FLOODING & SURFACE WATER ASSESSMENT FOR THE PROPOSED BULK SAMPLE DEVELOPMENT APPLICATION

PROPOSED BICKHAM COAL MINE

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DRAFT

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1 INTRODUCTION

1.1 Background

This flooding and surface water assessment report has been prepared for the Bickham Coal Company for a development application for excavation of a bulk sample for a proposed open cut mine to be located near Bickham in north western New South Wales. The exploration license for the proposed open cut lies midway between the towns of Blandford and Wingen, and approximately 50 km north of Muswellbrook.

The open cut resource lies on the eastern side of the New England Highway and occupies an area some 2.25 km by 0.7 km. This resource area is totally within land owned by Bickham Coal Company and is situated on the western side of the Pages River, a major tributary of the Hunter River catchment (**Figure 1**).

The aims of this assessment are to:

- Estimate the extent of flooding across the floodplain adjacent to the proposed open cut area.
- Provide a surface water management plan to mitigate against any possible environmental impacts on local receiving waters during excavation of the bulk sample and placement/rehabilitation of the overburden dump.

1.2 The Development Proposal

Bickham Coal Company plans to extract approximately 25,000 ROM tonnes of coal from a bulk sample site as shown in **Figure 2** This bulk sample will entail the removal of some 331,000 cubic metres of overburden. As part of this process a flooding and surface water assessment has been prepared to support the development application for the extraction of coal from the proposed bulk sample.

The area of surface disturbance in the bulk sample area, including ramps will be some 2.0 hectares. The overburden will be removed with excavator and trucks via existing on site road systems for disposal in an abandoned flint clay mine on the property owned by Bickham Coal Company. This flint clay void has a capacity of approximately 500,000 cubic metres and the overburden from the bulk sample will be used to rehabilitate the site.

2 DESCRIPTION OF EXISTING CONDITIONS

2.1 Local Climatic Conditions

The local climatic conditions near the proposed bulk sample location are shown in Table 2.1. The location of these Bureau of Meteorology stations relative to the project site are shown on Figure 1. Of the three stations, Murrulla is the closest to the proposed bulk sample being 4.7 km southwest. Evaporation data is only available at Scone, which is located approximately 25 km south of the proposed bulk sample.

Table 2.1
Summary of Local Climatic Data

Bureau of Meteorology Station	Decile 1 Rainfall (mm/y)	Decile 9 Rainfall (mm/y)	Mean Annual Rainfall (mm)	Highest Recorded Daily Rainfall (mm)	Mean Daily Evaporation (mm)	Mean Annual Evaporation (mm)
Scone -Station 61069	405.7	876.6	654.8	163.1	4.4	1,606
Murrulla -Station 61079	568.9	1,038	764.9	119.4	-	-
Murrurundi -Station 61051	572	1,072.1	831.5	227.3	-	-

It can be seen that rainfall increases towards Murrurundi due to the presence of the Liverpool Range, although evaporation would be relatively similar at all locations as their elevation and distance from the sea does not vary significantly.

2.2 Regional Catchments

The proposed open cut lies adjacent to the Pages River. The catchment of the Pages River upstream of the project Site is made up of four major sub-catchments shown in **Figure 3**, being:

- Warlands Creek;
- Scotts Creek;
- Splitters Creek; and
- the upper Pages River and its various minor tributaries.

The catchment area of the Pages River to the Bulk Sample is approximately 347 km^2. The Pages River is classified as a Schedule 3 stream under the Department of Land and Water Conservation (2002) *"Draft Guidelines for Management of Stream/Aquifer Systems in Coal Mining Developments- Hunter Region"*. It should be noted that the proposed bulk sample lies outside the Department of Land and Water Conservation notification area for a Schedule 3 stream.

2.3 Pages River Flow Characteristics

The flow characteristics of the Pages River are shown in the following two figures which present data from the Department of Land and Water Conservation stream gauge at Bickham (Station 210061) from 1983 to 1997. **Figure 4** shows that a flow of 0.1 ML is only exceeded 55% of days, and a flow of 10 ML is exceeded in approximately 2% of days. **Figure 5** shows that maximum daily discharge is greatest in the months of January and February.

