the expected weather conditions and risk of overland flows
- how best to prepare the soil for successful revegetation
- how best to prepare the land surface for successful revegetation (e.g. smooth or rough surface, hard or firm compaction, mulched or un-mulched)
- how best to minimise the risk of long-term erosion that may undermine the short-term success of the site revegetation and/or impact on the pipeline asset.

In the majority of cases, the pipeline corridor should be returned to its pre-disturbance conditions in respect to both land form and surface cover (as recommended in APIA, 2013) however, circumstances can exist where pre-existing land forms will not be stable if reinstated. Some soils become significantly more unstable once disturbed, even if recommended compaction is achieved.

Material characterisation, particularly with respect to dispersive subsoils, is critical in identifying the risks of future tunnel erosion and potential difficulties for site revegetation. Equally, information on soil erodibility can be combined with data on rainfall erosivity to develop regional batter guidelines for slope height, gradient, and target cover levels. Once established, erosion models can be used to rapidly, and at minimum cost, assess a wide range of design options, identify major risks for a specific site and soil conditions, consider impacts of various design storms, and estimate likely costs for sediment clean-up and removal.

The key to successful site rehabilitation is being able to identify those conditions where generic solutions can be applied (i.e. reinstatement of pre-disturbance conditions) and where specialist advice and site specific-site rehabilitation plans will be required. As such, the extent and complexity of the risk assessment must be commensurate with the complexity of the environment, and the extent and complexity of the soil disturbance.

P3.8.2 Slope gradient

Slope gradient influences:

- the ability to apply and hold topsoil or other growing media on the slope
- the complexity of incorporating ameliorants into soil
- the type of machinery needed to prepare the slope and apply revegetation
- the erosion risk presented by overland flows and potential land slips.

It can be difficult to replace and initially retain topsoil on slopes steeper than 1:2 (V:H). The recommended treatment of slopes is provided in Table P10.

Table P10 – Recommended thickness of placed topsoil

Land slope	Recommended topsoil treatment
Steeper than 1:2 (V:H)	• Stair-stepping steep cut batters may assist in securing topsoil. • Coir mesh (or similar) may be used to help secure topsoil on steep batters. • If slopes are too steep for the replacement of topsoil, then give appropriate consideration to the attributes of *Compost Blankets*. • In exceptional circumstances, *Cellular Confinement Systems* can be used to secure topsoil, but **not** at waterway crossings. • All reasonable efforts should be taken to replace topsoil on watercourse banks independent of bank slope. In exceptional circumstances, consideration should be given to the revegetation technique of 'jute bagging', where topsoil and seedlings are placed in small pockets formed from 'thick' jute blanket.
Slopes of 1:2 to 1:3	• Recommended topsoil depth of 50 mm.
Slope flatter than 1:3	• Desirable minimum topsoil thickness of 100 mm; however, consideration should also be given to the original undisturbed topsoil depth.

Slope gradient can significantly influence (or limit) the ability to successfully ameliorate the soil once it has been placed on the slope. Conventional earthmoving equipment can typically operate on slopes up to 1:3 (V:H). This allows soil ameliorants to be cost-effectively applied with broadcast type fertiliser spreaders. The applied chemicals can then be incorporated into the soil using ripper tynes or scarifiers attached to the machinery.

The maximum slope a dozer can walk (up and down a slope) varies with the machine weight and the experience of the operator. Typically the maximum slope is between 1:2 and 1:1(V:H) the latter being under ideal soil conditions. Although it may be possible to apply ameliorants to a steep slope, the difficulty is in mixing the amelioration into the soil without causing permanent vertical scarification marks that can increase the bank's erosion potential.

Excavators with a swivelling head attachment can use the bucket teeth to incorporate soil ameliorants. However, in most instances the depth of amelioration is too shallow and much of the loose soil needed to provide an appropriate seed bed is lost down the slope.

All bank stabilisation measures, including topsoil placement, are subject to damage as a result of excessive overland flows. If a permanent formed cut batter is required (i.e. a landform different from the pre-disturbance condition) then it may be necessary to establish a permanent flow diversion system up-slope of the cut batter.

If the pipeline corridor is reinstated to the pre-disturbance land contours, then the slope may still be subject to erosion if the up-slope catchment is capable of delivering excessive run-on flows. The majority of slope stabilisation techniques are only suitable if flow velocities do not exceed 1 m/s. There is no simple method of determining if excessive overland flows can occur other than performing a normal hydrologic analysis (refer to Appendix A – *Construction site hydrology and hydraulics*).

Independent of the up-slope catchment area, special care must be taken during site rehabilitation if the land fall <u>across</u> the pipeline corridor exceeds 3 metres.

P3.8.3 Suitability of growing media

Readers are referred to Appendix C – *Soils and revegetation* for detailed guidance on soil management and revegetation.

Plants need suitable soil conditions to germinate, grow and persist. During construction the natural soil profile can be substantially disturbed. Typically the focus of this disturbance is over the relatively narrow pipe trench. The practice of excavating, stockpiling and replacing subsoil within the trench can mix soil layers, thereby significantly altering the physical, chemical and biological properties of the soil.

However, in some cases the practice of stripping, stockpiling and respreading the topsoil layer can also result in the mixing of soil properties, especially if there is a substantial change in soil properties between the A and B-horizons (e.g. duplex soils).

RoW stabilisation may also involve revegetating subsoils that, if not adequately treated, will not have adequate soil conditions to sustain plant growth, for example when:

- the stripped topsoil contains excessive weed infestation and/or weed seed, and the construction contract requires the contractor to be responsible for weed management during a specified maintenance phase
- construction practices lead to excessive compaction or structural decline of topsoils
- the pipeline crosses land previously degraded by past farming practices—in such cases, very little natural topsoil may exist on the land prior to the commencement of the pipeline installation.

There are a range of physical, chemical and biological factors that are important for plant growth. These factors are summarised below.

Physical factors include:

- plant available water capacity (storage volume and energy required to extract it)
- infiltration rates and hydraulic conductivity (ability of water to flow into and through the soil, water logging)
- aeration and gaseous exchange (oxygen availability and exchange of carbon dioxide)
- mechanical impedance (seed and soil contact, root and shoot penetration).

Chemical factors include:

- plant available nutrients (particularly phosphorous, nitrogen, potassium)
- soil acidity (nutrient availability, metal and metalloid toxicity)
- cation exchange capacity
- salinity (water uptake)
- dispersion (surface crusting, water logging, chemical erosion).

Biological factors include:

- nitrogen fixation (rhizobium)
- nutrient and water uptake (mycorrhizae)
- organic carbon (nutrient release and cycling)
- raw carbon conversion.

P3.8.4 Soil amelioration

The ability to rapidly establish and then sustain vegetation growth is essential for RoW stability during rehabilitation works. It may therefore be essential to treat all or parts of the exposed soil to ensure that desirable vegetation outcomes are achieved.

A wide range of soil ameliorants are available, and include:

- fertiliser (nutrient deficiencies)
- lime or dolomite (low pH)
- sulfur (high pH, legume stimulant in some conditions)
- gypsum (sodicity, dispersion, and as a clay breaker and to improve soil structure)
- compost (low organic carbon, structure, water holding capacity)
- wetting agents (hydrophobicity)
- biological inoculants (Rhizobium, Mycorrhizae, humates).

The use of ameliorants, along with the selection of type, formulation, rate, and method of delivery of such ameliorants should ideally be based on the pre-construction soil analysis. As in all cases, the extent and complexity of the soil analysis, and the expertise of those providing such analysis, must be commensurate with the potential environmental risk, and the extent and complexity of the soil disturbance.

Ameliorants **must** be mixed into the soil to be effective. Ameliorants applied to the soil surface without mixing may be washed away before appropriate treatment of the soil occurs. For example, ameliorants applied by hydroseeding or *Hydromulching* to steep slopes are likely to be washed off the slope by either rainfall or plant watering.

The depth of amelioration depends on the desired outcome. Common ameliorants for plant growth such as lime, compost and fertiliser are typically incorporated to a depth of 150 mm to 300 mm by ripping. In some situations, such as highly dispersive subsoil exposed by a pipe trench, it may be necessary to incorporate gypsum to a depth of 1 m or more if pre-construction soil testing deems it necessary. For that reason, soil amelioration is most effective if undertaken during soil stripping; that is, the ameliorants are applied to the soil surface prior to soil stripping, thus allowing mixing during the stripping and stockpiling process.

It is extremely difficult to ameliorate the soil 'in-situ' on slopes steeper than 1:3 (V:H). The ability of heavy machinery to scarify the soil and appropriately incorporate ameliorants is highly variable given the range of equipment typically available at pipeline installations. It would therefore be preferable to look for opportunities to incorporate the ameliorants into the soil prior to its replacement on such steep slopes.

P3.8.5 Rehabilitation of waterways

The rehabilitation of pipeline corridors that cross waterways can be a complex issue requiring input from various professionals. The vegetation requirements best suited to the long-term maintenance of the pipelines are often in conflict with the vegetation requirements best suited to the long-term stability and functions of the waterway.

It MUST be accepted that in some circumstances the needs of the waterway will overrule the needs of the pipeline, while in other locations the needs of the pipeline will overrule the needs of the waterway. Unfortunately there is no 'measure' that can be developed that would allow the clear identification of each circumstance.

From an *erosion and sediment control* perspective, the emphasis is on:

- minimising the risk of causing unnatural or undesirable waterway instabilities that could lead to bed or bank erosion and/or exposure of the pipeline, and

- minimising the frequency and extent of future bed and bank disturbances associated with pipe maintenance.

It is acknowledged that establishing the pipe at a depth well below the waterway can reduce the interaction between the pipe and vegetation root system, thus allowing better revegetation outcomes; however, such a design would also increase the cost of construction, and the likely extent of damage to the waterway during pipe installation.

To assist designers in this area, the following **hierarchy** is recommended when considering issues associated with the revegetation of **waterways**. It is acknowledged that such a hierarchy is **not** appropriate for all waterways.

1. Ensure plants placed over the pipeline do not interfere with the structural integrity of the pipe. To the maximum degree practical, pipe crossings should be designed to avoid this problem (e.g. pipe type and depth below bed).
2. Ensure plants placed over the pipeline can be readily removed (including the root ball) in a manner that does not endanger the structural integrity of the pipe.
3. Ensure plants placed over the pipeline do not contribute to channel instabilities (including channel relocation and bank erosion) that would expose or endanger the pipe.
4. Ensure that in waterways containing permanent water, plants established along the water's edge and on the banks do not cause a 'barrier' to fish passage (expert advice will be required in order to assign the importance of bank and water's edge planting to fish passage).
5. Ensure plants placed over the pipeline can be readily removed (including the root ball) in a manner that does not cause undesirable disturbance to the waterway or bank stability.
6. Ensure plants placed over the pipeline do not cause an undesirable break in the movement corridor frequented by terrestrial wildlife.

Of course, in many cases, waterway rehabilitation requirements will be controlled by state legislation and/or waterway permits/licences.

P3.8.6 Revegetation techniques

Table P11 provides a list of common vegetative stabilisation techniques that are applicable to the majority of RoW stabilisation requirements in Australia. The table provides a quick reference for the application and limitations of each technique.

Table P12 summarises the quality control requirements of the various vegetative stabilisation techniques.

