Stage 2 Kerosene Vale Ash Repository
Sawyers Swamp Creek Draft Rehabilitation Plan

April, 2008

Delta Electricity

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Contents

DRAFT

List of tables

List of figures

List of appendices

DRAFT

1. Introduction

In accordance with the Environmental Assessment requirements under Part 3A of the Environmental Planning and Assessment Act 1979 issued by the Director General of the Department of Planning (27 February 2007), this document has been prepared to fulfil the following requirement: "The Environmental Assessment must include a draft Rehabilitation Plan for Sawyers Swamp Creek."

1.1 Background

In 2002 Delta Electricity assessed the use of Kerosene Vale Ash repository (KVAR) as an area for the placement of ash generated from Wallerawang Power Station (WPS). This assessment determined that the area over KVAR could be divided into two operational areas; areas that could be used without the need for engineering stability works (Stage 1) and areas that required engineering stability works prior to use (Stage 2).

Approvals for Stage 1 were obtained in 2002. This area has an operational design life of 5 years and is nearing its capacity. Stage 2 involves the expansion of the ash placement area, and will have the capacity to continue the placement of ash over KVAR for a further 11 years.

The engineering stabilisation works required for use of the Stage 2 area include the construction of a toe berm to ensure the stability of the KVAR embankment. Construction of this toe berm would require the realignment of an approximate 380 metre length of Sawyers Swamp Creek (Douglas Partners, 2001). The location of the proposed stability berm and requirement for the creek realignment are illustrated in Figure 1 and Figure 2, provided in Appendix A of this report.

This report presents a draft rehabilitation plan for the reach of the Sawyers Swamp Creek extending from the open channel below Sawyers Swamp Creek Ash Dam (SSCAD) to the Lidsdale cut. Particular focus is given to the section of the creek that is proposed to be realigned to allow for construction of the toe berm.

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1.2 Assessment objectives

The primary objective of this assessment is to develop a draft rehabilitation plan for the abovementioned reach of Sawyers Swamp Creek, incorporating a design for the realignment of the channel in the vicinity of the proposed KVAR toe berm. The assessment addresses the Director General of the Department of Planning's Environmental Assessment requirements for the project (Letter dated 27 February, 2007).

The assessment addresses the following key areas:

- development of rehabilitation objectives for Sawyers Swamp Creek
- design parameters for the proposed creek realignment
- rehabilitation of Sawyers Swamp Creek, including sections beyond the proposed realignment works as per the Department of Water and Energy requirements
- an overview of construction techniques and issues
- operational maintenance and monitoring requirements.

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2. Site context

2.1 Locality

The KVAR is located to the east of the village of Lidsdale, which is situated approximately 2.5 kilometres to the north east of WPS. The WPS is located approximately 10 kilometres north west of Lithgow.

2.2 Catchment drainage

The KVAR is located within the upper reaches of the Coxs River catchment, which forms part of the Hawkesbury-Nepean River system. Sawyers Swamp Creek flows in a westerly direction past KVAR to join the Coxs River approximately 2 kilometres downstream. Further details of regional and site drainage characteristics are discussed in the Surface Water Impact Assessment Report (PB, 2007a).

2.3 Existing creek alignment

The existing alignment of Sawyers Swamp Creek is significantly altered from its natural course. This has occurred as a result of previous mining and ash storage activities. The existing alignment of Sawyers Swamp Creek is shown in Figure 1 (Appendix A).

Key modifications within the catchment that have led to the existing channel alignment include:

- Construction of SSCAD — the original path of the creek passed through the middle of the existing SSCAD. A concrete channel was constructed to divert surface water from the upper reaches of Sawyers Swamp Creek around the southern boundary of the SSCAD.
- Mining and coal storage activities — the original path of the creek flowed through an area that has been used for coal storage.
- Construction of KVAR — while the natural course of the channel is understood not to have passed through the KVAR area, the existing channel alignment has been influenced by the construction of KVAR and currently flows around eastern and northern sides of the existing KVAR.

2.4 Existing flows

The Sawyers Swamp Creek catchment, upstream of the section proposed to be rehabilitated, is steep and densely vegetated. The catchment has an area of approximately 9.5 square kilometre; approximately 8 square kilometres of this drains to SSCAD, with only 1.5 square kilometres draining directly to Sawyers Swamp Creek. Flows generated from the 8 square kilometre catchment area are contained within SSCAD for all storm events up to the 100 year ARI event, based on advice from Delta Electricity (*pers. comm* Delta Electricity, 4/10/07). Water collected within SSCAD is pumped to the WPS for treatment.

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There are no flow records for Sawyers Swamp Creek. A hydrologic model was developed to determine flows generated from the catchment. Details of this modelling are provided within the surface water impact assessment report and the flows modelled in Sawyers Swamp Creek just upstream of the reach to be realigned are indicated in Table 2-1 below.

A digital terrain model was developed from survey data obtained from Craven, Elliston & Hayes (Lithgow) Pty Ltd (survey undertaken September 2007) and used to develop a hydraulic model of the existing channel (detailed in Appendix B). The hydraulic model was used to gain a better understanding of the flow regime within the existing and proposed creek alignments. The digital terrain model and hydraulic modelling indicate that the flood flows generated from the catchment upstream of KVAR are not contained within the existing main creek alignment. The existing channel is broad and not well defined in the bend near Centennial Coal's coal storage area (refer Figure 1, Appendix A). It is at this location that the hydraulic modelling predicts a significant portion of flow will divert from the creek alignment during flood events and flow in a north-westerly direction through the former coal storage area.

Modelling indicates that during flood events of a 2 year average recurrence interval (ARI) and above, spill out of the channel will occur. During extreme flood events (100 yr ARI event) it is estimated that approximately half of the peak flow will leave the main channel and flow in a north-westerly direction.

Table 2-1 Existing flows in Sawyers Swamp Creek

Location	2 Year ARI flow (m^3/s)	100 Year ARI flow (m^3/s)
Prior to point where water leaves main channel.	5.9	12.7
After point where water leaves main channel (in section to be realigned).	4.3	5.9

2.5 Existing channel condition

Sawyers Swamp Creek is a highly modified creek with little resemblance to its natural course in the vicinity of KVAR and SSCAD. The channel is relatively straight and has steep, eroded banks along much of its length. The channel substratum varies from shale bedrock to sections of soft clay and silt (The Ecology Lab, 2007). Further, bore logs located on the site indicate that geology of the site generally comprises sandy clay to between 5 and 7 metres underlain by shale and sandstone (PB, 2007b). This soil type generally has a high water erosion risk.

The existing channel was constructed approximately 40 years ago, with little to no apparent effort to reinstate natural features or protect the channel bed and banks from erosion. The channel appears to be over enlarged for the flows likely to be experienced. This is thought to be a result of over-design of the excavated channel and ongoing bank erosion. As a result, the existing channel has steep, eroded banks, shallow flow, is congested with dense reed growth, has minimal variation in bed material, and little hydraulic diversity. Pool and riffle sequences are typical of streams of this nature but are absent from this reach of the creek.

An assessment of the aquatic ecology of the creek, conducted as part of the preparation of the environmental assessment for the proposed KVAR Stage 2 operations, concluded that the creek is in a relatively degraded condition (The Ecology Lab, 2007). Riparian vegetation is sparse and comprises a mixture of native and exotic trees, shrubs and grasses.