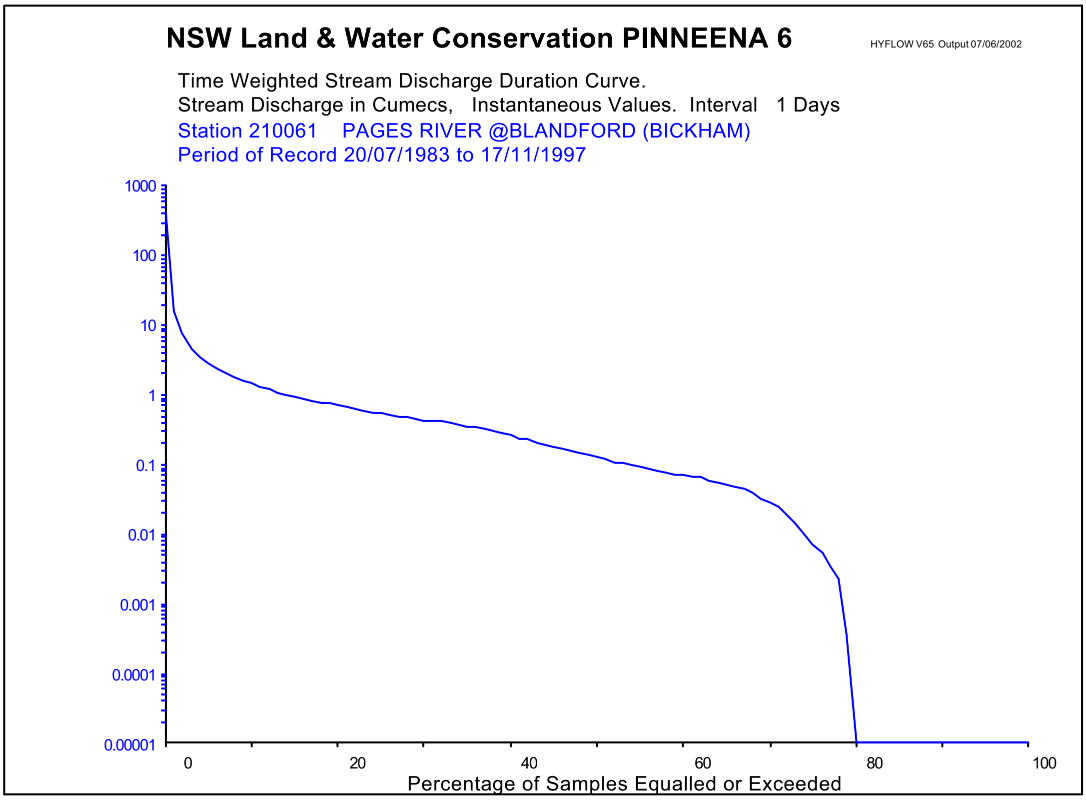


Figure 4
Time Weighted Stream Discharge Duration Curve

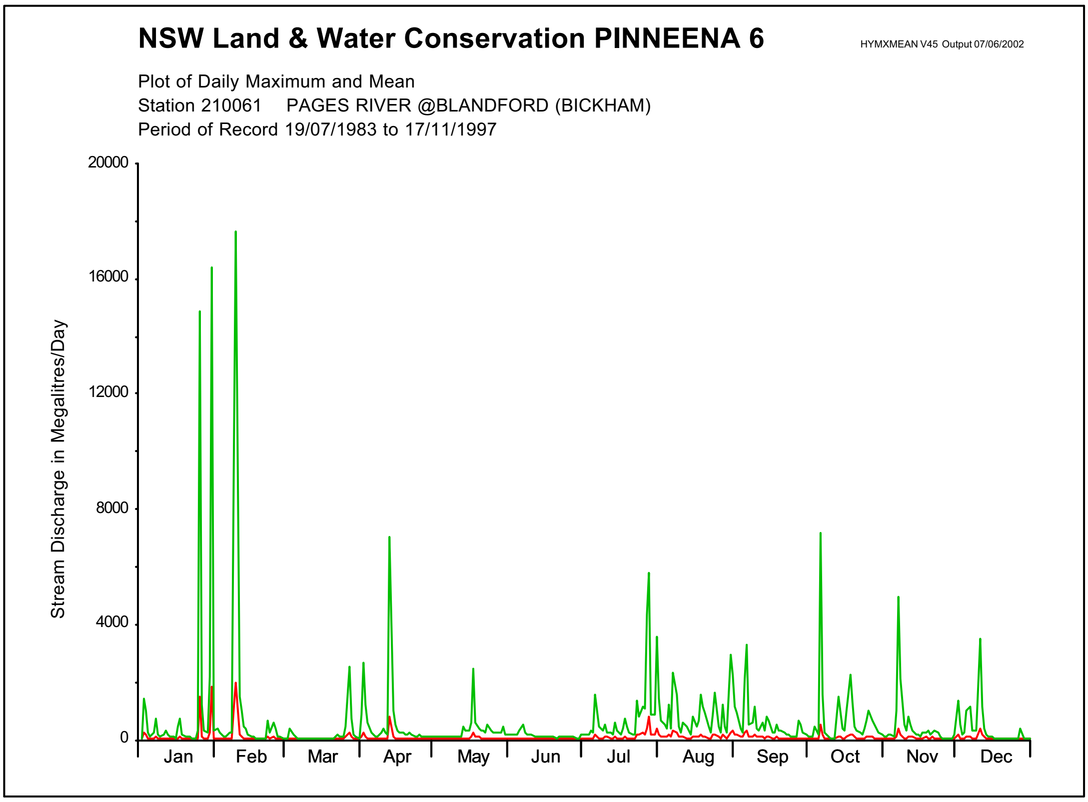


Figure 5
Daily Maximum and Mean Discharge (1983 to 1997)

2.4 Flooding in the Pages River

A flood study was conducted as part of this assessment to estimate the flood levels in the Pages River adjacent to the proposed open cut. The flood study conducted for this assessment was an extension of the *Murrurundi, Blandford and Willow Tree Flood Study* undertaken by Lyall & Macoun Consulting Engineers, (1997). The details of the flood study are presented in **Appendix A** and involved the use of the RORB hydrological model developed for the *Murrurundi, Blandford and Willow Tree Flood Study* (Lyall & Macoun Consulting Engineers, 1997) to estimate river flows, along with the HEC-RAS hydraulic model using surveyed river sections for flood level estimation adjacent to the project site. The location of these surveyed sections on the Pages River are shown on **Figure 6**. Flood levels for all floods up to the 100 year ARI flood were estimated from peak flows based on the RORB model. The extreme flood was estimated with a peak flow that was three times greater than that of the 100 year ARI peak flow.

Figure 7 shows a longitudinal profile of water levels for all floods analysed in the HEC-RAS model (5 year ARI flood to the extreme flood). It can be seen that the 100 year ARI flood level ranges from approximately 387 m AHD upstream to 386 m AHD downstream. The difference in flood level between the 5 year ARI flood and 100 year ARI flood is of the order of 3 m. The extreme flood level is approximately 6.5 m greater than the 100 year ARI flood.