Table P13 provides some general guidance on possible plant establishment options for difficult site conditions.

Table P11 – Vegetative stabilisation techniques, application and limitations

Attributes of plant establishment techniques, or preferred site conditions		**Drill & broadcast seeding**	**Hydroseeding**	**Hydromulching**	**Bonded Fibre Matrix (BFM)**	**Hydro-composting**	**Straw mulching**	**Compost blankets**	**Turf**
Maximum grade (V:H)		1:3	1:2	1:2	[9]	[9]	1:2	[9]	1:2
Application:	Topsoil	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Subsoil					[13]		Yes	
Can be incorporated with erosion blankets or TRMs			Yes	Yes	Yes	Yes			Yes
Types of vegetation:	Grasses [1]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Native grass	Yes	Yes	Yes	Yes	Yes		Yes	
	Trees/shrubs	Yes	Yes		Yes	Yes		Yes	
Erosion protection [2]		Nil	Nil	M	M-H	M-H	M	H	H
Incorporation of ameliorants		[6]	[8]	[8]	[10]	[14]	[15]	[16]	Nil
Overland flow conditions:	Sheet flow	Yes	Yes	Yes	Yes	Yes	[17]	Yes	Yes
	Concentrated				[11]	[11]		[11]	Yes
Soil preparation		[7]	[7]	[7]	[7]	[7]	[7]	[18]	[19]
Rate of establishment [3]		Slow	Slow	S-M	M-R	M-R	M	R	R

Notes:

[1] Typically includes cover crops and legumes.

[2] Protection against raindrop impact during plant establishment: M = moderate, H = high.

[3] S = slow, M = moderate, R = rapid, Yes = immediate erosion protection.

[4] Reapplication may be required if materials are displaced by storms or insufficient germination occurs.

[5] Further application of soil amelioration may be required if soil condition remains unsatisfactory.

[6] Soil ameliorants are delivered with the seed. Fertiliser can cause seed burn.

[7] Soil scarification and amelioration of topsoil and subsoil.

[8] Very low. Multiple applications may be required. Ameliorants can be easily washed off the slope.

[9] Generally no limits to bank slope for this application provided operators have good access.

[10] Moderate. Only a small quantity of ameliorants can be retained in the mulch.

[11] Concentrated flow may occur over the ordinary BFM, but only if combined with an erosion control mesh or TRM. Minor concentrated flows can pass over mechanically *Bonded Fibre Matrix Hydromulching* without the incorporation of erosion control mesh or TRM.

[12] Weed control may be required if weeds are present on adjacent lands.

[13] Assuming sufficient organic carbon can be applied to the subsoil by the hydro-compost.

[14] Moderate. Only a small quantity of ameliorants can be retained in the mulch. There is less nitrogen draw down with a hydro-compost than a BFM.

[15] Nil. Ameliorants provided by hydroseeding prior to the application of straw mulch. Hydroseeding has a very low ability to provide ameliorants. The subsoil and topsoil must be ameliorated prior to hydroseeding and the application of straw mulch.

[16] A 50 mm thick compost blanket has an excellent ability to store and leach ameliorants into the soil.

[17] Pneumatically applied straw mulch (applied with a binder e.g. emulsion or polymer) can be used in sheet flows. Hydraulically applied straw-based BFM's can be used in both 'concentrated' and 'sheet'.

[18] Soil scarification and amelioration of dispersive subsoils if present.

[19] Soil amelioration and raking or harrowing to provide an even surface and fine tilth.

Table P12 – Quality control requirements of vegetative stabilisation techniques

Typical quality control issues	**Drill seeding**	**Hydroseeding**	**Hydromulching**	**Bonded Fibre Matrix (BFM)**	**Hydro-composting**	**Straw mulching**	**Compost blankets**	**Turf**
Soil testing	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Soil preparation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Soil amelioration type	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Soil amelioration rate	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Seed germination	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Seed purity	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Seed application rate	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Seed carrier application rate [1]		Yes				Yes		
Binder type			Yes			Yes		
Binder application rate [1]		Yes	Yes	Yes	Yes	Yes		
Mulch type			Yes	Yes		Yes		
Mulch application rate			Yes	Yes		Yes		
Application surface cover [2]			Yes	Yes	Yes	Yes	Yes	
Compost quality					Yes		Yes	
Compost application rate					Yes		Yes	
Turf species								Yes
Turf placement								Yes

Notes:

[1] Where application rate has been specified.

[2] Percentage cover of treated soil, e.g. percentage cover of an square metre of the treatment area. This is <u>not</u> the fraction of the overall soil disturbance or overall work site treated.

Hydromulching

- The rate of plant establishment is slow to moderate.
- Typical organic matter application rate is 1500 kg/ha.

BFM hydromulching and Mechanically Bonded Fibre Matrix

- Requires good quality topsoil for vegetation growth (i.e. the treatment cannot compensate for poor topsoil conditions).
- A minimum organic matter application rate of 3500 kg/ha is required (and recommended) to achieve 100% soil surface cover on raked soil.

Hydro-compost

- Requires good quality topsoil for vegetation growth.
- A minimum organic matter application rate of 3500 kg/ha is required (and recommended) to achieve 100% soil surface cover on raked soil.

Compost blanket

- Can be used where topsoil is of poor quality or non-existent.
- Compost should be applied 25 to 50 mm thick (minimum) depending on slope conditions, supplier recommendations and desired outcomes.

Table P13 – Possible options for site revegetation in difficult locations

Site conditions	Possible responses and issues for consideration
Steep land subject to significant run-on water	• Consider applying a *Jute Mesh* (or similar) to the soil surface, or a combination of a *Jute Mesh* placed over a 'fine' jute *Erosion Control Blanket* to the soil surface. In either case, the topsoil is either seeded prior to application of the jute, or after placement of the jute, the surface is planted with tube stock. • Consider applying a *Compost Blanket* with incorporated seed and non re-wettable tackifier. • Consider applying well staked turf laid across the direction of surface flow. • Though less stable in such conditions, consider applying a *Bonded Fibre Matrix* at the maximum recommended application rate such that 100% coverage (i.e. fibre linkage) is achieved.
Steep land subject to possible high intensity rainfall during plant establishment	• Consider applying an *Erosion Control Blanket*, a *Jute Mesh* over loose mulch, or a *Jute Mesh* over a 'fine' jute blanket to the soil. • Consider applying a *Bonded Fibre Matrix* at an application rate that achieves 100% coverage. • Consider increasing the amount of tackifier used in hydraulically-applied products.
Land unlikely to experience good rainfall in the near future due to drought conditions or the normal dry season	• Consider applying plant seed to the soil, covering with straw, and anchoring the mulch (against wind) with a *Jute Mesh* (or similar). • In either case, the seeded surface can either be: – left unwatered, waiting for seasonal rainfall – watered with imported water to establish a cover crop, which is allowed to die (after watering has stopped) and is then allowed to capture and retain natural wind-blown seed that germinates when seasonal rains return – watered to establish the desired final plant cover.
Land with minimal existing topsoil	• Consider applying a *Compost Blanket* as a replacement. • Consider importing a replacement topsoil. • Both options can be uneconomical in a large scale.
Land subject to high weed infestation due to weed seed content of in-situ topsoil	• Consider burying the in-situ topsoil, and applying a *Compost Blanket* or imported topsoil as a replacement. • Consider thick mulches to control weeds. • Consider applying a 'thick' jute blanket (or similar) to the surface of the reinstated topsoil, watering or rolling to achieve good soil contact, and then planting with tube stock or a seed matrix (e.g. BFM) to the blanket surface.
Land likely to be subject to concentrated flows, such as drainage line crossings	• Consider the benefits provided by jute or coir mesh applied either in isolation, or over a cover of loose mulch or a jute blanket. • Consider a combination of rock, blankets and vegetation as commonly applied to many waterways. • Consider the suitability of initially stabilising the area with a fast-growing, sterile grass, and then planting native seedlings later. Alternatively, use selective herbicides to control the initial grass growth prior to it seeding, followed by the planting of native seedlings.

P3.9 Timing of rehabilitation works

The re-establishment of surface cover on disturbed soils is a fundamental component of reducing the risk of erosion and offsite sediment and turbid water release. Tables P14 and P15 outline the suggested timing of rehabilitation works based on erosion risk parameters and proximity to sensitive receiving environments.

Tables P14 and P15 should not be considered mandatory. Wherever practical, the contracted site rehabilitation conditions (e.g. timing of works and minimum required surface cover) should reflect actual site conditions and outcomes from site specific environmental management studies.

Table P14 – Recommended timing for rehabilitation works based on erosion risk

Site conditions during soil disturbance	Erosion risk rating [1]				
	Very low	Low	Moderate	High	Extreme
Maximum delay before start of site stabilisation [2]	10	10	10	10	5
Maximum days to achieve soil coverage [3, 4]	50	50	30	10	5

Notes:

[1] Erosion risk rating determined from Table P4 typically applied to a given 'corridor segment', but can be applied to a specific sub-catchment or landform such as a permanent cut or fill batter.

[2] Maximum days following completion of pipe laying and trenching or construction works before stabilisation and rehabilitation works commence.

[3] Maximum days following completion of pipe laying and trenching or construction works before the stabilised area achieves the specified soil cover.

[4] Soil cover may consist of organic or rock mulch, synthetic blankets, vegetation or combination there of, as appropriate for the area. Though uncommon in pipeline installation, this may, in certain instances, require the utilisation of techniques that achieve 'immediate' soil coverage with products such as mulch, blankets or turf. Turfing is more likely to be associated with installation of domestic pipe work along a road verge (refer to the ESC standards of the local council or regulatory authority).

Table P15 – Timing for rehabilitation works for specific site conditions

Proximity to sensitive receiving environments	Maximum [1] delay before start of site stabilisation	Maximum [2] days to achieve soil coverage
Identified Good Quality Agricultural Land (GQAL)	10	30
Works within 50 m of an ephemeral watercourse. Works less than 200 m upstream of a cultural heritage site, regional ecosystem, or organic farm.	10	10
Works within the banks of a watercourse that is likely to experience flow within the stabilisation period. Works within 100 m of a watercourse.	5	5

Notes:

[1] Maximum days following completion of pipe laying and trenching or construction works before stabilisation and rehabilitation works commence.

[2] Maximum days following completion of pipe laying and trenching or construction works before the stabilised area achieves the specified soil cover. In some cases this may require the utilisation of techniques that achieve immediate coverage with mulch or *Erosion Control Mats*.

P4 Operation and maintenance phase

During the operation and maintenance phase, RoWs should be inspected after rainfall and flood events to identify any areas of erosion, off-site sedimentation, and poor vegetation establishment. Some common issues and mitigation options are provided in tables P16 to P21.