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3. Creek rehabilitation

3.1 Approach

The rehabilitation plan proposed for Sawyers Swamp Creek has been developed based on guidance and principles presented in *A Rehabilitation Manual for Australian Streams* (CRCCH & LWRRDC, 2000) and *Works and Watercourse Design Guideline* (DWE, April 2007). The plan incorporates the section of the creek from the open channel below SSCAD to the Lidsdale cut. Rehabilitation of this section of the creek has been considered within three reaches: the reach upstream of the proposed realignment; the reach that is proposed to be realigned; and the reach downstream of the proposed realignment. The key focus of the plan is on the section of the creek that Delta Electricity proposes to realign to allow construction of a toe berm to stabilise the proposed embankments of the Stage 2 area of KVAR. Rehabilitation of Sawyers Swamp Creek in the reaches that are not proposed to be realigned would focus on preserving and stabilising the existing environmental habitat.

3.2 Rehabilitation objectives

Key objectives of the rehabilitation plan and concept creek realignment design are to:

- Ensure the geomorphic stability of Sawyers Swamp Creek and the long term stability of the proposed channel realignment.
- Maintain the existing hydrological flow regime within the catchment.
- Develop a naturalised channel, generating additional aquatic and riparian habitat and other local and regional ecological benefits.
- Provide a riparian buffer zone to assist in future protection and rehabilitation of Sawyers Swamp Creek's ecological value.

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3.3 Design flows

The realigned channel is designed to convey bankfull flow from the upstream catchment. Bankfull flow can typically be considered to be approximately the flow during a 2 year ARI event (CRCCH & LWRRDC, 2000). Assessment of the current flow regime within Sawyers Swamp Creek (refer Section 2.4) indicates that the 2 year ARI flow within the section of the creek to be realigned is 4.3 m^3/s. This flow has been adopted as the design flow for the realigned channel.

3.4 Proposed realignment planform

The proposed alignment for the section of Sawyers Swamp Creek that is proposed to be realigned is shown in Figure 1 (Appendix A). The alignment planform has been developed based on an assessment of physical site constraints and a combination of the historical reconstruction, reference reach and empirical catchment model approaches as outlined in *A Rehabilitation Manual for Australian Streams*. Further details of each of these approaches as they were applied for development of the concept alignment are provided below.

Key characteristics used in the discussion below to describe the alignment are defined in Figure 3-1.

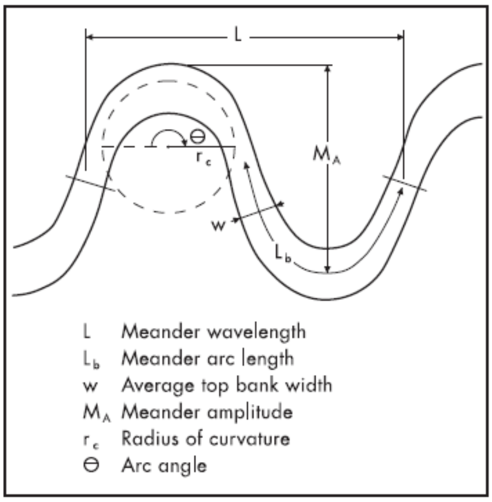

Figure 3-1 Variables used to describe planform of a stream (Source: page 118, Volume 2, CRCCH & LWRRDC, 2000)

3.4.1 Physical site constraints

The key physical site constraints to the creek realignment include:

- The creek must fit within the area between the toe of the stability berm to the south and the property boundary to the north.
- Space for an access road and toe drainage has been allowed for at the toe of the stability berm.
- The realigned creek should join into the existing creek prior to reaching the culvert under Private Coal Road.
- The creek must tie in seamlessly to the existing watercourse at either end of the section to be realigned.

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The proposed realignment of Sawyers Swamp Creek would necessitate relocating the internal road located to the north of the existing channel alignment and removing the culverts that are located approximately 100 metres upstream from the point where Sawyers Swamp Creek flows under Private Coal Road. Replacement of this crossing is not proposed following the removal of the culverts. As a result, traffic within the site will use the Private Coal Road to cross Sawyers Swamp Creek.

3.4.2 Historical reconstruction approach

This approach to stream design aims to reconstruct the original condition of the stream from available historic information. An old alignment of Sawyers Swamp Creek was identified on the 1:25 000 topographic map of Lithgow, showing the creek flowing in a north-westerly direction from the SSCAD. This historical alignment is indicative of site conditions after the construction of SSCAD, and prior to the diversion of the creek to its current location between KVAR and the coal storage area. However, it is unknown if this was the natural course of the creek.

It is not considered feasible or desirable to attempt to return Sawyers Swamp Creek to its historical course. The existing alignment of the creek has been established for a period of around 40 years; relocating the creek back to its historical alignment would destroy the existing ecological habitat and communities established within the lower reaches of Sawyers Swamp Creek. Further, the historical alignment of the creek would pass through areas that have been identified for potential future mining activities. This indicates that adopting this option may result in future realignments of the creek, which is not considered desirable for long-term creek rehabilitation.

While the historical alignment of the Sawyers Swamp Creek does not represent the preferred realignment option, features of the historical alignment are important to consider for incorporation into the proposed channel alignment. The historical alignment is relatively straight, with very few meanders within the channel. A channel slope of approximately 1% is indicated on the topographic map.

3.4.3 Reference reach approach

The reference reach approach aims to identify a reach nearby that is in good condition that can be used as a template for the design. At this stage of the realignment development a desktop study was carried out to identify potential references reaches to guide the planform design. During detailed design, reference reaches may be further investigated in the field to inform the design process in relation to in creek features, bed materials and variation in vertical alignment.

Given the disturbed nature of the Sawyers Swamp Creek catchment and surrounding areas, reference reaches were sought from catchments in the immediate vicinity of the site. Three reaches within separate catchments were identified, of which two were used as reference reaches for the aquatic ecology assessment (Kangaroo and Marangaroo Creeks). These reaches and their key characteristics are shown in Table 3-1. These characteristic were used to provide an indicative range of planform parameters for the proposed realigned section of Sawyers Swamp Creek.

Table 3-1 Reference reach approach creek characteristics

Kangaroo Creek  (Image source: Google maps, http://maps.google.com/ accessed 18/10/07)	*Key characteristics:* ▪ location: ~ 5km north of Sawyers Swamp Creek ▪ upstream catchment size: ~$10km^2$ ▪ estimated bank full flow: ~$40m^3/s$ ▪ top width of channel: ~ 8m ▪ meander wavelength: ~ 50m to 200m ▪ meander arc length: ~ 20m to 100m ▪ radius of curvature: ~ 25m to 100m ▪ channel slope:~ 1% (source 1:25000 series topographic map: Lithgow).

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Marrangaroo Creek

(Image source: Google maps, http://maps.google.com/, accessed 18/10/07)

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Key characteristics:

- location: ~ 5 km south of Sawyers Swamp Creek
- upstream catchment size: ~ 35km^2
- estimated bank full flow: ~140m^3/s
- top width of channel: ~ 14m
- meander wavelength: ~ 300m to 400m
- meander arc length: ~100m to 300m
- radius of curvature: ~100m to 200m
- channel slope: ~ 0.5% (source 1:25000 series topographic map: Lithgow).

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Pipers Flat Creek

(Image source: Google maps, http://maps.google.com/, accessed 18/10/07)

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Key characteristics:

- location ~ 5 km south west of Sawyers Swamp Creek
- upstream catchment size: ~ 60km^2
- estimated bank full flow: ~240m^3/s
- top width of channel: ~ 18m
- meander wavelength: ~ 50m to 1000m
- meander arc length: ~20m to 800m
- Radius of curvature: ~10m to 500m
- channel slope: ~0.3% (source 1:25000 series topographic map: Lithgow).