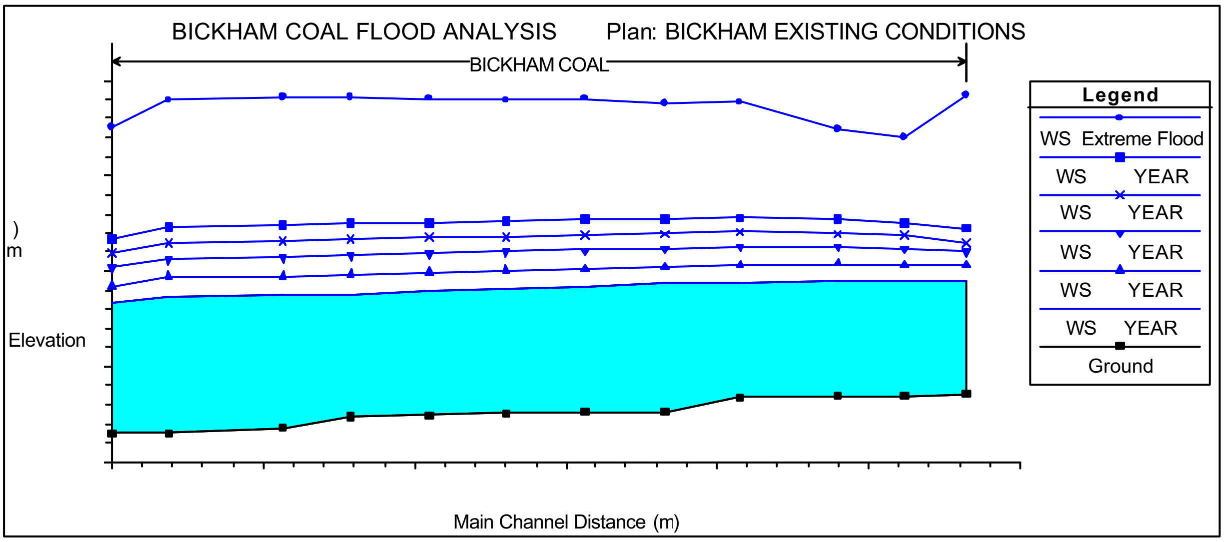


Figure 7
Longitudinal Water Surface Profile for Various ARI floods

The extent of flooding over the floodplain of the Pages River which lies adjacent to the proposed bulk sample cut is shown in **Figure 8**. This figure shows that lowest part of the proposed bulk sample lies immediately outside the extreme flood extent on the Pages River, and is approximately 7 m above the estimated 100 year ARI flood level on the Pages River.

3 SURFACE HYDROLOGY & WATER QUALITY IMPACTS

3.1 Overburden Dump

3.1.1 Impacts on Surface Runoff

It is proposed to place the overburden from the bulk sample (estimated at 331,000 m^3 of material) on the old flint quarry. This flint clay void has a capacity of approximately 500,000 m^3 and the overburden from the bulk sample will be used to rehabilitate the site. In total, the overburden dump will occupy some 6 ha.

The location of the overburden dump in the old flint quarry creates the potential for water containing sediment to enter the Pages River. This 'dirty' runoff would be generated off the 6 ha overburden dump, and from water passing over the overburden dump from the 10.6 ha catchment up-slope. Details of the methods of sediment control from the overburden dump are given in Section 4.0.

In addition to runoff mobilising sediment, overburden material can influence the chemistry of the surface water it contacts with. The quality of the bulk sample overburden material has been tested by Mining Exploration Geology Services and has indicated that this material exhibits neutral to slightly acidic pH (7.5 to 4.6), and a relatively low salinity (0.03 to 0.28 dS/m). Additionally, as the drainage line is dry for most of the year, there would be minimal contact time between surface water and the overburden material. Therefore, the combination of the 'low risk' overburden material quality and the minimal contact time with surface runoff would indicate that the overburden material would have no significant impact on surface water runoff chemistry. As a result, any profile would be suitable to form the uppermost profile in the overburden dump landform, with those profiles exhibiting a neutral pH being preferred.

3.2 Bulk Sample Excavation Effect on Catchment Runoff and Pit Water Quality

The extraction area of the bulk sample is only 2 ha, which is insignificant to the total catchment area of the Pages River at this location. Furthermore, the bulk sample area of disturbance will not isolate runoff to any significant stream in the local catchment.

Due to the nature of the extraction, all rainfall runoff from the extraction pit will drain to the pit sump. This runoff is likely to contain some sediment, although the overall water quality in the bulk sample will be most influenced by the groundwater quality. Consequently there would be no direct impact on the water quality in the Pages River.

Details of the methods of sediment control from the bulk sample are given in Section 4.0.

4 SURFACE WATER MANAGEMENT PLAN

A surface water management plan has been prepared for this development application to mitigate against any potential water quality impacts in the Pages River.

4.1 Runoff Diversion Works

4.1.1 Overburden Dump

The catchment runoff from the 10.6 ha area upstream of the overburden dump would be diverted around the overburden dump and proposed sedimentation dam, along with a 10.5 ha catchment area of two drainage lines to the north of the dump (**Figure 9**). This would ensure that the sediment and erosion controls on the dump only need to accommodate runoff from the overburden dump. The diversion drain would be used only until the overburden dump rehabilitation is complete, after which the drainage line will be restored through the rehabilitated overburden dump.

Figure 10 shows the diversion drain dimensions necessary to divert the 20 year ARI peak flow of 2.7 m^3/s around the overburden dump. The diversion drain has been sized on a 5 minute duration 20 year ARI peak discharge from the rural catchment as estimated using the rational method for eastern NSW in *Australian Rainfall and Runoff Vol 2* (Institution of Engineers Australia, 1998). Because of the steep grade of the proposed drain (10%), the velocity of flow in the drain is estimated to be 3.0 m/s if the drain was only grassed. Therefore, rock check dams and mitre drainage at 20 metre intervals will be utilised to reduce flow velocity and aid in drain stabilisation.

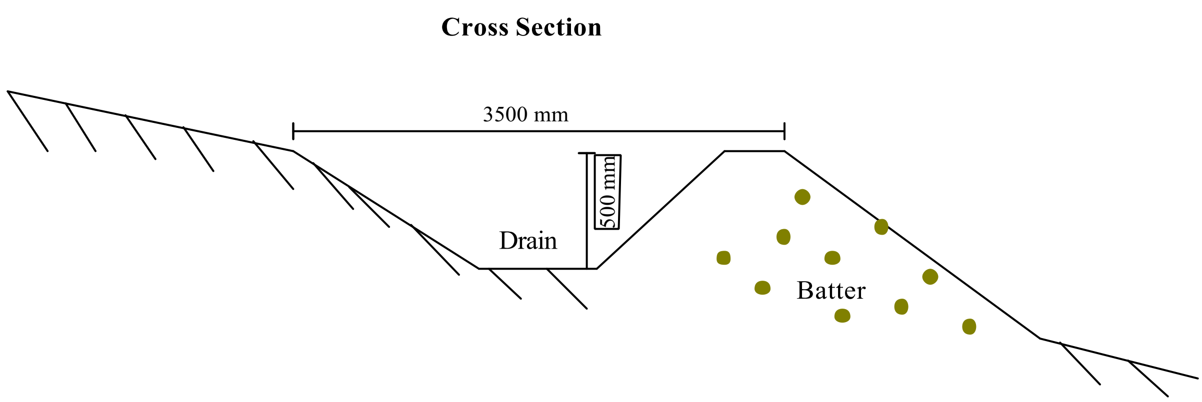


Figure 10
Diversion Drain Dimensions for the Overburden Dump

The following details are to be provided for the construction of diversion drains:

- All batter grades of the diversion drain should be no steeper than 2H:1V, and adequately compacted.