Table P16 – Management of gully erosion forming along the pipe trench

Potential mechanism of failure	Potential solutions
Issue 1.1: Settlement of backfill has resulted in the collection and concentration of flow along the pipe trench	Steps: 1. Excavate loose material from the pipe trench. 2. Install polyurethane foam trench breakers ensuring that key trenches are cut into the base and sides of the trench if possible. 3. Determine compaction levels of surrounding in-situ soils. 4. Backfill trench with non-dispersive, non-saline fill allowing space for topsoil placement. 5. Compact the backfill. 6. Determine from local experience if the finished level of the trench needs to be above (say 50 mm) adjacent ground levels to allow for expected soil settlement. 7. Place topsoil (if slope is no steeper than 1:2 (V:H) or other suitable growing media and revegetate. 8. Ensure the finished surface does not allow concentration of flow (may require the adjustment of final trench levels and cross banks). 9. Protect with appropriate erosion protection (BFM hydromulch, compost blanket, tree debris, rock, etc.).
Issue 1.2: Excessive up-slope run-on water can: (i) concentrate within the trench (ii) cause soil scour while passing over the trench (iii) cause the displacement of erosion control measures applied to the trench	• Identify opportunities to divert run-on at the top of the slope using structural controls if slope is ≤ 1:3 (V:H). • Identify opportunities to divert lateral flows across the RoW using structural controls if slope is ≤ 1:3 (V:H) and the soils are not dispersive, saline or non-cohesive. • If slope is steeper than 1:3 (V:H) and diversion is required, plant overlapping rows of deep-rooted grasses following implementation of the steps for Issue 1.1 above. • If diversion cannot be achieved, then complete the steps for issue 1.1 above, then armour the slope with tree debris or rock.
Issue 1.3: Flow diversion systems (berms, catch drains, etc.) either do not discharge outside of RoW or have failed	• If lawful to do so, extend the berms such that flows are diverted away from the pipe trench. • If the berms have failed due to overtopping or poor compaction, then re-establish the berm. • If the berm has failed due to dispersion or the presence of non-cohesive soils, then reconstruct the berms with treated soil or apply appropriate ameliorants.
Issue 1.4: Roof of tunnel erosion in trench has collapsed forming a gully	• Investigate the solutions provided in Table P17, and reinstate the trench as per Issue 1.1 above.

Table P17 – Management of tunnel erosion forming along the pipe trench

Potential mechanism of failure	Potential solutions
Issue 2.1: Tunnel erosion associated with poorly compacted backfill	• Identify tunnel inlet points and outlet points. • Treat as per Issue 1.1, but with a focus on achieving non dispersive soil properties.
Issue 2.2: Pipe trench backfilled with dispersive soil	• Identify tunnel inlet points and outlet points. • Remove or adjust any berms or other structural controls that can pond water over the pipe trench. • Treat as per Issue 1.1 using imported backfill or gypsum-treated in-situ soil.

Table P18 – Management of soil erosion due to low surface cover

Potential mechanism of failure	Potential solutions
Issue 3.1: Poor vegetation cover due to animal/stock damage	• Examine options for de-stocking or providing temporary fencing. • If vegetation establishment remains sub-optimal following de-stocking/fencing and adequate rainfall, then test soils, ameliorate if necessary, and re-seed.
Issue 3.2: Poor vegetation cover due to excessive soil compaction	• Scarify along the contour and re-seed. • If scarifying the soil is likely to cause undesirable damage to established root systems, then consider the benefits of heavy mulch/compost application.
Issue 3.3: Poor vegetation cover due to lack of suitable topsoil	• Test in-situ soil for physical, chemical and biological aspects and determine if soil can be ameliorated to form a suitable growing media. • If the slope is too steep, or the soil is too degraded to ameliorate, a proprietary growing media such as a compost blanket may need to be considered.
Issue 3.4: Poor vegetation cover due to unsuitable establishment technique	• Review site conditions to determine primary mechanisms of failure (e.g. seed/soil contact, lack of moisture, temperature, overland or concentrated flow, ant predation, bird predation, soil compaction from stock or vehicles). • Once mechanisms of failure have been determined, identify a more appropriate technique from tables P11 to P13 to address site constraints.
Issue 3.5: Poor vegetation cover due to unknown issues	Steps: 1. Test soil, and if necessary, also test plant tissue. 2. Check if germination tests were performed at time of planting. 3. Check for excessive shading of revegetation area. 4. Test soil compaction relative to adjacent undisturbed ground. 5. Check recent rainfall and scheduled watering records. 6. Check for stock damage. 7. Once mechanisms of failure have been determined, adjust site conditions and replant.

Table P19 – Management of rill or gully erosion along the service tracks

Potential mechanism of failure	Potential solutions
Issue 4.1: Surface of the service track is lower than the adjacent ground surface	• If slope is no steeper than 1:3 (V:H) and soils are non-dispersive or cohesive, install trafficable berms diverting flows away from the pipeline trench if appropriate stable outlet points can be located. • Treat the berms and track with a trafficable polymer or emulsion based soil stabiliser.
Issue 4.2: Runoff concentrates in the wheel ruts	• Adopt the techniques listed above for Issue 4.1. • Import suitable road base/gravel and reshape the track with either crowned or cross fall drainage depending on site conditions.
Issue 4.3: Service track is located <u>along</u> or adjacent to a drainage line	• Extend the rock protection on the track as appropriate to manage the gully erosion. • If suitable rock is not available, apply a trafficable polymer or emulsion-based soil stabiliser to the track surface.
Issue 4.4: Service track is located <u>across</u> a drainage line or ephemeral watercourse	• Ensure a trafficable berm (whoa-boy) is located back from the crest of the high flow bank to prevent run-on water running down the track. • Apply rock stabilisation to the in-bank section of track.

Table P20 – Management of service tracks that cross waterway beds

Potential mechanism of failure	Potential solutions
Issue 5.1: Existing scour protection rocks are displaced by stream/flood flows	• Confirm that the use of rock is appropriate. • Remove rock and replace with rock sized for the flow velocity, but do not adversely impact fish passage. • Rock less than 200 mm may not be appropriate in clay-based creeks.
Issue 5.2: Ford crossing not at bed level, thus potentially impacting on fish passage or bed erosion	• Check with state fisheries if fish passage is an issue. • Remove rock crossing, excavate bed material to the thickness of the rock backfill and reinstall; or consider utilising a different type of crossing.
Issue 5.3: Permanent culvert crossing is damaged by a minor flood event	• Request a professional review of the culvert design. • Check if the damage was caused by excessive flow velocity or debris blockage that is unlikely to re-occur. • Replace rock with rock sized for the design flow. • Reconstruct the culvert crossing with more pipes.
Issue 5.4: Insufficient flow capacity within the low-flow pipes (permanent culvert crossing)	• Request a professional review of the culvert design. • Confirm culvert sizing with local fisheries guidelines. • Ensure sufficient number of pipes are used to cover the full width of the low-flow channel, but preferably the full width of the channel bed. • Ensure pipe length allows for 1:3 (V:H) upstream and downstream batter slopes if rock fill is used.
Issue 5.5: Pipes are not located at bed level (permanent culvert crossing)	• Remove pipes and reinstall at or below bed level (seek local fisheries advice). • Ensure the culvert does not adversely affect fish passage or the natural migration of bed sediments (sand and gravel-based waterways).

Table P21 – Management of damages to waterway bank stabilisation measures

Potential mechanism of failure	Potential solutions
Issue 6.1: Erosion control blanket damaged by concentrated run-on flows OR Failure of an Erosion Control Mesh or Turf Reinforcement Mat (TRM)	• Remove failed blanket/mat. • Determine cause of failure. • If tunnel erosion exists (either initiated in pipe trench or in berms at the top of the bank) then repair in accordance with Table P17. • If a velocity-based failure, then either divert run-on water or replace with appropriate blanket/mesh. • Ensure blankets/mesh are appropriately anchored and overlap in the direction of flow (channel & lateral). • Ensure anchors are appropriate for soil type (e.g. duck-billed anchors for silty or sandy soils).
Issue 6.2: Failure of rock stabilisation or rock-filled baskets	• Determine reason for failure, possible causes include: – stream flows were above the specified design event – post-flood bank slumping – movement of stream bed during a flood – displacement of rock by high velocity flood flows – bank scour immediately downstream of rocks/baskets – tunnel erosion under the rocks/baskets. • Consider benching stream banks that are subject to post-flood bank slumping. • Rock protection should be used with caution in sand-based streams due to bed liquefaction during floods. • If the bank slope exceeds 1:3 (V:H) then ensure the stabilisation measures are linked to a stable bank toe. • If rocks are displaced by flow velocity, then replace with larger rocks or cover existing rocks with vegetation—ideally, the voids between rocks should be filled with soil and pocket planted. • The establishment of deep rooted vegetation at the rock/soil margins is critical on high (>2 m) steep (>1:3) banks where the weight of the rock can increase the risk of post-flood bank slumping. • If the bank protection measures are placed on the outside bank of a channel bend, then ensure the measures have sufficient hydraulic roughness to prevent induced bank scour immediately downstream of the bank protection measures. • Refer to Table P17 for the treatment of bank slumping resulting from tunnel erosion.

P5 Technique selection and treatment standard

P5.1 Introduction

The purpose of this section is to:

- Define a recommended design standard for ESC measures for use in pipeline construction (tables P22, P23 & P24). These tables supersede the equivalent tables and recommendations presented in Chapter 4 – *Design standard and technique selection*.
- Provide general guidance on the selection of drainage, erosion and sediment control measures (sections P5.2 to P5.4).

In many cases, the design standard for ESC measures will be set by the regulating authority, an industry code, or specified with a set of licence conditions. However, if a design standard has not been set, then the design standards outlined below are considered representative of current (2015) best practice.

As outlined within Chapter 2 of this document, Erosion and Sediment Control measures primarily consist of three groups of techniques; those being 'drainage control', 'erosion control' and 'sediment control'. As a general guide, every work site should aim to incorporate control measures from each of these three groups of techniques. However, in pipeline construction it is common for exceptions to this rule to exist.

Both the speed of the construction process, and the environment in which the works often occur, can present circumstances where it is not considered fair and reasonable for all three groups of techniques to be applied to each segment of a pipeline. As a result, it is necessary to outline those circumstances when reduced ESC standards are considered warranted.

Also, it is typical, and in fact strongly recommended, that different design standards (or design storms) are set for each of the key site activities of drainage, erosion and sediment control. An example of this would be the design of a *Flow Diversion Bank*. It would not be unreasonable for the flow velocities adjacent to these banks (or windrows) to be checked for a design storm of only a 4-EY (four exceedances per year), but for any stabilised overflow weirs formed in these banks to be designed for a 1-year or 2-year ARI event. Similarly, a sediment trap may be sized to function appropriately during a 4-EY storm, while the emergency spillway of a *Sediment Basin* may be sized for a 10-year or 20-year ARI storm.

Table P22 – Recommended drainage control standard for pipeline RoW [1]

Site conditions		Required drainage control standard
Average monthly rainfall < 10 mm [2]		• No specific drainage controls required other than the utilisation of topsoil windrows as *Flow Diversion Banks*.
Erosion risk rating for corridor segment [3]	Very low	• No specific drainage controls required other than the utilisation of topsoil windrows as *Flow Diversion Banks*.
	Low	As above plus: • Any formed drainage controls are designed for a 4-EY (four exceedences per year) storm event.
	Moderate	As above, except: • Any formed drainage controls (e.g. *Flow Diversion Banks* and temporary drainage chutes, but <u>not</u> *Cross Banks* (berms) located across the RoW) designed for at least a 1 year ARI storm.
	High	As above, plus: • Spill-through weirs formed into *Flow Diversion Banks* and are designed for at least a 1 year ARI design storm. • Appropriate consideration given to the need for intermediate flow release points for up-slope run-on water collected by the up-slope *Flow Diversion Bank* (windrow). Refer to the discussion in Section P3.3.1. • Appropriate consideration given to releasing locally generated stormwater runoff from the RoW at regular intervals down long slopes to reduce the risk of soil scour along the RoW. Refer to the discussion in Section P3.3.4.
	Extreme	As above, except: • Drainage control standard specified for each individual project based on assessed erosion risk and the potential for causing environmental harm. Otherwise, adopt the drainage design standards specified elsewhere in this document for general construction works.