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Kangaroo Creek provides the most suitable reference reach, as the catchment characteristics are most similar to that of Sawyers Swamp Creek.

A summary of the characteristics of the above reference reaches is provided in *Table 3-2.* As a means of comparison, typical relationships for meander arc length and radius of curvature are 4 to 9W and 1.5 to 2.5W respectively (CRCCH & LWRRDC, 2000).

Table 3-2 Reference reach method: creek characteristics

Reference reach	Estimated bankfull width (m)	Meander arc length (as multiplier of width(W))	Radius of curvature (as multiplier of W)
Kangaroo Creek	8	2.5W – 12.5W	3W – 12.5W
Marrangaroo Creek	14	7W – 21W	7W – 14W
Pipers Flat Creek	18	1.1W – 44W	0.5W – 27W

3.4.4 Empirical catchment model approach

The empirical approach applies empirical relationships based on hydraulic geometry and regime equations to predict a channel form to adopt for design to provide geomorphic equilibrium. The 'alignment first' approach, as outlined in *A Rehabilitation Manual for Australian Streams* (pg. 140), was adopted. This approach determines suitable ranges for the meander arc length and radius of curvature as functions of the average bankfull width such that a stable channel alignment can be defined.

The bankfull width used to develop the stream characteristics outlined in Table 3-3 below was determined using the Manning equation for normal flow in a channel. Channel characteristics used in this calculation are detailed in Section 3.5 below. The width of the existing channel has also been used in this assessment.

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Table 3-3 Empirical method creek characteristics

	Bankfull width (W)	Meander arc length (4 - 9W)	Radius of curvature (1.5 – 2.5W)
Calculated channel (refer Section 3.5)	9.2m	37m to 83m	14m to 23m
Existing channel	Varies – 10 to 14m	56m to 126m	21m to 35m

3.4.5 Proposed creek alignment

The proposed alignment shown in Figure 1 (Appendix A) was developed by applying the range of parameters defined using the three methods outlined above and determining a creek alignment that fits within the physical site constraints. Table 3-4 indicates the range adopted for characteristics of the proposed alignment.

Table 3-4 Proposed concept creek alignment characteristics

Parameter	Concept design range
Bankfull width	9m to 12m
Meander wavelength	45m to 90m
Meander arc length	20m to 70m
Radius of curvature	15m to 50m
Channel slope	1.2% - will vary with addition of pools and riffles during detailed design

3.5 Realigned creek cross sections

3.5.1 Capacity

An approximate size of the required cross sections for the realigned section of creek was determined using the Manning equation for normal flow, assuming a trapezoidal channel. The main channel was sized to contain the 2 year ARI flow, with the 100 year ARI flow contained within the riparian zone. Details of the adopted preliminary design parameters are provided in Table 3-5. The Manning's roughness coefficient (Manning's n) adopted is representative of the established stabilised channel, with winding sections, vegetation, snags, stones, and some pools and riffles (Adopted from Table 15, CRCCH & LWRRDC, 2000). A typical preliminary cross section is shown in Figure 2 (Appendix A).

Table 3-5 Preliminary design: cross-section typical parameters

Parameter	Design Size
Design flow	4.31 m^3/s
Base width	2m
Side slopes	1V: 5H
Depth	0.65m
Manning's n	0.045
Channel slope	1.2%

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3.5.2 Cross-section variation

The preliminary design parameters presented above represent a typical cross section of suitable capacity to contain the bankfull (2 year ARI) flow. The proposed creek realignment will incorporate variation in cross sections along the channel to provide hydraulic variability, and to allow aquatic habitats and a more naturalised channel to establish. The following features would be incorporated into the channel at appropriate locations during detailed design:

- A low flow channel — this channel would be allowed to form naturally within the base of the main channel as a result of low flows.
- Variation in bank slopes — as indicated in Figure 2, banks would be designed to have slopes varying from 1 vertical in 5 horizontal to 1 vertical in 10 horizontal.
- Variation in flow depth and velocity — this would be provided through incorporation of pool and riffle sections, and vegetation within the channel.
  - Riffle sections would be incorporated into the channel at inflection points between bends and would be spaced at approximately 5 to 7 stable channel widths (similar to the range in meander arc length). Riffles would be constructed using a variation of snags and rock. Appropriate sizing of material for construction of riffle sections would be determined during detailed design, and would ensure that riffle material is resistant to erosion. Riffle sections would also be designed with consideration of the ecological habitat requirements of endemic aquatic fauna. Local material would be sourced for construction of riffle sections where available.

- Pools would form as a result of the backwater created from the riffle sections and from bed scour at termination of riffles. Pools would also form at locations with highest scour velocities (typically at bends). Pool and riffle sequences would be designed to ensure velocities are slowed in sections upstream of riffle sections, minimising the potential for excessive scour and erosion at bends.
- Vegetation would be planted on the banks and within the bed of the main channel to assist with the establishment and growth of macrophytes. This would enhance channel stability, maintain water temperatures through shading, create hydraulic variability along the channel, provide aquatic habitat and assist in the achieving a more naturalised channel. Species endemic to the area would be planted, with specific species determined during detailed design. Options for sourcing seed from areas adjacent to the rehabilitation area would be assessed to ensure that local intra-species genetic variability is maintained where possible. A vegetation management plan would be developed in conjunction with the detailed channel design, which would aim to ensure long term stability and management of vegetation, both in-bank and within the riparian zone.

3.6 Riparian zone

3.6.1 Proposed realignment

A riparian zone will be provided on either side of the realigned creek to assist in stabilising the creek banks, to provide shade (temperature control), assist in improving the water quality of runoff to the creek, and to provide ecological habitat. The riparian zone would be extended upstream to the bend where water leaves the main channel during high flows and downstream to where the creek crosses Private Coal Road (refer to Figure 1, Appendix A).

The riparian zone has been designed to be a minimum of 20 metres from either side of the top of the bank of the channel (defined as the area that contains the 2 year ARI flow). The 100 year ARI flows within the realigned section of the creek would be contained within the riparian area. The typical cross-section shown in Figure 2 (Appendix A) indicates how the riparian zone would be incorporated into the realigned section of the creek.

The riparian zone would be planted with species that are endemic to the area and considered beneficial to the ecology of the creek. Details of the species to be incorporated would be determined during detailed design. A vegetation management plan would also be prepared in conjunction with the detailed design. This plan will be developed in accordance with Department of Water and Energy guidelines (*How to prepare a vegetation management plan guideline*, DWE March 2007) and will aim to ensure long-term stability and management of the riparian area and long-term enhancement of native vegetation communities in the area. The vegetation management plan would also consider options for incorporating the rehabilitated riparian zones into local habitat corridors.

3.6.2 Reaches adjoining the proposed realignment

The primary rehabilitation efforts proposed within the reaches either side of the proposed realignment would focus on vegetation management.

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Within the reach upstream of the proposed realignment, there is limited space available to develop a riparian zone. The right hand side of the bank contains the steep embankment of SSCAD; the left hand side of the bank contains a narrow strip of land, approximately 20 metres wide, between the creek and the embankment of the KVAR. It is proposed that this 20 metre corridor of land be incorporated into the Sawyers Swamp Creek riparian zone and that the preservation and enhancement of vegetation in this area is incorporated into the vegetation management plan that would be established for the proposed realigned reach.

Similarly, it is proposed that within the reach downstream of the proposed realignment, a 20 metre corridor on either side of the creek would be incorporated into the Sawyers Swamp Creek riparian zone and that preservation and enhancement of vegetation in this area is incorporated into the vegetation management plan.