- Check dams should be constructed of rocks weighing at least 10 kg to avoid being destabilised, and riprap scour protection provided for 2 m downstream of each check dam.
- The check dam should be excavated at least 200 mm below the diversion drain bed level, and 100 mm above ground level to reduce the risk of undercutting.
- The spillway section of the check dam should be 150 mm below the crest of the check dam.
- Re-entry points into the existing drainage line will be adequately stabilised using rocks, erosion control fabrics and grasses.

4.1.2 Bulk Sample

The area occupied by the bulk sample consists of a predominantly rock surface. It is proposed to locate clean water diversion bunds up-slope of the bulk sample as shown in **Figure 11**. These bunds will ensure that no surface runoff from the 2 ha grassed catchment up-slope of the bulk sample enters the bulk sample excavation area. The bunds will direct flow into the two drainage lines that exist either side of the bulk sample, and would be 200 mm in height.

4.2 Water Demand for the Bulk Sample Operations

It is proposed to utilise the existing water within a existing void at the old flint quarry (proposed overburden dump site) to provide water for dust suppression for the operations associated with the extraction of the bulk sample. The existing water in the old flint quarry void is approximately 7 to 8 m in depth and its storage volume has been estimated at 40 ML. It is estimated that the volume water in the old flint quarry void originates from surface water. This is because the groundwater table has been estimated at being some 15 m below the void in this location and the void exhibits minimal seepage due to the presence of a clayey layer at the bottom of the void. In addition, evaporation losses are minimal from the void as it is protected from prevalent winds and most of its storage volume is made up of its depth. It is estimated that some 16 ML or runoff could be expected to occur from the catchment upstream in an average rainfall year, along with approximately 23 ML from the old flint quarry void. The large volume of runoff originating from the void is a result of its rocky nature, which results in a high volumetric runoff coefficient (0.9).

Minimum water demand for dust suppression is estimated to be between 0.25 and 0.5 ML/d and will be used on haul roads and in the bulk sample extraction area. This would give at least 80 weeks water supply.

4.3 Groundwater Seepage Management in the Bulk Sample

Depending on the quantity and quality of groundwater inflow into the bulk sample excavation, this water will either be managed by either:

- pumping groundwater to existing farm dams on the property (the storage of these dams has been estimated at 30 ML when partially full to 40 ML if empty);
- pumping groundwater to the old flint quarry void;

- irrigation to surrounding fields, or for dust suppression.

5 SEDIMENT AND EROSION CONTROL

5.1 Overburden Dump Sediment and Erosion Controls

The overburden dump will include sediment and erosion controls to minimise runoff off the landscape until the soil surface is fully stabilised. The stabilisation of the overburden dump would be undertaken in two phases, being:

- the primary stabilisation and revegetation of the landform; and
- the secondary revegetation stage of rehabilitation.

These two forms of stabilisation will be undertaken for areas subjected to sheet and concentrated flow on the overburden dump landform.

5.1.1 Areas Subjected to Sheet Flow

The objective of the primary stabilisation of the overburden dump landform will be to stabilise the landform as quickly as possible. For areas of the overburden dump landform subjected to sheet flow this will involve:

- Respreading of stockpiled topsoil from the bulk sample excavation over the overburden dump final landform.
- Stabilisation of this topsoil by using straw and sterile grasses to aid in reducing soil erosion from direct rainfall and wind. This would also aid in slowing overland flow velocity which reduces soil erosion. Depending on topsoil fertility, a fertiliser may need to be applied to promote good stabilisation with vegetation.
- Location of sediment control structures such as a sediment fence or rock embankment parallel to the landform contours at 25 m spacing maximum.

5.1.2 Areas Subjected to Concentrated Flow

The proposed design of the overburden dump landform will create a drainage line along its northern and southern sides, where the overburden dump meets with the existing landform. These drainage lines will be subject to concentrated flows, and with a slope of approximately 18%, suitable erosion control measures must be adopted. It is proposed to undertake the following sediment and erosion control works in these two areas:

- Stabilisation of the drainage line with rock lining to prevent scour. These rocks should be placed on a suitable geo-textile fabric to prevent scour under the rocks. Depending on the availability of rocks, erosion control matting could be used with grass seeding as a replacement for rock lining.
- Check dams should be placed every 25 m along the drainage line, preferably corresponding to erosion control fencing on areas subject to sheet flow (see above). Ideally these check dams would have small plunge pools located immediately down-slope stabilised by rocks.

The design of the drainage line would be such that runoff from the overburden dump landform or from the upstream catchment area can be directed through this drainage line. This would be accomplished by removal of the diversion drain skirting the overburden dump. A typical cross section of the drainage line through the overburden landform is shown on **Figure 12.**

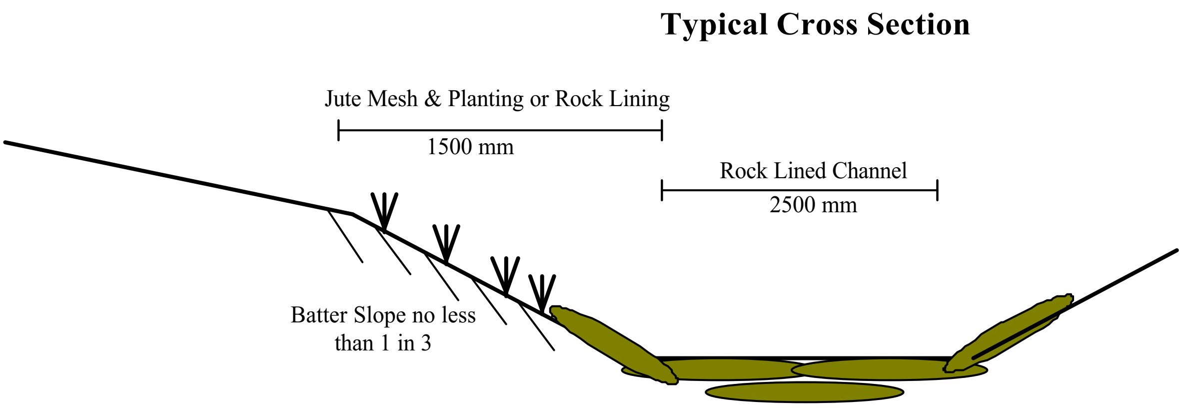


Figure 12
Typical drainage Line Section in Overburden Dump Landform

Secondary vegetation of the overburden dump will be conducted with guidance from the Department of Land and Water Conservation.