Notes:

[1] Based on all months during which there is elevated soil disturbance within the RoW, but excludes drainage line and waterway crossings where channel flows can be independent of local rainfall.

[2] Includes all months from time of grubbing and/or topsoil stripping to achieving a soil cover of 40% (independent of specified target soil cover). In arid areas the minimum soil cover may be reduced. This condition supersedes the requirements set out below of various erosion risk ratings, but **only** if the soil disturbance period is **known** to exist wholly within months of low rainfall (< 10 mm).

[3] Refer to erosion risk rating defined in Table P4.

Table P23 – Recommended erosion control standard [1]

Site conditions		Required erosion control standard
All locations:		
Average monthly rainfall < 10 mm [2]		• No specific erosion controls required other than normal best practice requirements for minimising the duration of soil disturbance, and promptly rehabilitating disturbed areas.
Drainage line crossings:		
Rainfall erosivity rating [2]	Very low to low	• No specific erosion controls required other than normal best practice requirements for minimising the duration of soil disturbance, and promptly rehabilitating disturbed areas.
	Moderate	• Use an appropriate down-slope velocity control device (e.g. *Geo Log*) to minimise the risk of soil erosion within the disturbed area of the drainage line. • Give appropriate consideration to the need/benefits for rock stabilisation of the vehicle crossing, and the placement of flow control *Cross Banks* (berms) within the RoW either side of the drainage line.
	High to extreme	• Use an appropriate down-slope velocity control device (e.g. *Geo Log*) to minimise the risk of soil erosion within the disturbed area of the drainage line. • Stabilise the vehicle crossing with rock or similar. • Install flow control *Cross Banks* (berms) across the RoW either side of the drainage line.
Waterway crossing:		
Rainfall erosivity rating [3]	Very low	• No specific erosion controls required other than normal best practice requirements for minimising the duration of soil disturbance, and promptly rehabilitating disturbed areas.
	Low	• Give appropriate consideration to the need/benefits of applying suitable erosion control measures to disturbed in-bank areas as soon as works are completed within the waterway. • Stabilise the vehicle crossing with rock or similar, and install flow control *Cross Banks* (berms) across the RoW either side of waterway. • Recommended minimum 'design discharge' for a vehicle crossings (e.g. temporary culvert) is the expected base flow of the waterway (i.e. no allowance for stream flows elevated by wet weather).
	Moderate	• Apply appropriate erosion control measures to disturbed in-bank areas before and after pipe trenching. • Stabilise the vehicle crossing with rock or similar, and install flow control *Cross Banks* (berms) across the RoW either side of waterway. • Recommended minimum 'design discharge' for a vehicle crossings (e.g. temporary culvert) is twice the expected base flow.
	High to extreme	• Take all reasonable and practicable measures to delay any waterway disturbances until suitable stream conditions exist. • Obtain site-specific advice on waterway stabilisation measures from an appropriate waterway specialist. • Recommended minimum 'design discharge' for a vehicle crossings (e.g. temporary culvert) is the 1 year ARI stream flow. The crossing should be structurally stable during a 2 year ARI stream flow.

Notes:

[1] All measures are in additions to the erosion control measures specified in Table P24.

[2] Based on all months during which there is elevated in-bank soil disturbance.

[3] Refer to the rainfall erosivity rating defined in Table P39 in Section P6.4.

Table P24 – Recommended erosion and sediment control treatment options [1]

Type of crossing	Drainage line crossings		Waterway crossings		
Expected channel flow conditions	**Channel flow unlikely**	**Channel flow possible**	**Stream flow unlikely**	**Stream flow possible**	**Flowing stream [2]**
Ave. monthly rainfall < 10 mm [3]	No specific sediment controls required other than normal best practice ESC requirements for responding to forecast storms			E1 & S2 or S3	E1 & S3
Default	S1 (but all options are possible)	S1, S2, S3 or S4	S1 (only if flows are extremely unlikely) S2 or S3	E1 & S2 or S3	E1 & S5C, S5D, S7C or S7D
Construction equipment requires near-continuous windrows	S1 (but all options are possible)	S1, S2, S3, S4, S6A or S6B	S1, S2, S3, S5, S7A or S7B	E1 & S3, S5C, S5D, S7C or S7D	E1 & S5C, S5D, S7C or S7D
Expanded RoW width allowable at sediment traps	S1 (but all options are possible)	S1, S2, S3, S4 or S6	S1, S2, S3, S5 or S7	E1 & S3, S5 or S7	E1 & S5C, S5D, S7C or S7D

Notes:

[1] Refer to Section P3.3 for discussion on erosion and sediment control options (E1, S1 to S7). It should not be assumed that all listed options for a given category will be appropriate or viable is all circumstances, ultimately it is the task of the ESCP designer to identify which treatment option is most appropriate in any given situation.

[2] Other site issues may require an alternative construction process. Refer to Section P3.6 for further discussion on pipeline construction across waterways.

[3] Based on all months during which there is elevated soil disturbance at the crossing.

Erosion control options E1 (refer to Section P3.3.2) refers to the stabilisation of any exposed or disturbed soil within the drainage line and waterway crossing.

Sediment control options S1 to S7 (refer to Section P3.3.3) refer to the following:

S1 Continuous soil windrows with no specific sediment controls other than that provided by water pooling up-slope of the soil windrows.

S2 A break in soil windrows across the drainage line with a suitable velocity/scour control *Check Dam*, or similar, structure formed across the valley floor.

S3 A break in soil windrows across the drainage line with a Type-3 sediment control system integrated into a suitable velocity/scour control *Check Dam*, or similar, structure formed across the valley floor.

S4 Four layout options, either with a continuous upstream soil windrow (S4A & S4B) or non-continuous upstream soil windrow (S4C & S4D), and with off-stream Type-3 sediment traps.

S5 Four layout options, either with a continuous upstream soil windrow (S5A & S5B) or non-continuous upstream soil windrow (S5C & S5D), and with off-stream Type-2 sediment traps.

S6 As per S4, but with the off-stream Type-3 sediment traps located within an expanded RoW width.

S7 As per S5, but with the off-stream Type-2 sediment traps located within an expanded RoW width.

P5.2 Technique selection – drainage control

Table P25 outlines key features of temporary drainage control techniques commonly associated with the diversion of run-on water along the up-slope boundary of a pipeline RoW.

Table P25 – Techniques for the diversion of clean up-slope water

Technique	Recommended conditions of use
Catch Drains	• Cutting drainage channels into the in-situ soil is generally considered the **least preferred option**, and typically only adopted when the drainage channel will remain as a permanent structure. • Drains used to divert 'clean' water must be suitably lined to prevent clean water coming into contact with exposed soil. • Formal design is required to manage flow velocity and erosion problems associated with poor (dispersive) subsoils.
Flow Diversion Banks [1]	• The use of *Flow Diversion Banks* are preferred if subsoils are dispersive or otherwise highly erodible. • *Flow Diversion Banks* are most commonly formed from topsoil (refer to topsoil windrows below). • Diversion banks formed from local subsoil should be used with caution. • The determination of flow velocity adjacent the bank should assume 2D flow conditions with a flow depth equal to the maximum flow depth adjacent the bank (i.e. hydraulic radius 'R' = max flow depth) rather than on the average flow velocity determined from Manning's equation.
Mulch Berms	• *Mulch Berms* can be formed from imported compost or locally generated (tub ground) mulch. 'Chipped' mulch should not be used for flow diversion. • The mulch must contain some proportion of topsoil to help bind it together.
Topsoil Windrows	• Wherever practical, the stripped topsoil should be stockpiled into stable windrows to act as *Flow Diversion Banks*.

Note:

[1] Average flow velocities within drainage channels have traditionally been determined using the Manning's equation, which adopts a 'hydraulic radius' (R = A/P) as the best representation of flow depth. This approach is appropriate when the channel has a depth and width of similar dimensions. However, if the drainage channel is wide and shallow, as is the case for the hydraulic properties of a *Flow Diversion Bank*, then Manning' equation can grossly underestimate the flow velocity at the point of maximum flow depth. To compensate for this hydraulic problem, flow velocity calculations should be based on the hydraulic radius being set equal to the maximum flow depth (i.e. R = Y); however, the actual discharge (Q) passing down the *Flow Diversion Bank* should be based on normal Manning's calculations with the hydraulic radius being set equal to the ratio: R = A/P.

Tables P26 to P28 outline key features of temporary drainage control techniques commonly associated with the management of soil scour along constructed drainage channels and flow diversion systems.

In general, soil scour within drainage channels can be managed by either slowing the flow velocity through the use of *Check Dams*, or increasing the scour resistance of the channel through the use of a temporary or permanent channel liner.

Table P26 – Velocity control check dams

Technique	Recommended conditions of use
All Check Dams	• Only suitable for use in low to medium gradient (< 10%) drains. • Use with EXTREME caution if the soils are dispersive. Instead, treat the exposed soil or line the drain with a non-dispersive soil. • Critical to ensure water does not spill around the ends of the *Check Dams* causing erosion.
Geo Logs	• Their use is often favourable on pipeline projects. • Use of the smaller-diameter flexible logs, <u>not</u> the larger (> 300 mm) low flexibility jute and coir logs. • Can be used in both shallow (> 400 mm) and deep (> 500 mm) drains.
Gravel-filled Sandbags	• Their use is often preferred if the channel is shallow (< 400 mm). • Use of *Geo Logs* is often preferred because of their quicker installation.
Rock Check Dams	• Can only be used in deep (> 500 mm) drainage channels.

Table P27 – Temporary drain and channel linings

Technique	Recommended conditions of use
Erosion Control Mats	• Suitable for use in both low and steep gradient drains. • A better option than *Check Dams* in shallow (< 300 mm) drains.
Flexible Hydraulically Applied Liners	• Their use depends on the expected life-span of the drain and the expected flow velocity. • Used to provide durable, temporary erosion protection in concentrated flow environments. • Minimal soil preparation required. Can be applied to steep or remote sites using hydromulching equipment. Grass will grow through the liner over time. Observed life to be greater than two years.
Filter cloth	• Typically used to line temporary batter drains and temporary concentrated flow paths that pass across the RoW.
Jute/Coir Mesh	• Best used in medium-gradient permanent drains while a grass cover is being established.