Opportunities to mitigate local erosion and scour issues within these reaches would be identified and investigated as part of the detailed design; however, it is noted that the preservation of the limited established habitat is imperative.

3.7 Geomorphic stability

3.7.1 Proposed realignment

One of the key objectives for rehabilitating Sawyers Swamp Creek is to ensure the long term stability of the proposed channel realignment. The approach taken in developing the concept design aimed to ensure that a stable creek alignment and cross-section would result. Additional features would be incorporated into the channel during detailed design of the creek realignment. It is proposed that these features would include:

- Incorporating pools and riffles into the channel — as discussed in *Section 3.5.2*, pool and riffle sequences would be incorporated into the channel design. Riffle sections would be designed with snags and rocks which would be sized to ensure protection against erosion. Riffle sections would also be designed such that pools form at the bends upstream and at the termination of riffle sections. The formation of pools would result in slower velocities, which in turn would assist in reducing the potential for scour and erosion.
- Incorporating vegetation within the creek bed and banks — vegetation growing within the creek bed and on the creek banks increases the channel roughness and hence reduces flow velocities close to the bank. Slowing of flow velocities would result in reduced scour. Vegetation also directly strengthens bank material, making it harder to remove from the bank face. Particular attention would be given to developing vegetation growth on the outside of meander bends, as these areas tend to be subject to higher flow velocities and shear stresses. Appropriate species would be investigated and selected during detailed design. Weed management measures would be implemented as part of revegetation.
- Establishment of riparian vegetation — riparian zones would be established for a minimum of 20 metres from the top of bank of the realigned channel. These areas would be planted with endemic species to assist in achieving stability of the land surrounding the creek, which would enhance the stability of the channel during flood flows. Weed management measures would be implemented as part of revegetation.

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In order to protect and enhance newly established and existing riparian habitat, weed management measures would be implemented as part of the rehabilitation plan for the realigned section of Sawyers Swamp Creek. Weed management measures would include:

- Preventing germination and establishment of weeds within the creek channel (new and existing) and adjacent riparian areas through active weed control. Weed control techniques would vary depending on the species to be targeted and the area to be treated.
- Development of a weed control strategy as part of the project construction environmental management plan.

3.7.2 Reaches adjoining the proposed realignment

The stability of sections of Sawyers Swamp Creek that are not proposed to be realigned would be enhanced through vegetation management within the riparian corridors (including weed management), as discussed above. Any requirement for additional planting within these areas would be assessed during development of a revegetation strategy during preparation of the construction and/or operation environmental management plan(s).

The reach upstream of the proposed realignment currently consists of a relatively steep, straight channel that is subject to bank erosion. In-stream rehabilitation/realignment works are not proposed for this reach due to access difficulties and limited space being available to adapt the channel. Incorporating in-stream controls, such as establishment of riffle and pool sections, may prove beneficial and options for this will be considered during detailed design of the creek rehabilitation plan.

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3.8 Preliminary design evaluation

The preliminary design for the realignment of a section of Sawyers Swamp Creek has been evaluated using the hydraulic model HEC-RAS (refer to Appendix B for details of modelling and modelling results). The model was used to assess:

- the capacity of the realigned channel to contain design bankfull flows
- the capacity of the realigned channel to contain flood flows during a 100 year ARI event
- any changes to the existing flow regime, particularly in relation to any changes to the flow leaving the main channel and flowing through the coal storage area
- average velocities within the channel and potential for scour.

3.8.1 Channel capacity

Hydraulic modelling indicates that the 2 year ARI flow would be contained within the main channel. Additionally, the 100 year ARI flow would be contained within the riparian zone.

3.8.2 Changes to flow regime

Naturalising the channel and incorporating riffle and pool sequences would increase the roughness of the channel and slow flows within the main channel. Modelling indicates that this would cause a marginal increase in the flow leaving the channel at the bend near the coal storage area, and hence decrease flows down the realigned section of the channel. The proposed realignment of the channel aims to result in no change to the existing flow regime within Sawyers Swamp Creek. During detailed design of the proposed creek realignment, further assessment would be made of the suitability of adopted roughness values and opportunities to undertake any works required to assist in retaining flows within the channel in this section of the bend.

3.8.3 Potential for scour

The potential for scour within the proposed creek realignment has been assessed by comparing predicted channel velocities and shear stress to literature values relating to maximum permissible velocities and shear stress to prevent scour. A range of values are reported in the literature, which are dependant on factors including soil type, vegetation cover, and channel slope. Table 3-6 below summaries a range of values applicable to Sawyers Swamp Creek. Further assessments of appropriate design maximum velocity and shear stress would be made during detailed design in relation to the soil type and proposed vegetation cover.

Table 3-6 Literature values: maximum permissible velocity and shear stress

	Maximum permissible velocity (m/s)	Maximum permissible shear stress (N/m^2)
Bare soil	0.5[1]	3.6[2]
Grass mixture	1.2[1]	101[3]
Aquatic (swampy) vegetation	-	105[4]

Source:
1. Chow, 1981
2. Stallings, 1999
3. Fishchenich, 2001
4. Prosser and Slade, 1994

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Velocities and shear stress predicted by the modelling are summarised in Table 3-7 below. Channel velocities and shear stresses are shown only, as these are predicted to be significantly higher then overbank velocities and shear stresses. The summary provided in the table indicates that the proposed channel would be less prone to scour then the existing channel. Detailed design would incorporate additional measures into the creek design to reduce this further. The results of the literature studies show that bare soil has very little ability to resist erosion, therefore, the design would incorporate interim measures to stabilise the creek bed and bank until vegetation establishes within the realigned creek.

Table 3-7 Modelled channel velocity and shear stress during the 100 year ARI event

	Channel Velocity within reach proposed to be realigned (m/s)	Channel Shear Stress within reach proposed to be realigned (N/m^2)
Existing creek alignment (Section 409.29 to 67.26)	0.76 – 2.30	9.45 – 105.38
Proposed creek alignment (Section 434.94 to 67.26)	0.79 – 1.92	13.1 – 102.18

4. Construction

The construction of the proposed creek realignment would be undertaken in a manner designed to minimise environmental disturbance and mitigate risks associated with construction of this type. The northern part of the proposed realignment site has previously been used as a coal stockpile area. Preparation of this area for construction would include removal of any coal on the ground surface associated with previous mining and storage activities to prevent this material from entering the proposed creek realignment. Prior to cutting the creek channel, topsoil would be stripped and stockpiled, to be replaced on cut surfaces prior to revegetation. Site layout and channel access points for excavation equipment would be located to protect established riparian vegetation. The realigned creek channel would be formed in isolation from the existing channel, with diversion of flows only occurring following completion of environmental and erosion control features, planting, and stabilisation of cut surfaces.

The topography of the area and the proposed construction sequence effectively minimises many of the risks associated with flooding and erosion by isolating the creek realignment construction area from the existing creek. Runoff from the creek realignment works area would naturally flow in a northerly direction away from the existing creek. Despite the low risk of the works, erosion and sediment control measures would be implemented to protect any potential receptors by managing erosion at source rather than relying solely on sediment capture at discharge. Natural vegetation would be maintained where possible to minimise disturbed areas, which can contribute to sediment loads. Where the design would require clearing of vegetation, stabilisation of exposed surfaces and slopes would be undertaken as soon as possible following completion of earthworks. An erosion and sediment control plan for the construction phase would be prepared during detailed design in accordance with *Soils and Construction: Managing Urban Stormwater* (Landcom 2004).