5.1.3 Overburden Dump Sedimentation Basin Design

As the overburden is placed on the old flint quarry site, there is considerable opportunity for runoff to become laden with sediment as the dump surface would not have been stabilised with vegetation (although areas exposed to concentrated flows will be stabilised using sediment fences).

It is proposed to place a sedimentation dam on the downstream end of the overburden dump, but above the extreme flood level (**Figure 9**). The sizing for this dam has been based on the Department of Housing (1998) *Managing Urban Stormwater: Soils and Construction Handbook*. The sedimentation basin criteria adopted for the design are based on a Type F sedimentation basin which is suitable for clay soils (>33% fines), and include:

- A volumetric runoff coefficient of 0.5;
- 90th percentile 5 day total rainfall depth of 44 mm interpolated between Tamworth and Newcastle rainfall depths in *Managing Urban Stormwater: Soils and Construction Handbook*;
- Total disturbed catchment area of 6 ha for the bulk sample overburden dump;
- Sediment storage zone initially based on the RUSLE formulae, but found to be <30% of the settling volume. Therefore, 50% of the settling zone adopted giving a settling zone storage volume of approximately 700 m^3.

Using this criteria the sedimentation basin volume required for a Type F design is 2.1 ML, of which 1.4 ML of the volume is for the settling zone.

For basins designed for Type F and Type D soils, *"Managing Urban Stormwater: Soils and Construction"* requires that the design volume should be restored within five days of the end of a storm provided that acceptable water quality (eg 50 mg/L NFR) has been achieved for discharge. However, the water stored in the sedimentation dam would be used for site dust suppression or irrigation to surrounding fields rather than discharging to the drainage line. The water level in the sedimentation dam would be controlled be an automated float system with pump designed to irrigate the water so that the dam capacity is restored no later than 5 days after receiving runoff.

5.2 Bulk Sample Excavation

5.2.1 Topsoil Stripping & Stockpiles

During the initial phase of excavation of the overburden any topsoil will be removed and stockpiled for rehabilitation use. Before topsoil stripping commences a bund would be placed on the down-slope side of the excavation area to prevent any runoff from leaving the excavation area.

All temporary stockpiles will be located no closer than 10 m to any drainage pathway and have some type of suitable sediment control skirting the stockpile (eg. sediment control fencing). Any stockpile that is to be left longer than 1 month should be seeded with sterile grass to reduce soil erosion.

5.2.2 Sediment Control During Extraction

As all catchment runoff will be diverted around the bulk sample, all rainfall runoff that occurs within the excavation will be confined to the bulk sample low point. However, as the runoff component of water in the bulk sample will be minimal compared to groundwater inflow there would be no substantial degradation in groundwater quality.

5.3 Haul Roads

The existing unsealed road system will be used to convey the overburden from the bulk sample excavation to the old flint quarry site. The haul road from the bulk sample to the overburden dump will be subject to dust suppression via wetting of the road surface with a water cart. Runoff from the road will be managed by forming cross drainage to allow runoff to drain into the grassed paddocks after passing through a staked straw bail or geo-textile sediment retention fabric. This cross drainage should be provided at approximately 50 m intervals.

These sediment controls would be inspected after each significant rainfall event and excess sediment removed.

6 WATER QUALITY MONITORING

Water quality monitoring of the Pages River has commenced upstream and downstream of the proposed open cut mine on the Pages River. It is proposed that information obtained from this sampling will be used in establishing baseline conditions prior to the excavation of the bulk sample.

During the creation and rehabilitation of the overburden dump, the water quality of any discharge from the sedimentation basin to the drainage line will be monitored. In addition, the water quality 50 m upstream and downstream of the confluence of this drainage line with the Pages River will be monitored during any discharge event to determine if discharge is having any significant impact on water quality in the Pages River.

Surface water samples would be analysed for the following water quality parameters:

- Total nitrogen
- Total phosphorous
- Suspended solids
- Turbidity
- Salinity (EC)
- Metals

Water quality in the Pages River would be referenced against either the baseline data obtained during the water quality sampling prior to the excavation or ANZECC (2000) default trigger values for NSW.

7 REFFERENCES

Australian and New Zealand Environment and Conservation Council (2000). The Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

Department of Land and Water Conservation (2002) *"Draft Guidelines for Management of Stream/Aquifer Systems in Coal Mining Developments- Hunter Region"*.

Lyall Macoun Consulting Engineers Pty Ltd. 1997. *Murrurundi, Blandford and Willow Tree Flood Study.*

APPENDIX A

FLOOD STUDY OF PAGES RIVER

8 PAGES RIVER FLOOD STUDY

8.1 HYDROLOGICAL ANALYSIS

8.1.1 Selection of Hydrologic Model

For hydrologic modelling, the practical choice is between the models known as RAFTS, RORB and WBNM. Each of these models converts storm rainfall to discharge hydrographs using a procedure known as runoff-routing. There is little to choose technically between these models, and their usage in previous studies in the area, as well as the familiarity of the user with the model, normally decides which is selected.

For this study the RORB model was used, based on the RORB model developed and calibrated for the *Murrurundi, Blandford and Willow Tree Flood Study* undertaken by Lyall Macoun Consulting Engineers, (1997).

8.1.2 Brief Review of the RORB Model

The RORB program envisages the catchment to be comprised of a series of concentrated storages which represent sub-catchments defined on watershed lines, plus concentrated special storages which represent dams and additional stream routing effects.

All storage elements within the catchment are represented via the storage-discharge equation:

$$S = kQ^m \qquad \text{....3.1}$$

where	S	=	volume of storage
	Q	=	discharge
	k	=	a storage delay parameter
	m	=	a measure of the non-linearity of a catchment. When m is set equal to unity the routing response is linear for the catchment.

The storage parameter "k" within the general storage equation is modified to reflect the catchment storage and the reach storage as follows:

$$k = k_c.kr \qquad \text{....3.2}$$

where	k_c	=	an empirical coefficient applicable to the entire catchment and stream network
	kr	=	a dimensionless ratio called the relative delay time, applicable to an individual reach storage

8.1.3 Hydrological Modelling - RORB Analysis

The RORB model sub-catchments for the Pages River are shown on **Figure 3**. The sub-catchment areas utilised for the original RORB model for the Murrurundi, Blandford & Willow Tree Flood Study undertaken by Lyall Macoun Consulting Engineers, (1997) are shown in **Table A.1**. The RORB modelling for this study an additional five sub-catchments immediately downstream of the Blandford Gauging Station on the Pages River, with areas and channel lengths as shown in **Table A.2**.