Table P28 – Permanent drain and channel linings

Technique	Recommended conditions of use
Concrete Lining	• Do NOT place directly on untreated dispersive soil. • Often preferred on steep batter chutes. • The finished concrete surface should be flush with the surrounding soil so that lateral flows can enter the channel and minimise the potential for erosion between the concrete and soil. • Should not be used in environments where differential settlement can be anticipated as cracking may occur.
Grass Lining	• The allowable flow velocity depends on the soil condition and the percentage cover of grass. • Soil and climatic conditions must be able to maintain vegetation cover. If not, a TRM or suitable hard armour should be used.
Rock Mattress Lining	• Used to stabilise steep, high-velocity batter chutes and *Sediment Basin* spillways. Best used when large rock is not available or affordable. • Dispersive subsoils will need to be treated otherwise tunnel and gully erosion under or at the edges of the channel can be anticipated. • Channel failures are commonly associated with the finished rock surface being above the adjacent land thus preventing or restricting the free entry of lateral flows into the channel. • The mesh must be appropriate for the environment, e.g. a high gravel bed load may abrade the mesh causing the mattress to fail.
Rock Lining	• Used to stabilise steep, high-velocity batter chutes and *Sediment Basin* spillways. • Dispersive subsoils will need to be treated otherwise tunnel and gully erosion under or at the edges of the channel can be anticipated. • Channel failures are commonly associated with the finished rock surface being above the adjacent land thus preventing or restricting the free entry of lateral flows into the channel.
Turfing	• Best used in medium-gradient permanent drains. • Maximum permissible flow velocity ranges from 1.5 to 2 m/s depending on soil type and grass species. The subsoil must have physical and chemical properties to sustain grass growth. • The turf may need to be anchored to the soils if flow is anticipated before roots have time to penetrate the subsoil.
Turf Reinforcement Mats (TRMs)	• *Turf Reinforcement Mats* are non-biodegradable 3-dimensional mesh designed to interact with the roots and stems of grasses to protect soil in concentrated flow from erosion. • Used to stabilise steep, high-velocity drains that are intended to be grassed. Best used when large rock is not available or affordable. • The two key types are soil or compost filled TRMs and non-soil filled TRMs. Soil-filled 3D poly-amide TRM's are recommended to minimise UV exposure, fire damage, stock damage and animal entrapment. Where suitable topsoil is not available, high quality compost may be substituted. • Anchors/staples must be appropriate for the soil type, e.g. wire staples in clay soils, duck-billed soil anchors in sandy or silty soils.

Tables P29 and P30 outline key features of temporary drainage control techniques commonly associated with the interception and diversion of site runoff (dirty water) to sediment traps.

Table P29 – General drainage techniques

Technique	Recommended conditions of use
Catch Drains	• Cutting drainage channels into the exposed subsoil is generally considered highly undesirable. • Preference should be given to the use of *Flow Diversion Banks* wherever possible, especially if the surface soil is dispersive.
Cross Banks (berms)	• Used to reduce erosion potential of flows by reducing the volume and velocity of the flow along access tracks, travel roads and RoWs. • They may be permanent structures on permanent access tracks, or temporary structures on travel roads and RoWs. • Should not be used as permanent controls where dispersive soils are present on RoWs, due to the high risk of long-term ponding leading to tunnel erosion in the pipe trench.
Flow Diversion Banks	• The use of *Flow Diversion Banks* are preferred if subsoils are dispersive or otherwise highly erodible. • *Flow Diversion Banks* are most commonly formed from topsoil (refer to topsoil windrows below).
Mulch Berms	• The use of *Mulch Berms* to divert 'dirty' water depends on the local stormwater release standards because a portion of the dirty water will filter through the berm and thus will not flow towards the nominated sediment trap. • *Mulch Berms* can be formed from imported compost or locally generated (tub grinded) mulch. 'Chipped' mulch must not be used. • The mulch must contain some proportion of topsoil to help bind it together.
Topsoil Windrows	• Stockpiled topsoil formed into long windrows can be used to capture and direct dirty water flows when the access track is located down-slope of the pipe trench. • If scouring of the up-slope face of the topsoil berm is possible due to the expected flow velocity, then where practical, protect the up-slope face from erosion with applied erosion control measures, or through the use of velocity-control *Check Dams*. • Subject to issues of cost and scour resistance, suitable temporary scour protection measures include: polymer or emulsion geobinder (*Soil Binders*), geofabric, erosion control mesh (≥ 700 g/m^2), grasses and legumes, BFM (*Bonded Fibre Matrix*) *Hydromulch* and hydraulically applied *Erosion Control Blankets*.

Table P30 – Batter drainage techniques

Technique	Recommended conditions of use
Batter Chutes	• Used to direct flows (including 'clean' water) down steep slopes. • Also used to carry concentrated flows down the face of watercourse banks during construction of pipeline crossings. • Temporary batter chutes may be lined with geofabric, flexible hydraulically-applied channel liners, or commercial drains. • Permanent batter chutes are typically constructed from rock, rock filled mattresses or concrete.
Benching	• Used to reduce effective slope length of cut and fill batters, or to increase the stability of reinstated high watercourse banks. • Permanent benching on high risk locations should be designed by a geotechnical engineer. 'High risk locations' refer to the degree of complications and adverse effects that may result from the hydraulic or geotechnical failure of the bench. • Benches cut into dispersive or silty soils have a very high risk of tunnel erosion and slope failure. Extreme care must be taken in their design and construction.
Slope Drains	• *Slope Drains* are temporary pipe drains used to convey stormwater runoff down cut or fill banks, or redirect flows around soil disturbances. • *Slope Drains* may be formed from flexible solid-wall or lay-flat pipes.

P5.3 Technique selection – erosion control

Tables P31 to P34 outline key features associated with mulches, soil binders and erosion control blankets.

Table P31 – Mulches

Technique	Recommended conditions of use
Compost	• Instant erosion control in areas of sheet flow and minor concentrated flow (the latter case may require additional treatment). • **Hydro-compost** is best used in circumstances similar to a Bonded Fibre Matrix, but when the area contains good topsoil cover. • **Compost Blankets** are best used when it is not desirable or possible to replace the original topsoil (e.g. the topsoil contains excessive weed seed, the land slope is so steep it restricts the placement of topsoil, or insufficient topsoil exists).
Cover Crops	• Fast-growing, temporary vegetation cover of the RoW and some embankments.
Mulching	• **Straw mulching** is best suited to site revegetation in cases where water supply is limited and it is important to minimise water loss (evaporation) from the soil. Areas subject to sheet flow only. Caution the potential bio-security (weed) hazard. • **Tree mulch** is used as a form of erosion control when excess tree mulch is generated during initial land clearing. Areas subject to sheet flow only. • **Hydromulch** is possibly best used in temperate zones when weather conditions are not hot, dry or windy, which can result in high soil moisture loss and failure of the hydromulch treatment. Areas subject to sheet flow only. • ***Bonded Fibre Matrix*** is also best used in areas subject to sheet flow, but has the advantage of increased stability during periods of high intensity rainfall during the plant growth phase.
Rock Mulching and Gravelling	• Commonly used as a natural soil cover in arid and semi-arid lands. • Site derived or imported gravel and rock can be placed on the soil surface. • Can be integrated with a *Cellular Confinement System* to allow placement of the rock/gravel on steep slopes. • Can be integrated with grasses to form a *Structural Soil* that can improve a soil's bearing strength when wet, or used to improve a soil's resistance to light traffic (i.e. maintenance access tracks).
Tree Debris	• Commonly applied to steep slopes where the RoW was cleared of natural bushland. • It is not a form of mulch, rather it is used to help anchor or stabilise an underlying applied mulch. • The spreading of site-gained tree mulch over steep slopes can help to maintain sheet flows over the site thus reducing the risk of the underlying topsoil, mulch and applied seed being washed from the site. • Retained or imported timber debris is cut/sheared into short (approximately 1 m) lengths and placed on the contour. It is then track rolled or compressed to ensure intimate soil contact.

Table P32 – Soil binders

Technique	Recommended conditions of use
Soil Binders (geobinders)	• Various soil binders exist including cross-linking and non-cross linking polymers. • They can be used for the stabilisation of stockpile, RoW and temporary embankment protection. • Cross-linking and non-cross linking polymers include: – cross linking and non-crossing hydrocolloids – Lignosulphonates – vegetable oil based – emulsion based. • To minimise erosion due to raindrop impact and minor overland and concentrated flows by: – gluing soil particles together – partially sealing the surface to minimise water ingress, and/or – aggregation of soil particles providing increased water infiltration and reduced runoff. • For stockpile, RoW and embankment protection, give preference to products that penetrate the soil and cause aggregation of the soil particles. • For concentrated flows such as temporary drains, give preference to non re-wettable products that seal the soil.

Table P33 – Stabilisation of windrow overflow weirs, and drainage line and waterway crossings during construction period

Technique	Recommended conditions of use
Filter cloth	• Suitable for short-term use only (i.e. during the active construction phase).
Erosion Control Mats	• These mats typically have a high allowable shear stress. • Can be used during both the construction phase and site rehabilitation phase. • Caution the use of synthetic reinforced mats in waterway habitats where the plastic mesh can entangle wildlife.
Erosion Control Mesh	• Unlikely to provide adequate scour protection to overflow weirs formed in soil windrows. • Typically only used during the rehabilitation of drainage line and waterway crossings. • generally manufactured from biodegradable jute or coir (coconut fibre) mesh. Coir mesh is more durable than jute mesh.

Table P34 – Erosion control blankets (areas not subject to concentrated flows)

Technique	Recommended conditions of use
Erosion Control Blankets (fine)	• 'Fine' or 'thin' *Erosion Control Blankets* are used to promote grass growth and provide raindrop splash and low velocity overland flow protection of newly seeded areas in sheet flow environments. • Typically applied to areas that will be grassed. • Intensive soil preparation is required. These blankets must have intimate soil contact (the soil must be raked smooth, but take care to avoid excessive compaction of topsoils). They must be securely anchored in anchor trenches and pinned at 300 mm centres. The pins must be suitable for the soil type.
Erosion Control Blankets (thick)	• 'Thick' *Erosion Control Blankets* are used to suppress weed growth when planting seedlings, and to provide raindrop splash and low velocity overland flow protection of newly seeded areas in sheet flow environments. • Typically used on areas to be planted with trees and shrubs. • These blankets are typically made from jute or recycled fibres. • Intensive soil preparation is required. These blankets must have intimate soil contact (the soil must be raked smooth, but take care to avoid excessive compaction of topsoils). • They must be securely anchored in anchor trenches and pinned at 300 mm centres. The pins must be suitable for the soil type. • Design life typically less than one year (depending on weather conditions). • Any holes cut for seedlings must be done in a way that minimises the ingress of water under the blanket. • Generally not recommended on pipelines due to their cost and effectiveness compared with hydraulically and pneumatically applied mulches and compost.
Erosion Control Mesh	• Unlike a 'blanket' or a 'mat', a 'mesh' is an open weave fabric that provides minimal protection of soils from raindrop impact; rather these fabrics are used to provide temporary scour control and anchorage of loose mulches and seeded surfaces. • May consist of biodegradable jute or coir (coconut fibre) mesh. Coir mesh is more durable than jute mesh. • Although maximum permissible velocities may be up to 2.3 m/s for short time periods, as the mesh biodegrades the maximum permissible velocity will reduce to that able to be carried by the soil and grass. • Intensive soil preparation, anchoring and pinning is required for this technique to work effectively. The anchors/pins must be appropriate for the soil type, e.g. wire pins in clay soils, duck-billed soil anchors in sandy or silty soils.