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5. Monitoring and maintenance

During detailed design, performance and completion criteria would be established for the proposed creek realignment and riparian zone. A program to monitor and maintain the realigned creek and associated riparian zone would also be developed. The monitoring and maintenance program would include assessment of erosion and scour, management of exotic weeds, and contingency plans to respond to any potential failures of the realigned creek channel or planting carried out in the riparian corridor.

As recommended in the aquatic ecology assessment undertaken for the project, post-realignment monitoring should be undertaken to determine the success of the creek realignment in achieving the stated objectives. As part of the monitoring program, an assessment of Sawyers Swamp Creek before and after realignment against the two reference sites would be undertaken. At least two sample periods before and two sampling periods after realignment would be required as well as the establishment of an additional sampling site downstream of the realigned section of creek to provide replication at a site level. The monitoring program would require greater focus on the quantitative data provided by macroinvertebrate samples, water quality, macrophytes and variables representing physical stream processes.

In addition to the above, the monitoring programs proposed as part of the surface and groundwater impact assessments would also be implemented and provide feedback as to the success of the proposed realignment. The proposed surface water monitoring program should be based on the existing monitoring undertaken at the site. This currently involves quarterly monitoring at 4 surface water locations across the site (2 located within Sawyers Swamp Creek, 1 within Dump Creek and 1 within the SCCAD). A detailed groundwater monitoring program, which also encompasses surface water quality at the likely groundwater discharge zones (Sawyers Swamp Creek), would be developed and implemented. During the first 12 months of Stage 2 activities monitoring should be undertaken on a monthly basis, and if impacts are not observed during this time could then continue on a quarterly basis.

As previously stated, this draft document has been prepared in accordance with the Environmental Assessment requirements under Part 3A of the Environmental Planning and Assessment Act 1979 issued by the Director General of the Department of Planning (27 February 2007). The final Sawyers Swamp Creek Rehabilitation Plan will be submitted to the Department of Planning for approval prior to the commencement of any construction activities.

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Appendix A

Figures

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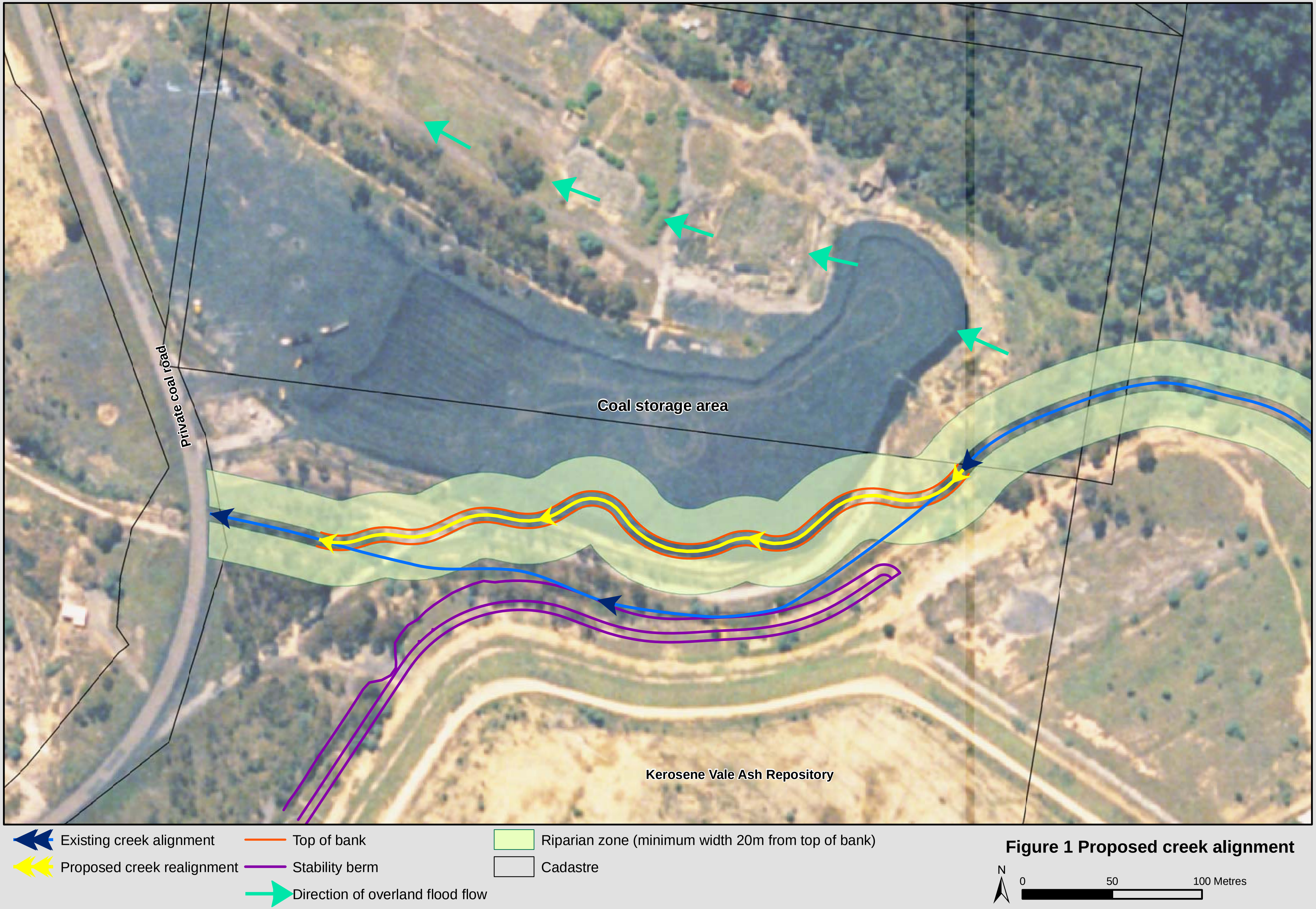
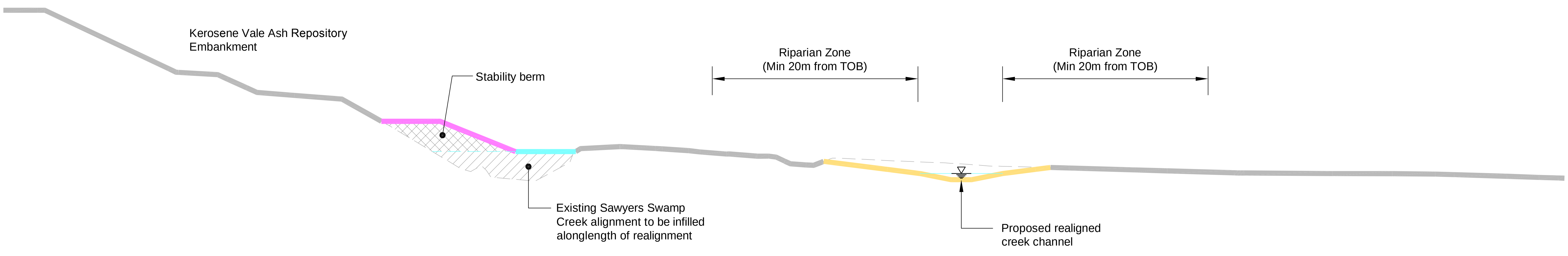
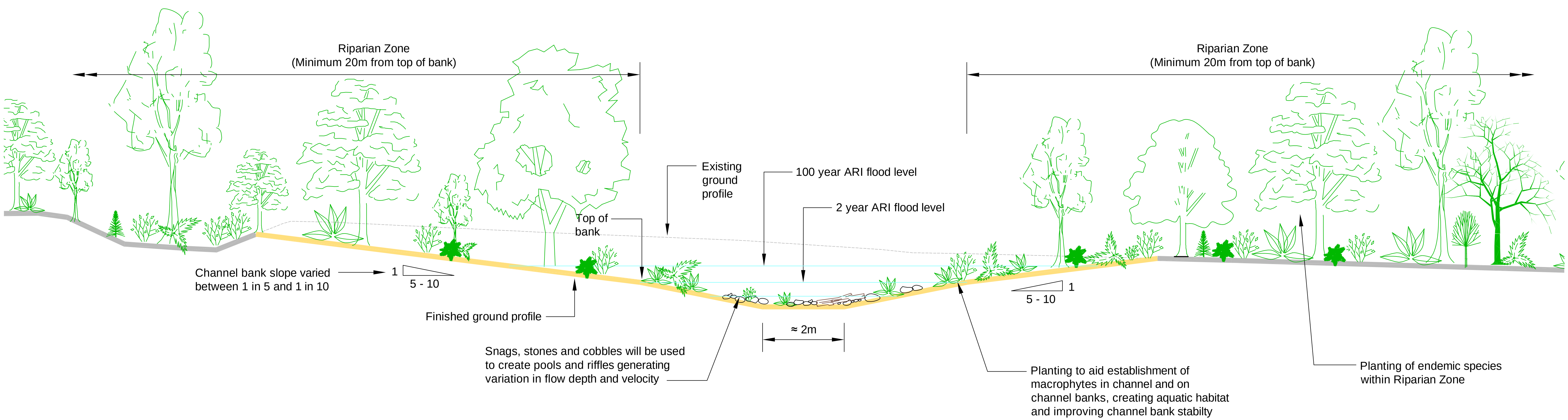