Table A.1
Original Model Sub-Catchments for the Pages River

Sub-Catchment		Catchment Area km^2
A-F	Pages R. u/s Cohens Gully	64
G-H	Cohens Gully	2.3
J-K	Halls Creek	5.4
M	Campbells Creek	12
O	Murulla Creek	7.4
P-U	Warlands Creek	103
X-Z	Scotts Creek	55
A-Z	Pages R. at gauging station	300

Table A.2
RORB Sub-Catchment Details

Sub-Catchment		Area (km^2)	Channel Length (km)
AB	Pages River	5.29	2.72
AC	Splitters Creek	34.0	3.33 (from centroid)
AD	Pages River	1.17	1.77
AE	Tributary Creek	6.34	0.50 (from centroid)
AF	Pages River	1.17	1.08

The RORB model was operated with the parameters derived for the Pages River for the Murrurundi Flood Study, as shown in **Table A.3**.

Table A.3
RORB Model Parameters

Parameters	Average Recurrence Interval (Years)				
	5	10	20	50	100
IL mm	55	55	55	50	40
CL mm/h	2.5	2.5	2.5	2.5	2.5
k_c	9.5	9.5	9.5	9.5	9.5
m	0.80	0.80	0.80	0.80	0.80

In order to run the model for the expanded catchment it was necessary to estimate the rainfall depths for each additional sub-catchment for each recurrence interval and duration storm modelled. In the

Murrurundi, Blandford & Willow Tree Flood Study (Lyall Macoun Consulting Engineers, 1997) this was derived for a range of frequencies up to 100 year ARI using principles provided in Chapter 2 of *Australian Rainfall and Runoff* (Institution of Engineers Australia, 1987). The procedure adopted in that flood study was to generate intensity-frequency-duration data over the catchment. The steps involved in this process were:

- Five uniformly spaced points were used for defining the areal distribution of rainfall over the study area. Thiessen weighting was used to determine the area of influence of each point.
- A computer program based on procedures outlined in ARR, calculated the rainfall intensity at each grid point. The intensities derived were for frequencies of 5, 20, 50 and 100 year ARI and durations of 1 to 72 hours.
- For each design frequency and duration, a rainfall depth was calculated at each grid point.
- Finally, rainfall depths at the centroids of each RORB sub-area were estimated using the Thiessen areas. An areal reduction factor was applied to the depths prior to inclusion of the data in the RORB model.

It was not considered appropriate to carry out this process again to estimate rainfall depths for each of the sub-catchments in this current study. Instead the rainfall depth calculated in the *Murrurundi, Blandford & Willow Tree Flood Study* for sub-catchment AA (contributing to Blandford GS) was adopted for the 5 additional sub-catchments. The variations in rainfall depths for frequencies up to the 100 year ARI flood across the whole catchment was not large and therefore this approach is not likely to introduce large errors into the analysis.

The results of the modelling at the Bickham Coal site (downstream end of sub-catchment AE) are presented in **Table A.4**. It should be noted that the estimate of the extreme flood peak discharge is based on 3 times the 100 year ARI peak discharge.

Table A.4
RORB Results of Catchment Discharge for Various Average Recurrence Intervals

Duration (hours)	Discharge (m^3/s)					
	ARI (years)					
	5	10	20	50	100	Extreme Flood
Bickham Coal Site						
2	-	-	-	-	-	-
3	-	-	-	-	-	-
4	-	-	-	-	-	-
24	204.6	324.7	-	-	-	-
30	**523.8**	**721.7**	956.0	1,162	1,384	-
36	432.4	640.8	928.9	**1,232**	**1,496**	**4,488**
48	-	-	**984.0**	1,211	1,449	-
72	-	-	414.0	-	-	-

The flows presented in bold were used as the input flows for the hydraulic modelling in HEC-RAS to estimate flood levels.

8.2 Hydraulic analysis of the Pages River

8.2.1 Selection of Hydraulic Model

The hydraulic model selected for this study was the HEC-RAS (version 3) model developed by the U.S. Army Corps for one dimensional hydraulic analysis. The model was deemed appropriate given the that the section of the Pages River running adjacent to the proposed open cut area has an easily defined channel and floodplain.

The HEC-RAS model uses flows estimated from the hydrological model and surveyed cross sections to estimate conveyance through each section, along with an estimation of friction losses at each section estimated from user defined manning's values and expansion/contraction coefficients. All these factors influence the resulting flood level estimated at each surveyed cross section for each Average Recurrence Interval (ARI) flood analysed.

8.2.2 HEC-RAS Model Setup

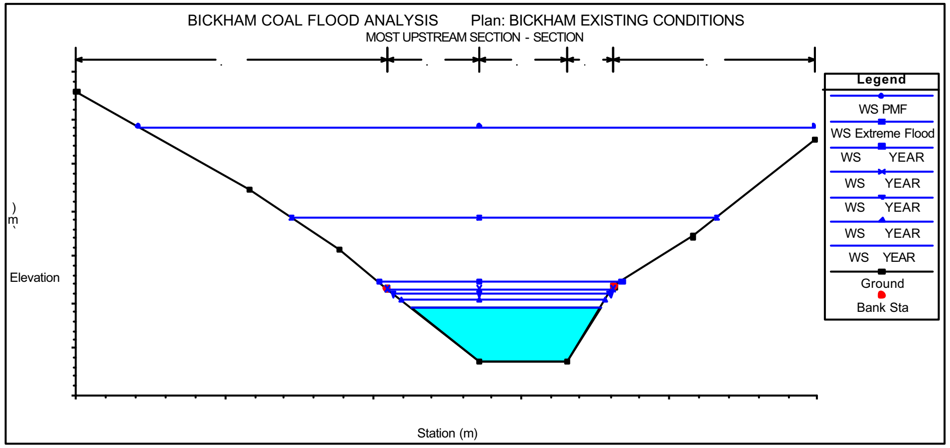
The HEC-RAS model (version 3) was used to model flows in the Pages River in the vicinity of the proposed bulk sample area, which is the area of the open cut which is closest to the Pages River. A total of 12 cross sections were surveyed after briefing by Perrens Consultants. These cross sections were used in HEC-RAS, with appropriate roughness values allocated to parts of each cross section to represent the different surface roughness along the river (examined during a site inspection). The roughness values used are shown in **Table A.5**.