P5.4 Technique selection – sediment control

Table P35 – Treatment of sheet flow

Technique	Recommended conditions of use
Fibre Rolls	• Used as a minor (supplementary) sediment trap on cut and fill batters, and to help maintain sheet flow conditions down these batters. • *Fibre Rolls* are typically made from straw or wood fibres contained within a synthetic mesh. • They are more flexible and have a smaller diameter than geo logs.
Geo Logs	• Typically used when it is desirable to combine the functions of a velocity-control *Check Dam* and a minor Type 3 sediment trap. • Typically manufactured from coir or jute. • Typically coir logs are used at the end of cross banks or in drains to trap primarily small quantities of sand-sized particles. • These systems are generally less effective than *U-Shaped Sediment Traps* and excavated sediment traps as it is difficult to achieve an effective seal with the soil to prevent leakage under the logs.
Mulch Berms	• A *Mulch Berm* is either a Type 2 or Type 3 control measure depending on the particle size of the mulch, thickness and height of the berm. • Primarily used to remove silt and sand-sized particles from sheet flow. • *Mulch Berms* must have stable outlets at regular intervals along the RoW to minimise berm failure. • Some regulators are concerned about tannin releases from *Mulch Berms* to waterways. As such, they may require *Mulch Berms* be located at least 20 m away from any watercourse for *Mulch Berms* with a design life of less than 1 month, and at least 50 m away from a watercourse for *Mulch Berms* with a design life greater than 1 month.
Sediment Fences	• A Type 3 control measure designed to trap small quantities of primarily sand-sized particles in sheet flow environments.

Table P36 – Treatment of minor concentrated flow

Technique	Recommended conditions of use
Filter Tube Dams	• Filter tubes can be used to enhance the hydraulic capacity of various Type 2 and Type 3 sediment traps. • Filter Tube Dams can be used in narrow work environments where space does not permit the use of a sediment sump.
Rock Filter Dams	• A Type 2 sediment trap designed to retain primarily silt and sand-sized particles for the design storm event. • Gravel or geofabric may be used as the 'filter component' to assist in sediment retention; however, for short-term installations such as used in pipeline construction, only geofabric filters are recommended.
Sediment Sumps	• An excavated Type 2 or Type 3 sediment trap designed to retain primarily silt and sand-sized particles for the design storm event. • Typically used at the end of a cross bank and at RoW release points.
U-Shaped Sediment Traps	• A Type 3 sediment trap designed to retain primarily silt and sand sized particles for the design storm event. • Typically used in pipeline construction when an excavated sediment trap cannot be used at the end of a cross bank.

Table P37 – Construction exits

Technique	Recommended conditions of use
All Construction Exits	• Used to minimise mud being tracked onto sealed public roads. • Generally all *Construction Exits* are listed as 'supplementary' sediment traps, which means they cannot be relied upon to treat runoff from adjacent soil disturbances.
Rock Pads	• Generally best used in light traffic areas. • Rock sizes 75 to 100 mm are generally avoided due to their increased risk of capture between dual tyres. • Gravel is generally considered unsuitable as a surface material because it contains a wide range of rock sizes and therefore has insufficient void spacing to capture and hold sediment. • Rock or gravel must be placed between the *Vibration Grid* and the sealed roadway to prevent re-contamination of the tyres.
Vibration Grids	• Commonly used in heavy traffic areas, particularly during extended periods of dry weather.
Wash Bays	• Used to wash sediment and weed seeds from vehicles and machinery. • The complexity of design is dependent on the function of the wash-down facility, volume of traffic and anticipated life. A simple bunded rock pad draining to a sediment basin, with a water tank and portable high pressure spray unit may be adequate for most pipeline constructions situations.

Table P38 – Sediment basins [1]

Technique	Recommended conditions of use
Type C Basins	• A Type 1 control sized to capture all sediment sizes from the design storm in coarse-grained soils (refer to Appendix B). • They are not suitable for use in clay or dispersive soil regions.
Type F & D Basins	• Type 1 control sized to capture all sediment sizes from the design rainfall depth in clay or dispersive soils (refer to Appendix B). • Primarily used when turbidity reduction is required. • The embankment should not be constructed from dispersive soil. • Coagulants and flocculants are used to aggregate suspended particles to form larger particles that settle faster. • Ideally should be constructed with a forebay to aid coagulant/ flocculant mixing and reduce sediment removal costs.
High efficiency basins	• Used when it is essential to minimise the size of the basin without reducing treatment standards compared to traditional Type F/D basins.

Note:

[1] Space limitations within the pipeline RoW means that *Sediment Basins* are generally only used on broad-acre ancillary works (e.g. processing plants) and for the treatment of process water and stream de-watering associated with some trenchless waterway crossing procedures.

P6 Overview of planning, construction & maintenance actions

P6.1 Introduction

Planners, designers, contractors and maintenance teams often need to respond to similar site issues. In most cases, the preferred response to any given 'issue' will be the same. This section of the appendix has been presented in order to avoid repetition of key statements, and to provide a single location for the listing of key ESC-related actions.

Unless otherwise stated, it should be assumed that each of the following dot points is preceded with the statement *'All reasonable and practicable measures must be taken to'*. Also, any reference to a 'high' level of rainfall, erosion risk, or other risk-based parameter, should also include 'very high' and 'extreme' levels of that same parameter if such levels exist within the adopted ranking system.

P6.2 Preparation of Erosion and Sediment Control Plans

Activity	Management measures
Design phase	• Ensure the extent and complexity of ESC-related data collection is commensurate with the environmental risk, and the extent and complexity of the proposed soil disturbance. • Ensure the adopted risk assessment procedures are appropriate for the type of works and assessed environmental sensitivity. • Develop 'Primary ESCPs' that outline the 'default' drainage, erosion and sediment control processes for the project. • Ensure ESC measures are only applied in response to a recognised 'need' or assessed environmental risk. • Ensure ESCPs contain sufficient information to allow the specified ESC measures to be adjusted for the season of the year in which the soil disturbance is occurring, and as such, ensure time and money is not wasted installing ESC measures that are not required. • Ensure the extent and complexity of the applied ESC measures are commensurate with the assessed environmental risk, and the extent and complexity of the proposed soil disturbance. • Ensure the cost and time consumption associated with the application of ESC measures are consistent with the expected duration of the soil disturbance and the potential risk of environmental harm. • Ensure the maximum value is obtained from materials won from the site (e.g. rock mulch, organic matter, woody debris) for the control of erosion and aiding site rehabilitation. • Ensure that the adopted ESC strategy is not unnecessarily complex. • Ensure, where practical, ESC measures do not impede safe and efficient construction practices. • Ensure the RoW width, particularly at waterway crossings, is

	sufficient to allow the construction and operation of the required sediment controls (Type 1, 2 or 3) without undue interference to construction activities, including material and pipe deliveries. This may require an allowance for variations in the RoW width at specific locations.
Construction	• Ensure 'Progressive ESCPs' are prepared for any area where the site conditions are significantly different from those assumed within the Primary ESCP, and for all waterway crossings. • Ensure ESC measures are installed in accordance with the specified 'installation sequence'. • Ensure ESC measures are installed, maintained and removed correctly (contract Standard Drawings should provide installation, maintenance and removal procedures for all specified ESC measures). • Ensure that synthetic materials associated with ESC measures (e.g. fabric and stakes) are appropriately removed from the site when they are no longer needed. • Ensure all ESC measures are inspected, and repaired and/or cleaned out if necessary, prior to forecast rain.

P6.3 Management of forward clearing and soil disturbance

Erosion risk rating	Management measures
Very low to low (refer to Table P4 for erosion risk rating)	• Land clearing limited to 8 weeks work if rainfall is possible. • Maximum of 10 days delay after trench backfilling within any corridor segment before commencement of site stabilisation. • Maximum of 50 days after commencement of site stabilisation within any corridor segment before the specified minimum ground cover (e.g. organic or rock mulch, synthetic blankets, vegetation or combination there of) is achieved.
Moderate	• Land clearing limited to 6 weeks work if rainfall is reasonably possible. • Maximum of 10 days delay after trench backfilling within any corridor segment before commencement of site stabilisation. • Maximum of 30 days after commencement of site stabilisation within any corridor segment before the specified minimum ground cover is achieved.
High	• Land clearing limited to 4 weeks work if rainfall is reasonably possible. • Maximum of 10 days delay after trench backfilling within any corridor segment before commencement of site stabilisation. • Maximum of 10 days after commencement of site stabilisation within any corridor segment before the specified minimum ground cover is achieved.
Extreme	• Land clearing limited to 2 weeks work if rainfall is reasonably possible.

	• Maximum of 5 days delay after trench backfilling within any corridor segment before commencement of site stabilisation. • Maximum of 5 days after commencement of site stabilisation within any corridor segment before the specified minimum ground cover is achieved.

P6.4 Weather conditions

Table P39 outlines a procedure for determining the rainfall erosivity rating in circumstances when the likely weather conditions during the time of construction or maintenance are known (i.e. when preparing a Progressive ESCP). This table is different from the 'erosion risk rating' presented in Table P4 because the focus is solely on the expected weather conditions, and not land slope or soil erodibility.

Table P39 – Rainfall erosivity rating [1]

Site conditions during soil disturbance	Rainfall erosivity rating [2]				
	Very low	**Low**	**Moderate**	**High**	**Extreme**
Average monthly erosivity (RUSLE R-factor) [3]	0–60	61–100	101–285	286–1500	> 1500
Average monthly rainfall depth (mm)	0–30	31–45	46–100	101–225	> 225
Forecast rainfall [4]	< 4-EY	< 4-EY	4-EY to 1-EY	1–2yr ARI	> 2 yr ARI

Notes:

[1] This table is used to define a rainfall be adopted in the absence of an adopted regional scale

[2] The R-factor classification system should be given preference over the average monthly rainfall depth in circumstances where reliable monthly R-factor values are available for the local area.

[3] Refer to Appendix E – *Soil loss estimation* for details on the R-factor as used in RUSLE analysis.

[4] Forecast rainfall depth or intensity for an imminent 24 hour period. 4-EY means four exceedances per year in accordance with current Australian Rainfall and Runoff rainfall classification system.

Activity	Management measures
Planning and design	• Where practical, schedule construction works to avoid periods of high rainfall erosivity (Table P39). In particular, this should apply to higher-risk corridor segments such as steep lands or waterway crossings. • Consider specifying within the contract conditions a maximum allowable area of disturbance during specified high-risk months of the year (preferably based on Table P39). • Consider specifying within the contract conditions the minimum percentage cover required on rehabilitated land prior to the commencement of a month with a specified rainfall rating (preferably based on Table P39). • If the annual average rainfall limits the ability to establish vegetation cover (e.g. arid and semi-arid regions) give preference to those RoW alignments and slope gradients that can be considered stable with reduced vegetative cover.
Construction, operation and maintenance	• Where practical, ensure soil disturbances on steep slopes (> 10%) and within 50 m of a waterway are scheduled to avoid periods of high rainfall and/or stream flows (Table P39).