Figure 1 Proposed creek alignment

J:\A353-ENVPLN\PROJ\2116669A_EMA_Kerosene_Va\10_GIS\Projects\ArcView\2116669A_2021_Creek_realignment.mxd COD 15 Oct, 2007

Client: Delta Electricity
Project: Stage 2 - Kerosne Vale Ash Repository
Location: Sawyers Swamp Creek Realignment





Typical Cross Section of Realigned Channel

Figure 2

Plot Date: 17/10/07 - 09:39 Cad File: J:\A354-HAZ\PROJ\2115206A__Stg__2__Kerosne__V\09__CADD\DRAWINGS\2115206A-ENV-F001.dwg

Appendix B

Hydraulic modelling – HEC RAS

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Overview

A hydraulic model of the section of Sawyers Swamp Creek proposed to be realigned was developed using the computer model HEC-RAS. This model was used to gain a better understating of flow behaviour within the existing channel and to evaluate the design for the proposed realignment.

Description of HEC-RAS

HEC-RAS is a hydraulic model developed by the United States Army Corps of Engineers. It has been developed from the HEC 2 model that has been widely used for flood modelling over the past 25 years both in Australia and the United States.

HEC-RAS calculates water surface profiles assuming steady state or gradually varied flow. It is able to simulate flows in branched river systems. The steady flow component can model subcritical, supercritical, and mixed flow regimes.

The basic computational procedure of HEC-RAS for steady flow is based on the solution of the one-dimensional energy equation. Energy losses are evaluated by friction and contraction/expansion. The momentum equation may be used in situations where the water surface profile is rapidly varied. These situations include hydraulic jumps, hydraulics of bridges, and evaluating profiles at river confluences.

Model setup and input parameters

Model layout

The HEC-RAS model was developed from a digital terrain model of the existing land surface, which included detailed channel section survey. The digital terrain model was developed using the computer package 12D and is based on survey data obtain by Craven, Elliston & Hayes (Lithgow) Pty Ltd during survey undertaken during September 2007. Details of the creek alignment were defined in the digital terrain model, including information relating to the creek centreline, location of left and right banks and location of cross-section to define the main channel and floodplain geometry. The River Module within the 12D computer package was used to create a HEC-RAS file containing details of the existing geometry of the creek.

The proposed creek realignment was incorporated into the digital terrain model. This was then used to extract details of the proposed creek geometry to represent the creek within the HEC-RAS model. For the purposes of the preliminary design, a channel with constant cross-sectional area and constant grade was modelled. As discussed in the main body of this report, a more natural state would be provided for the channel, with variations in cross-sections and incorporation of pool and riffle sequences in the design. These have not been incorporated into the hydraulic model at this stage and would be further assessed during development of the detailed design.

The layouts of the existing and proposed hydraulic models are shown in Figure B-1 and Figure B-2 respectively.

Structures

Culverts

There are two culvert crossing along Sawyers Swamp Creek within the section covered by this rehabilitation plan — a single barrelled piped culvert under Private Coal Road (1800 millimetres diameter) and a culvert with three barrels (each 1800 millimetres), which is located approximately 100 metres upstream from Private coal road and which passes under an internal road adjacent to the existing KVAR.

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Details of these culverts were surveyed by Craven, Elliston & Hayes (Lithgow) Pty Ltd during the site survey in September 2007. It is proposed that the culverts under the internal road would be removed as part of the creek rehabilitation works.

Out of bank flow

Close review of the digital terrain model and preliminary modelling of the existing channel showed that flood flows generated from the catchment upstream of KVAR are not contained within the main creek alignment. The channel is broad and not well defined in the bend near the Centennial Coal owned coal storage area (Figure B-1 and Figure B-2: approximate HEC RAS model chainages 460 – 590m). It is at this location that it is predicted by hydraulic modelling that a significant portion of flow leaves the creek during flood events to flow through the area to the north.

To incorporate this into the hydraulic model, the high ground level on the right hand bank in the area where water leaves the main channel was modelled as a lateral weir structure.

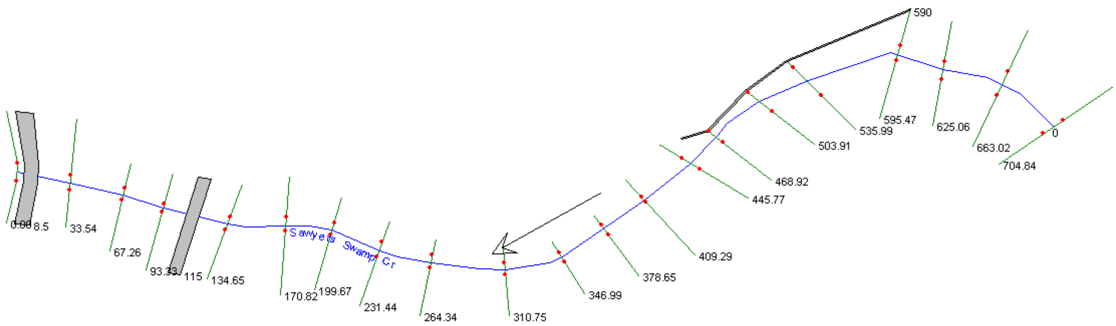

Figure B-1 Hydraulic model layout: existing creek alignment

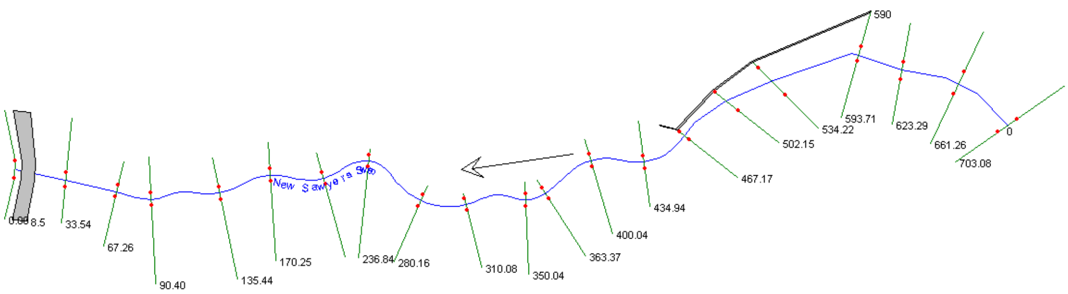

Figure B-2 Hydraulic model layout: proposed creek alignment

Roughness values

Manning's 'n' roughness coefficients were assigned to the left overbank, right overbank and main channel for each cross-section. Roughness values were estimated by field inspections and are based on guidance provided in Table 15 of *A Rehabilitation Manual for Australian Streams* (CRCCH & LWRRDC, 2000). Values adopted for the modelling are shown in the table below. It should be noted that during detailed design, roughness values for the proposed channel would be reassessed in relation to channel variations that are incorporated into the design, and variation in roughness values at different locations along the channel would be incorporated into the design.