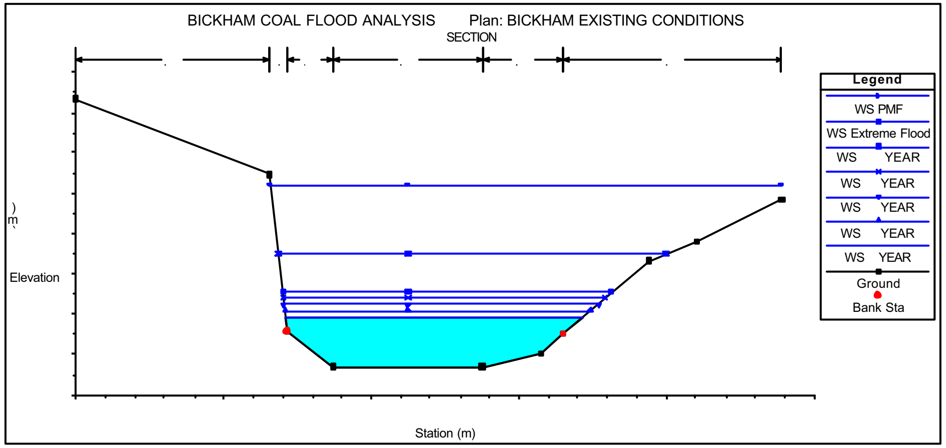
Table A.5
Manning's Roughness Values

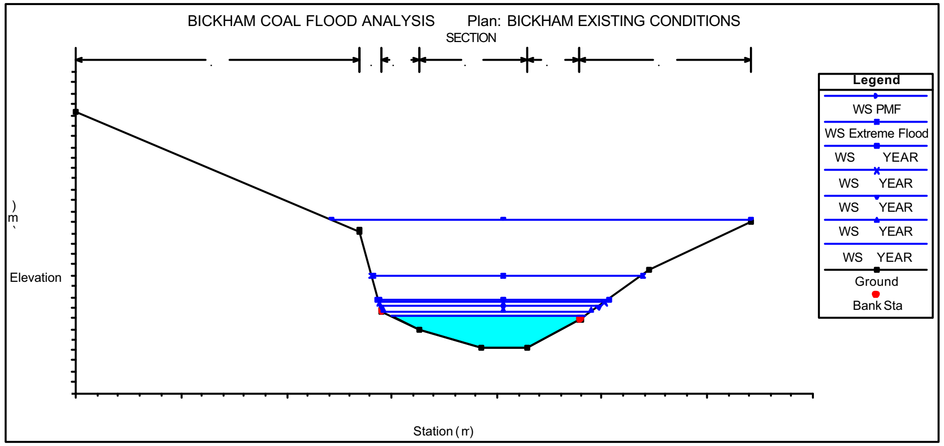
Manning's n	River Bed	River Banks	Overbanks
0.03	✓straight, clear, flat		
0.035	✓some rocks		✓long grass
0.04	✓large rocks		✓grass with some shrub/brush
0.05	✓large boulders		✓scattered brush
0.06		✓rock banks some veg	✓rock cliffs with some vegetation
0.07			✓light-medium brush
0.075			✓medium sized brush on rock
0.08		✓ medium to dense brush	✓medium to dense brush

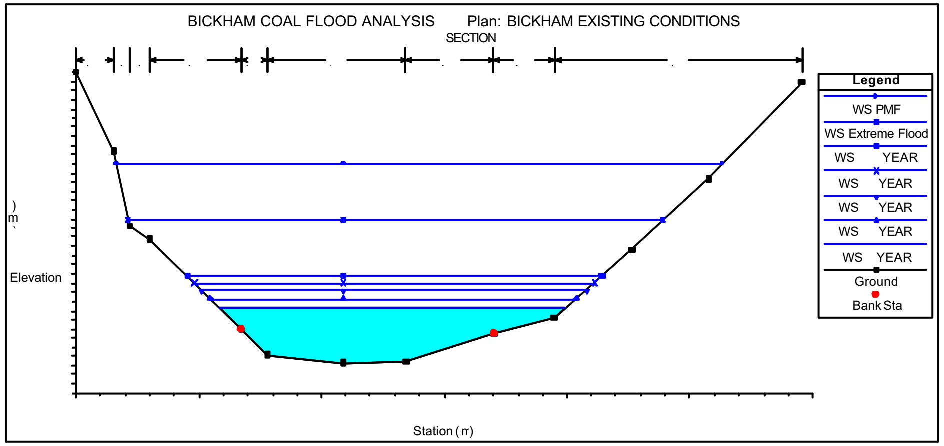
The flows obtained from the RORB modelling were entered at the upstream end of the modelled river length, and peak flood levels were determined at each cross section for the 5, 10, 20, 50, 100 year ARI floods and the extreme flood.

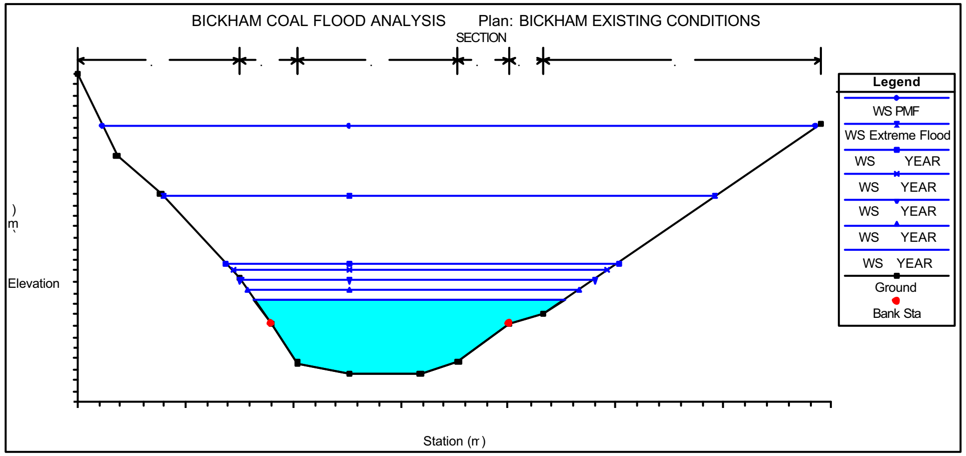
8.3 HEC-RAS Results at Each Cross Section of the Pages River