- Minimise forward clearing during months of high to extreme rainfall (Table P39).
- If works are conducted in areas subject to cyclones and/or severe tropical storms, then construction site planning must consider (prior to the wet season) the required response to any such storm warnings, even though such storms are in excess of the adopted 'design' storm for ESC measures.
- Ensure that if runoff-producing rainfall or elevated stream flows are forecast, appropriate temporary drainage and erosion control measures are implemented (in accordance with the technical notes attached to the ESCP) prior to the start of rainfall. If such technical notes do not exist, then appropriate consideration shall be given to:
  - (i) forming temporary diversion berms (e.g. *Straw Bale* or *Geo Log* banks) up-slope of trenches to minimise inflows
  - (ii) lining unstable drains with well-secured (staked, not pinned) filter cloth, *Erosion Control Mats*, or fast-drying hydraulically-applied channel linings (as appropriate for the expected flow conditions)
  - (iii) protecting exposed drainage line and waterway surfaces with filter cloth or purpose-made *Erosion Control Mats*
  - (iv) constructing suitable spill-through points into earth and mulch berms to avoid such structures overtopping at inappropriate locations.
- Ensure that during expected periods of persistent strong winds, appropriate steps are taken to minimise dust, for example, the use of water carts, *Soil Binders, Surface Roughening* techniques and construction scheduling to minimise the duration of soil exposure.
- Schedule rehabilitation works to minimise the duration disturbed soils are exposed to erosive wind, rainfall or overland flow as appropriate for the assessed erosion risk (refer to Table P4, Section P2.4).
- During those months when rainfall is not expected to be sufficient to establish the required surface cover, consider:
  - (i) using, on cut and fill batters, heavy duty *Hydromulches* or *Compost Blankets*, and coated seed (to protect the seed) until suitable rainfall occurs
  - (ii) using soil polymers to provide short-term erosion protection following completion of construction works and undertaking seeding immediately prior to predicted rainfall
  - (iii) identifying and preserving site materials that can be used to provide soil surface protection until suitable vegetation cover can be established (e.g. woody debris, rock mulch).
- If climatic conditions limit the ability to establish vegetation cover (e.g. arid and semi-arid regions) consider identifying and preserving site materials that can be used to provide soil surface protection until suitable vegetation cover can be established (e.g. woody debris, rock mulch).

Operation and maintenance	• Where practical, schedule maintenance works within drainage lines and waterways to avoid periods when rainfall is likely to elevate normal dry weather flow conditions.

P6.5 Topography issues

Activity	Management measures
Planning and design	• Give appropriate consideration to 'land slope' as a factor in pipeline route selection, including safety risks associated with working on cross slopes, the severity of flow velocities passing along the RoW, the desire to reduce the catchment area feeding run-on water into the RoW, and the difficulties of revegetating steep slopes. • Avoid RoW alignments that require the permanent formation of cut and fill batters; instead, aim to always return the RoW back to the natural contours. • Where options exist, select alignments where run-on water can be temporarily diverted away from the RoW. • Utilise ridge lines wherever possible. • Specify the spacing of trench breakers relative to trench slope in order to minimise the risk of tunnel erosion.
Construction, operation and maintenance	• To the maximum degree practicable, aim to release water from the RoW (during both construction and operational phases) in a manner similar to the pre-disturbance condition. • Utilise temporary drainage control measures on slopes less than 18% to reduce the adverse impacts of run-on stormwater flows, but only when exposed soils are not dispersive, and suitable discharge points exist. • Seek expert drainage/erosion control advice if: (i) slopes exceed 18% (ii) the dispersion hazard rating is high (Table P3) (iii) slopes are considered too steep for placement of topsoil (iv) stable flow release points do not exist. • Ensure trench breakers are suitably keyed into the base and sides of the trench. • Ensure that if compaction standards are not specified, trench backfill is compacted to a soil compaction equivalent to the surrounding (in-situ) soil on steep slopes and other areas where the risk of tunnel erosion within the pipe trench is a major concern. • If final land contours are not provided, ensure that pre-disturbance contours are re-established. • Favour slope stabilisation solutions that maintain pre-construction sheet flow conditions. • On slopes steeper than 10% (either down or across the RoW) identify and preserve site materials that can be used to help stabilise disturbed soils and help maintain sheet flow

	conditions down the slope (e.g. woody debris, rock mulch). • Consider the practicality of erosion control measures (e.g. trafficable spray-on soil stabilisers) to provide soil stabilisation during the rehabilitation phase.

P6.6 Soil issues (supplementary to APIA, 2013, Section 9.6)

Activity	Management measures
Planning and design (all soils)	• Ensure the extent and complexity of collected soil data is commensurate with the potential environmental risk, and the extent and complexity of the proposed soil disturbance (refer to Section P2.3). • Ensure sufficient information on the appropriate management of problematic soils is provided with the construction contract, or otherwise ensure the contract specifies a level of consultation with soil experts that is commensurate with the potential environmental risk, and the extent and complexity of the proposed soil disturbance. • When traversing cropping land: (i) the objective should be to minimise changes to the 'value' of the land for agriculture (ii) soil testing (type and density) shall occur in consultation with a soil specialist and the land owner/operator (iii) subsoils are sampled to the full depth of the pipeline trench to identify if adverse soil properties increase with depth (iv) where necessary to achieve the specified outcomes, and where sufficient space exists within the RoW, the most problematic subsoil is stockpiled separately, and is the first to be backfilled in the trench (v) soil amelioration shall occur in consultation with a soil specialist and the land owner/operator (vi) for acid soils, soil amelioration is carried out to a depth of at least 1.0 m.
Acid soils	• Refer to APIA (2013) Section 9.6.8.
Acid sulfate soils (actual or potential ASS)	• Refer to APIA (2013) Section 9.6.3. • Soil testing, sampling locations and treatment to be conducted in accordance with state-approved guidelines.
Arid or semi arid soils	• Refer to APIA (2013) Section 9.6.6.
Expansive/reactive soils	• Refer to APIA (2013) Section 9.6.4.
Hard-setting soils (Planning and design)	• Ensure surface soil amelioration, mulch application, and watering program are signed-off by the project's soil specialist and revegetation contractor.

Hydrophobic soils (Planning and design issue if soil is identified during this phase, otherwise a construction issue)	• Identify and preserve site-generated organic matter that can be respread over the hydrophobic soils as a mulch during rehabilitation works. • Ensure soil treatment specifications supplied to revegetation contractors give appropriate consideration to the use of wetting agents. • Ensure specifications for rehabilitation works include contouring and scarification to encourage the ponding and infiltration of water.
Saline soils (Planning, design and construction)	• Refer to APIA (2013) Section 9.6.5. • Soil testing, sampling locations and treatment to be conducted in accordance with regional soil-conservation / land-management guidelines. • Ensure careful selection of suitable species for revegetation.
Shallow rocky soils	• Refer to APIA (2013) Section 9.6.9.
Slaking or sodic (dispersive) soils	• Refer to APIA (2013) Section 9.6.2. **Planning and design issues:** • Wherever practical, favour pipeline alignments that minimise longitudinal gradient with the aim of minimising the potential for tunnel erosion. • Use trench breakers at regular intervals to minimise tunnel erosion in the pipe trench. The trench breakers must be keyed into the base and sides of the trench. **Construction issue:** • Take all reasonable measures to minimise the mixing of the topsoil with the dispersive and/or slaking subsoils during trenching, stockpiling and backfilling. • Consider gypsum treating dispersive backfill prior to backfilling to minimise the risk of tunnel erosion, especially immediately adjacent any waterway crossing. Ideally the upper 300 mm of the sodic soil should be treated with gypsum to reduce ESP to approximately 4% or less, and/or capped with a 300 mm layer of (site sourced) non-dispersive soils. • Compact the trench spoil to the equivalent compaction of the surrounding soil on steep slopes and other areas where the risk of tunnel erosion within the pipe trench is a major concern.
Soils of low fertility	**Planning and design issues:** • Prepare rehabilitation specifications that include soil fertility amendment where appropriate. **Construction issue:** • Schedule forward topsoil stripping works to minimise the duration topsoil is stockpiled to help maintain soil fertility. • Within cropping land, take all reasonable measures to

	protect topsoil stockpiles from wind and water erosion with the primary objective being to minimise the loss of fertility from the rehabilitated land. • Avoid mixing topsoil and subsoil.
Wetland soils	• Refer to APIA (2013) Section 9.6.7.

P6.7 Water management

Activity	Management measures
Planning and design	• Where options exist, select alignments where run-on water can be temporarily diverted away from the RoW.
Construction, operation and maintenance	• Ensure topsoil flow diversion windrows (if any) are installed as soon as possible. • To the maximum degree practicable, ensure water is released from the RoW in a manner similar to the pre-disturbance conditions. • Minimise the risk of soil erosion along drainage line crossings of the RoW either by: (i) stabilising the exposed soil with rock, geotextile mat, or other suitable material, or (ii) minimising the velocity of flows passing over exposed soil (e.g. by minimising the hydraulic gradient of the flow through the use of velocity-control *Check Dams* or other drainage/sediment control measures, such as Geo Logs). • Maintain sheet flow conditions across the rehabilitated area wherever practical. • Stabilise rehabilitated areas with appropriate *Erosion Control Matting* or similar if these areas are likely to be subjected to unacceptable erosion risk as a result of concentrated flow. • If final land contours are not provided, ensure that pre-disturbance contours are re-established. • If it is not practical to release run-on water at regular intervals from the **rehabilitated** RoW, or in a manner that simulates pre-disturbance conditions, then take reasonable steps to ensure a formal drainage design is prepared before establishing final land contours. • Favour slope stabilisation solutions that maintain pre-construction sheet flow conditions.

P6.8 Gully and drainage line crossings

Activity	Management measures
Planning and design	• Give preference to route options that avoid the crossing of actively eroding gullies. • If the pipeline must cross an active gully, then either: (i) set the pipe invert below the expected long-term bed elevation of the gully, or

	(ii) design appropriate scour protection measures to avoid the future exposure of the pipe.
Construction, operation and maintenance	• Schedule construction activities for periods when surface flows are least likely. • Minimise the extent and duration of works within gullies and drainage lines to the shortest time possible. • If the soils exposed within the pipe trench are dispersive, then ensure: (i) trench breakers are installed as close as possible to the gully (usually below top-of-bank) but beyond the likely extent of future bank erosion (ii) trench breakers are keyed into the base and sides of the trench (iii) the excavated trench in the region of the gully's bed and banks is backfilled only with suitably treated soil. • Compact the trench spoil to a compaction equivalent to the surrounding soil (the *intent* being to reduce the risk of tunnel erosion within the trench, and to avoid the redirection of groundwater flows passing through the backfilled trench). **Gullies only:** • Unless otherwise directed within a drainage plan, install a flow diversion bank at the top-of-bank to temporarily divert run-on water away from all disturbed gully banks both during the construction and rehabilitation phases. • Where appropriate, provide temporary fencing adjacent to the bank rehabilitation to minimise the risk of animal or vehicle damage to the gully banks.