Roughness values

	Channel roughness	**Bank roughness (left and right banks)**
Existing channel	0.04	0.05
Proposed channel	0.045	0.05

Boundary conditions

The HEC-RAS model when used for subcritical flow simulations requires input for downstream boundary conditions only. The downstream boundary condition was set at normal depth for all design storm simulations.

Flow inputs

The peak design flood flows for the creek were determined using an XP-RAFTS model (refer to surface water impact assessment report) and entered into the HEC-RAS model at a point upstream of the bend where water leaves the main channel. The lateral weir function within HEC-RAS was used to assess how much water leaves the main channel, and how much water remains in the channel.

Model results

Detailed modelling results of both the existing and proposed creek alignments are tabulated on the following pages, with a brief discussion of key points below.

Existing creek alignment

As discussed above, the modelling results indicate that some of the flow leaves the main channel at bend near the Centennial Coal owned coal storage (from just downstream of cross-section 595.47). The modelling indicates the following split in flows during the 2 year ARI and 100 year ARI events.

Existing flow in Sawyers Swamp Creek

	Peak flow from catchment (m^3/s)	**Peak spill flow to the north(m^3/s)**	**Peak flow retained in channel (m^3/s)**
2 Year ARI	5.94	1.63	4.31
100 Year ARI	12.69	6.75	5.94

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Proposed realignment

The hydraulic model was used to evaluate the proposed design for the realignment of a section of Sawyers Swamp Creek. Specifically, the model was used to assess:

- the capacity of the realigned channel to contain design bankfull flows
- the capacity of the realigned channel to contain flood flows during a 100 year ARI event
- any changes to the existing flow regime, particularly in relation to any changes to the flow leaving the main channel and flowing through the north
- average velocities within the channel and potential for scour.

Channel capacity

Hydraulic modelling indicates that the 2 year ARI flow would be contained within the main channel. Additionally, the 100 year ARI flow would be contained within the riparian zone. Cross-sections from the HEC-RAS model indicating water levels within the channel are attached after the tabulated modelling results below.

Changes to flow regime

Naturalising the channel and incorporating riffle and pool sequences would increase the roughness of the channel, slowing flows within the main channel. Modelling indicates that this would cause more of the flow generated from the catchment upstream of KVAR to leave the channel at the bend. The proposed realignment of the channel aims to result in no changes to the existing flow regime within Sawyers Swamp Creek. During detailed design of the creek realignment further assessment would be made of the suitability of adopted roughness values and opportunities to undertake any works required to assist in retaining flows within the channel in the section of the bend.

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Potential for scour

The potential for scour within the proposed creek realignment has been assessed by comparing predicted channel velocities and shear stress to literature values relating to maximum permissible velocities and shear stress to prevent scour. A range of values are reported in the literature, which are dependant on factors including soil type, vegetation cover, and channel slope. The table below summarises a range of values that are applicable to Sawyers Swamp Creek. Further assessments of appropriate design maximum velocity and shear stress would be made during detailed design in relation to the soil type and proposed vegetation cover.

Literature values: maximum permissible velocity and shear stress

	Maximum permissible velocity (m/s)	**Maximum permissible shear stress (N/m^2)**
Bare soil	0.5[1]	3.6[2]
Grass mixture	1.2[1]	101[3]
Aquatic (swampy) vegetation	-	105[4]

Source:

1. SCS, 1982
2. Stallings, 1999
3. Fishchenich, 2001
4. Prosser and Slade, 1994

Velocities and shear stress predicted by the modelling are summarised below. Channel velocities and shear stresses are shown only as these are predicted to be significantly higher then overbank velocities and shear stresses. The summary provided in this table indicates that the proposed channel would be less prone to scour then the existing channel. Detailed design would incorporate additional measures into the creek design to reduce this further. Detailed design would also provide further investigations into interim measures for bed and bank stabilisation until vegetation establishes within the realigned creek.

Modelled channel velocity and shear stress during the 100 year ARI event

	Channel velocity within the reach proposed to be realigned (m/s)	**Channel shear stress within the reach proposed to be realigned (N/m^2)**
Existing creek alignment (Section 409.29 to 67.26)	0.76 – 2.30	9.45 – 105.38
Proposed creek alignment (Section 434.94 to 67.26)	0.79 – 1.92	13.1 – 102.18

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Existing Creek Alignment

Cross section	Profile	Q total (m^3/s)	Top width (m)	Froude # channel	Velocity LOB (m/s)	Velocity channel (m/s)	Velocity ROB (m/s)	Shear LOB (N/m^2)	Shear channel (N/m^2)	Shear ROB (N/m^2)
704.84	2 YR ARI	5.94	19.52	0.44		0.84	0.72		15.55	17.08
	100 YR ARI	12.69	20.37	0.51		1.19	0.98		26.91	28.31
663.02	2 YR ARI	5.94	17.76	0.72	0.19	1.23	0.63	3.02	35.5	18.09
	100 YR ARI	12.69	24.51	0.68	0.35	1.52	0.79	7.13	45.61	23.65
625.06	2 YR ARI	5.94	18	0.49	0.43	1.05	0.17	8.19	22.52	2
	100 YR ARI	12.69	22.03	0.58	0.76	1.47	0.44	20.22	38.87	8.82
595.47	2 YR ARI	5.94	20.73	0.93	0.9	1.64		35.19	62.02	
	100 YR ARI	12.69	21.65	1	1.34	2.06		65.56	89	
590		Lateral Structure								
535.99	2 YR ARI	4.31	41.47	0.13	0.15	0.3	0.1	0.84	1.71	0.4
	100 YR ARI	6.53	41.86	0.14	0.19	0.35	0.14	1.28	2.25	0.8
503.91	2 YR ARI	4.31	38.97	0.17	0.2	0.37	0.17	1.56	2.79	1.21
	100 YR ARI	5.94	40.23	0.16	0.23	0.38	0.13	1.77	2.76	0.77
468.92	2 YR ARI	4.31	8.93	0.78		1.42			45.56	
	100 YR ARI	5.94	9.25	0.66		1.4			40.58	
445.77	2 YR ARI	4.31	14.66	0.14		0.4	0.1		2.75	0.44
	100 YR ARI	5.94	15.26	0.16		0.48	0.15		3.69	0.88
409.29	2 YR ARI	4.31	7.23	0.98	1.08	2.01	0.11	46.81	85.03	
	100 YR ARI	5.94	7.67	0.97	1.24	2.19	0.38	55.93	94.1	9.4
378.65	2 YR ARI	4.31	6.74	0.66		1.39			39.99	
	100 YR ARI	5.94	7.1	0.69	0.14	1.59		1.76	49.35	
346.99	2 YR ARI	4.31	6.58	1.01		1.9	0.3		80.37	7.18
	100 YR ARI	5.94	6.89	0.98		2.05	0.6		87.07	19.42
310.75	2 YR ARI	4.31	6.64	0.7	0.63	1.5		17.34	46.26	
	100 YR ARI	5.94	7.18	0.7	0.69	1.64		19.94	52.2	
264.34	2 YR ARI	4.31	4.4	1.01		2.13			95.09	