P6.9 Waterway crossings

Activity	Management measures
Planning and design	• Give preference to route options that minimise the number of waterway crossings. • Consult with appropriate experts (creeks or rivers) with regards: (i) waterway stability (ii) expected movement of bed sediments (iii) preferred bed and bank stabilisation methods. • Give preference to route options that cross waterways at: (i) stable channel sections not subject to concentrated lateral inflow that could initiate lateral bank erosion (ii) a straight channel reach, or the mid point between channel bends (iii) pools, not riffles (if a pool-riffle system exists); however, pools are often located at channel bends, and riffles at inflection points, so there are many circumstances where

	the riffle is more likely to be located at the most stable section of the channel reach. • Give preference to route options that avoid: (i) permanent flowing waterways (ii) permanent pools within ephemeral waterways (iii) situations where it would be necessary to alter the natural bed conditions in order to protect the buried pipe (iv) sections of waterway containing unique, protected, or critical riparian vegetation, for example, mature canopy trees that provide shading of habitat pools (v) sections of waterway that are likely to experience future bed lowering that may expose the pipeline (vi) actively eroding channel banks, such at the outside of channel bends (vii) waterway reaches containing dispersive subsoils (viii) waterway reaches that contain deep layers of bed sediment that are likely to mobilise during severe floods. • Refer to additional measures listed in the following table that address issues related to specific types of waterways.
Construction, operation and maintenance	• All works to comply with local waterway policies, codes and approvals. • Select the construction method based on an appropriate risk-based process—refer to APIA (2013). • Wherever practical, schedule construction activities within waterways for periods of least flow, and periods when elevated (storm related) stream flows are least likely. • Minimise the duration of works within flowing waterways. • Maintain the maximum soil surface cover below the low bank, particularly where dispersive soils are present. This may require a narrowing of the RoW in the region of the waterway. • Minimise forward clearing of the waterway banks, especially below the low bank, even if forward clearing occurs above the elevation of the low bank. • Minimise the contamination of stream flows passing through the RoW. • Give preference to the use of off-stream sediment control systems (i.e. dirty water pumped to sediment traps located on the floodplain) instead of instream sediment traps. • Give preference to work practices that avoid the need for, and use of, instream sediment control systems. • Maintain fish passage as required by state regulators/ fisheries. This may require consultation with fisheries experts with regards to potential impacts of temporary barriers or sediment control measures.

- Ensure soil and other material stockpiles are located:
  (i) outside any area from where the material could reasonably be expected to wash into the waterway
  (ii) outside the bankful zone (i.e. stockpiled above the elevation of the low bank)
  (iii) outside the riparian zone (if such actions aid in reducing the required clearing of riparian vegetation).
- Manage stormwater runoff from travel/access roads in a manner that minimises harm to the waterway. This may require such runoff to be diverted through sediment traps or an adjacent riparian filter before entering the waterway.
- Ensure temporary vehicle access crossings of waterways are either located at bed level, or just above the dry weather water level, and are structurally stable during the 2 year ARI (39% AEP) flow event.
- Ensure vehicle crossings are constructed from clean durable rock primarily 200 mm in diameter or larger, with geofabric underlay (the *intent* being to minimise disturbance to the bed, minimise the risk of rocks being washed away if flows overtop the crossing, and minimise sediment releases into the waterway).
- Strip topsoil from the waterway channel (below the low bank) in a manner that best preserves the natural riparian seed bank, but only if the RoW requires the re-establishment of natural riparian vegetation (which may not be desirable for all pipeline crossings).
- If soils exposed on the banks are dispersive, slaking or non cohesive, then ensure:
  (i) trench breakers are installed as close as possible to the waterway (usually below top-of-bank) but beyond the likely extent of future bank erosion
  (ii) trench breakers are keyed into the base and sides of the trench
  (iii) the excavated trench in the region of the waterway's bed and banks is backfilled only with suitably treated soil
  (iv) top-of-bank flow diversion systems do not allow dispersive, slaking or non cohesive soils to be exposed to surface flows.
- Compact the trench spoil to a compaction equivalent to the surrounding soil (the *intent* being to reduce the risk of tunnel erosion within the trench, and to avoid the redirection of groundwater flows passing through the backfilled trench).
- Wherever possible, restore the natural (pre-construction) bed conditions to the waterway.
- Unless otherwise directed within a drainage plan, install a flow diversion bank at the top-of-bank to temporarily divert run-on water away from all disturbed waterway banks both during the construction and rehabilitation phases.

	• Apply appropriate erosion control measures to disturbed areas of the waterway banks for the purpose of minimising rill erosion, minimising the risk of initiating lateral bank erosion, and minimising the disturbance of introduced revegetation measures. • Unless otherwise directed by a waterway expert, use stream flow re-directive techniques and vegetative erosion control measures on stream banks instead of hard engineering scour control techniques. • Identify and preserve site materials (e.g. rocks and tree debris) that can be used safety to enhance post-works erosion control on the waterway banks. Such measures may not be appropriate in all circumstances. • Where appropriate, provide temporary fencing adjacent to the bank rehabilitation to minimise the risk of animal or vehicle damage to the banks.

P6.10 Management issues associated with specific waterway types

Activity	Management measures
Alluvial (sand and gravel-based) waterways	• Locate the pipe at an elevation that is below any mobile bed material, such as deep sand or gravel, that is likely to be mobilised during severe floods. • Ensure any pipe scour protection measures are finished flush with the solid bed material and do not extend into the bed load material that is expected to move (migrate) during severe floods. • Exercise extreme care when using rock bank stabilisation measures in sand-based creeks as the rock can slump and fail when the sandy bed liquefies during severe flood events. If rock is used, then it must rest firmly on stable channel bank material (i.e. bank slopes of 1:3 (V:H) of flatter may be required). • Never place rock, rock-mattress, or hard armouring measures directly on sandy bed material.
Clay-based waterways	• Avoid introducing sand and gravel sized materials to clay-based creeks, particularly on temporary access tracks, as these materials, if displaced by unexpected high flows, can damage bed and bank vegetation in high flows. • Favour vegetative solutions over hard armour solutions where possible.

P7 Glossary of terms

Bankful elevation – A water surface elevation estimated by various procedures that describe the channel flow condition preceding significant overbank flow. If *benches* are well established within the channel, then significant *overbank flows* might occur prior to the inundation of the floodplain. To avoid erroneous and/or highly variable results, bankful elevation should not be determined by the shape of a single cross-section, but with observations made along a length of the channel.

Catchment – That part of a drainage catchment, including the land up-slope of a pipeline corridor, that would naturally drain to a single waterway or drainage line passing through the pipeline corridor.

Corridor segment – That part of an individual ‘catchment’ that is contained within the pipeline corridor or Right-of-Way. In effect, this is the full surface area of the pipeline corridor from hilltop to hilltop.

Cross bank (berm) – A mound of earth constructed across a RoW or track with a channel on the up-slope side so that runoff is effectively diverted from the RoW or track to a suitable discharge area. Cross banks can convey larger flows than cross drains. They need to be constructed of material that won't scour, particularly where maintenance budgets / regimes are not guaranteed.

Drainage line – A lower category of watercourse or drainage swale that does not have clearly defined bed or banks. It carries water only during or immediately after periods of heavy rainfall, and riparian vegetation may or may not be present.

ESC – Means ‘Erosion and Sediment Control’. This term includes and control measures that fall under the headings of temporary ‘drainage control’, ‘erosion control’ and ‘sediment control’.

ESCP – Means ‘Erosion and Sediment Control Plan’. These plans include generic ESCPs, Primary ESCPs and Progressive ESCPs.

Expert – Means a person suitably trained (either through formal tertiary training and/or on-site training) and experienced (meaning having successfully managed or addresses similar situations or issues in the past) within a given topic or activity. For example, a ‘waterway expert’ would require appropriate tertiary training river morphology or creek engineering, as well as field experience managing waterways for the same type as that experienced on a site.

Filter cloth – A non-woven geofabric used as a coarse filter in the sediment control industry, or to separate different soil/rock groups within a manufactured soil profile.

Generic ESCP or Generic Primary ESCP – A Primary ESCP that is not specific to a given location or pipeline project. These plans are typically applied on low risk projects and during regular maintenance activities.

Geofabric – A woven or non-woven fabric used in soil engineering.

Geotextile – A woven fabric used in soil engineering.

Gully – An open, incised erosion channel in the landscape generally deeper than 30 centimetres. These are ‘drainage lines’ that have experienced recent (in geological terms) erosion, and as such, may or may not be stable at the time of pipeline construction.

High bank – The high bank normally defines the outer limits of the floodplain. In circumstances where a waterway has a well defined floodplain, and the far reaches of the floodplain are defined by a well defined topographic feature (i.e. bank) then the high bank is the top elevation of this topographic feature. In circumstances where a waterway does not have a well defined floodplain, but consists of a deep irregular or multi-staged trapezoidal channel, then the high bank may be defined as the highest bank of the channel.

Low bank – The low bank of a waterway is usually defined by the elevation of the lowest floodplain (assuming a floodplain exists on both sides of the main channel). If the waterway has only one floodplain, then the low bank is the waterway bank that immediately adjoins the floodplain. If the waterway does not have a well defined floodplain, then the low bank may be defined as the lowest bank of the main channel. The 'low bank' should not be confused with the channel bed or banks immediately adjacent the low-flow channel that would regularly flood when the waterway experiences elevated flows.

Low-flow channel – The channel or portion of a waterway bed that contains waterway discharge (i.e the low-flow or base flow) that cannot be directly attributed to recent storms. It includes any regular, long-term inflows such as environmental flows from regulated lakes or reservoirs. This low-flow is usually not constant throughout the year, and typically varies with groundwater levels and long-term weather conditions.

Primary ESCP – An overarching ESCP that demonstrates general drainage, erosion and sediment control practices for the whole construction project. Typically these plans are produced during the planning and design phase.

Progressive ESCP – Detailed ESCPs developed as the project progresses and the actual site conditions and time of year of the soil disturbance are known. These plans provide up-to-date details on the location and installation of the required ESC control measures, and are usually prepared at the expense of the contractor.

Rainfall erosivity – A numeric representation of the ability of soils to resist the erosive energy of rain that considers texture, organic matter content and soil dispersion.

Riparian zone – That part of the landscape adjacent to a waterway that influences, and is influenced by, waterway processes. Usually includes the instream habitats, beds, banks and floodplains of waterways, or their parts. As a guide only, in partially cleared catchments, the retained riparian zone (measured from the water's edge) should be as wide as the top-of-bank width, or three times the bank height, whichever is the greater.

Sub-catchment – Any sub-section of a drainage catchment, whether temporary or permanent, that drains to an individual drainage control measure, sediment trap, or flow release point from the pipeline corridor. A 'sub-catchment' is typically the drainage area considered when designing an individual flow diversion system or sediment trap.

Top-of-bank width – In circumstances where the main waterway channel can be clearly distinguished from the floodplain, and the low bank is defined by the elevation of the lowest floodplain, then the top-of-bank width is the channel width measured at the elevation of the low bank.

Waterway/watercourse – A channel with defined bed and banks, including any gullies and culverts associated with the channel, down which surface water flows on a permanent or semi-permanent basis or at least, under natural conditions, for a substantial time following periods of heavy rainfall within its catchment.

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P8 References

1. Australian Pipeline Industry Association, 2013 Code of Environmental Practice Onshore Pipelines.
2. Canadian Association of Petroleum Producers (CAPP), Canadian Energy Pipeline Association (CEPA) and Canadian Gas Association (CGA), 2005 Pipeline Associated Watercourse Crossings. Prepared by TERA Environmental Consultants and Salmo Consulting Inc. Calgary, AB.