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Cross section	Profile	Q total (m^3/s)	Top width (m)	Froude # channel	Velocity LOB (m/s)	Velocity channel (m/s)	Velocity ROB (m/s)	Shear LOB (N/m^2)	Shear channel (N/m^2)	Shear ROB (N/m^2)
	100 YR ARI	5.94	4.86	1.01		2.3			105.38	
231.44	2 YR ARI	4.31	9.82	0.34		0.8	0.07		12.37	0.45
	100 YR ARI	5.94	10.23	0.35	0.12	0.9	0.17	1.04	14.79	1.68
199.67	2 YR ARI	4.31	6.94	0.58	0.2	1.27		2.91	32.47	
	100 YR ARI	5.94	7.19	0.6	0.32	1.45		5.83	40.04	
170.82	2 YR ARI	4.31	7.21	0.48	0.24	1.12		3.35	24.16	
	100 YR ARI	5.94	7.32	0.56	0.33	1.37		5.92	35.27	
134.65	2 YR ARI	5.31	5.88	1		2.07			90.24	
	100 YR ARI	6.07	6.01	1.01		2.16			95.36	
115		Culvert								
93.33	2 YR ARI	5.31	6.21	0.79		1.9	0.76		69.24	24.38
	100 YR ARI	6.07	6.78	0.58		1.58	0.76		44.55	20.72
67.26	2 YR ARI	5.31	8.02	0.29	0.1	0.81		0.69	11.35	
	100 YR ARI	6.07	8.31	0.25	0.14	0.76		1.03	9.45	
33.54	2 YR ARI	5.31	7.58	0.19	0.08	0.65		0.43	6.76	
	100 YR ARI	6.07	8.36	0.18	0.12	0.64		0.75	6.3	
8.5		Culvert								
0	2 YR ARI	5.31	4.68	0.68		1.73			56.24	
	100 YR ARI	6.07	4.75	0.68		1.8			59.91	

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Proposed Creek Alignment

Cross section	Profile	Q total (m^3/s)	Top width (m)	Froude # channel	Velocity LOB (m/s)	Velocity channel (m/s)	Velocity ROB (m/s)	Shear LOB (N/m^2)	Shear channel (N/m^2)	Shear ROB (N/m^2)
703.08	2 YR ARI	5.94	19.58	0.4		0.77	0.74		16.28	17.79
	100 YR ARI	12.69	20.46	0.45		1.08	1.01		28.06	29.43
661.26	2 YR ARI	5.94	18.14	0.63	0.26	1.12	0.65	4.75	36.46	18.71
	100 YR ARI	12.69	24.95	0.62	0.43	1.41	0.82	9.61	48.66	25.2
623.29	2 YR ARI	5.94	18.51	0.45	0.47	0.99	0.2	9.64	24.81	2.64
	100 YR ARI	12.69	22.59	0.52	0.8	1.35	0.48	21.93	40.81	10.06
593.71	2 YR ARI	5.94	20.71	0.91	0.98	1.6		42.34	75.53	
	100 YR ARI	12.69	21.53	0.99	1.46	2.01		78.14	108.06	
590		Lateral Structure								
534.22	2 YR ARI	3.96	41.68	0.11	0.14	0.25	0.09	0.78	1.52	0.41
	100 YR ARI	6.23	41.92	0.12	0.2	0.31	0.15	1.31	2.25	0.85
502.15	2 YR ARI	3.92	39.09	0.14	0.19	0.3	0.16	1.31	2.24	1.05
	100 YR ARI	5.46	40.28	0.13	0.22	0.32	0.14	1.59	2.44	0.78
467.17	2 YR ARI	3.92	9.18	0.47	0.48	1.02	0.44	9.97	26.49	8.91
	100 YR ARI	5.46	9.41	0.49	0.57	1.16	0.51	13.1	32.38	10.9
434.94	2 YR ARI	3.92	8.15	0.66	0.05	1.28	0.06		44.66	
	100 YR ARI	5.46	9.48	0.68	0.28	1.46	0.28	5.3	54.52	5.52
400.04	2 YR ARI	3.92	8.1	0.67	0.04	1.29	0.05		45.78	
	100 YR ARI	5.46	9.49	0.68	0.28	1.45	0.28	5.43	54.4	5.5
363.37	2 YR ARI	3.92	8.19	0.65	0.07	1.27	0.07	0.67	44.25	0.67
	100 YR ARI	5.46	9.49	0.68	0.28	1.45	0.28	5.47	54.27	5.47
350.04	2 YR ARI	3.92	8.1	0.67	0.05	1.29	0.04		45.94	
	100 YR ARI	5.46	9.43	0.69	0.28	1.47	0.28	5.49	55.6	5.34
310.08	2 YR ARI	3.92	8.23	0.65	0.08	1.26	0.08	0.77	43.58	0.84
	100 YR ARI	5.46	9.49	0.68	0.28	1.46	0.28	5.43	54.46	5.5
280.16	2 YR ARI	3.92	7.97	0.69		1.31			47.79	

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Cross section	Profile	Q total (m^3/s)	Top width (m)	Froude # channel	Velocity LOB (m/s)	Velocity channel (m/s)	Velocity ROB (m/s)	Shear LOB (N/m^2)	Shear channel (N/m^2)	Shear ROB (N/m^2)
	100 YR ARI	5.46	9.32	0.7	0.28	1.49	0.27	5.36	57.5	5.06
236.84	2 YR ARI	3.92	8.38	0.62	0.11	1.23	0.11	1.21	40.96	1.27
	100 YR ARI	5.46	9.64	0.66	0.29	1.42	0.29	5.56	51.67	5.63
205.22	2 YR ARI	3.92	7.65	0.77		1.44			58.67	
	100 YR ARI	5.46	9.03	0.75	0.24	1.55	0.25	4.62	63.49	4.88
170.25	2 YR ARI	3.92	9.5	0.48	0.2	1.04	0.2	2.81	27.55	2.67
	100 YR ARI	5.46	10.44	0.56	0.32	1.28	0.31	5.86	40.17	5.67
135.44	2 YR ARI	4.92	7.58	1		1.85			97.16	
	100 YR ARI	5.59	7.9	1.01		1.92			102.18	
90.4	2 YR ARI	4.92	12.9	0.34	0.29	0.87	0.29	3.85	17.07	3.91
	100 YR ARI	5.59	15.09	0.28	0.3	0.78	0.3	3.59	13.15	3.62
67.26	2 YR ARI	4.92	7.89	0.31	0.08	0.83		0.52	15.53	
	100 YR ARI	5.59	8.14	0.27	0.13	0.79		1.08	13.1	
33.54	2 YR ARI	4.92	7.21	0.2	0.06	0.66		0.28	8.87	
	100 YR ARI	5.59	7.85	0.19	0.11	0.65		0.71	8.34	
8.5		Culvert								
0	2 YR ARI	4.92	4.7	0.6		1.55			57.35	
	100 YR ARI	5.59	4.77	0.61		1.62			60.92	

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