BICKHAM COAL FLOOD ANALYSIS
Plan: BICKHAM EXISTING CONDITIONS
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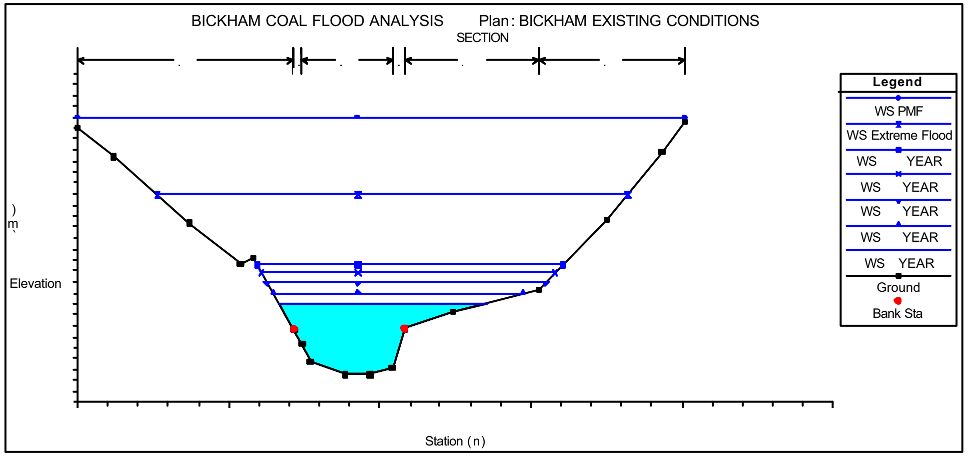
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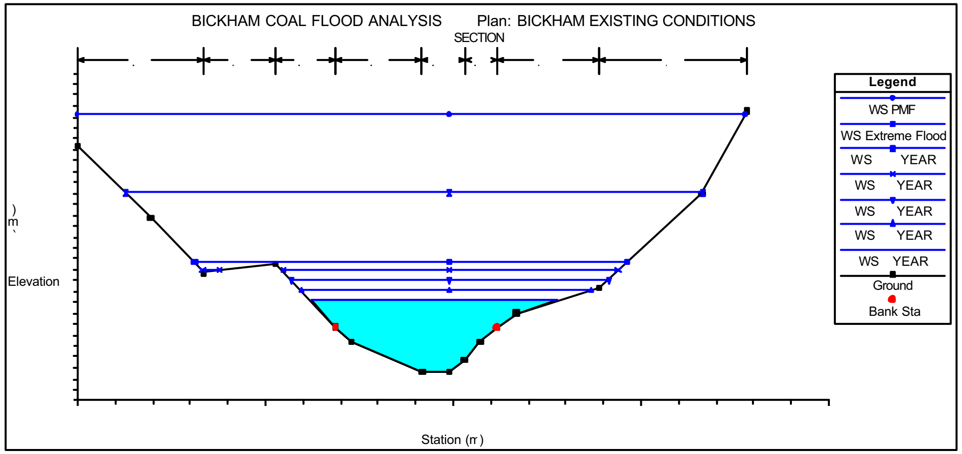
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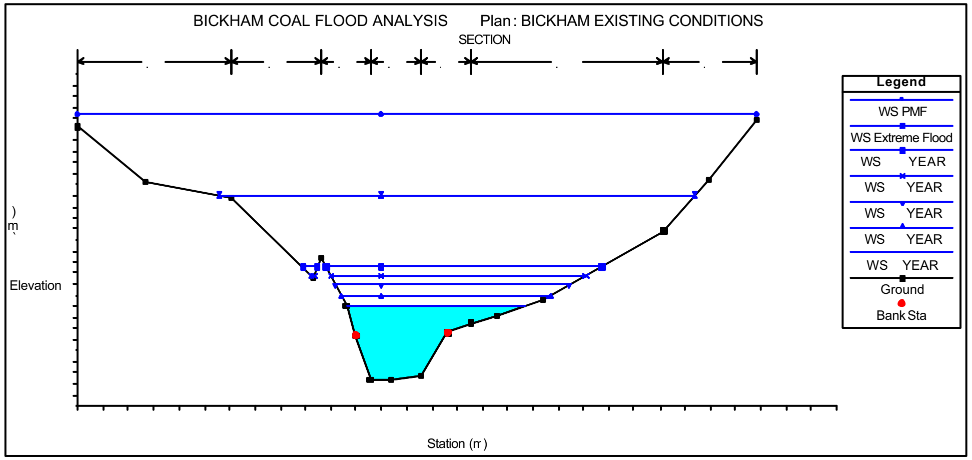
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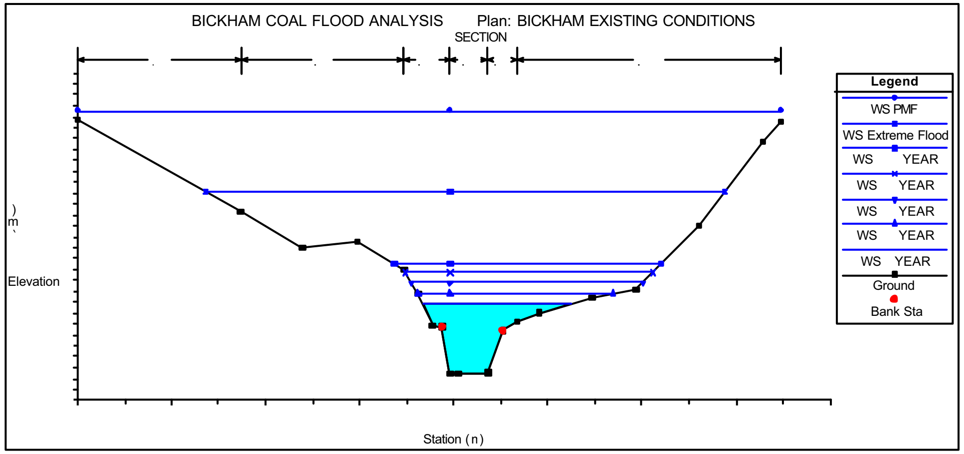
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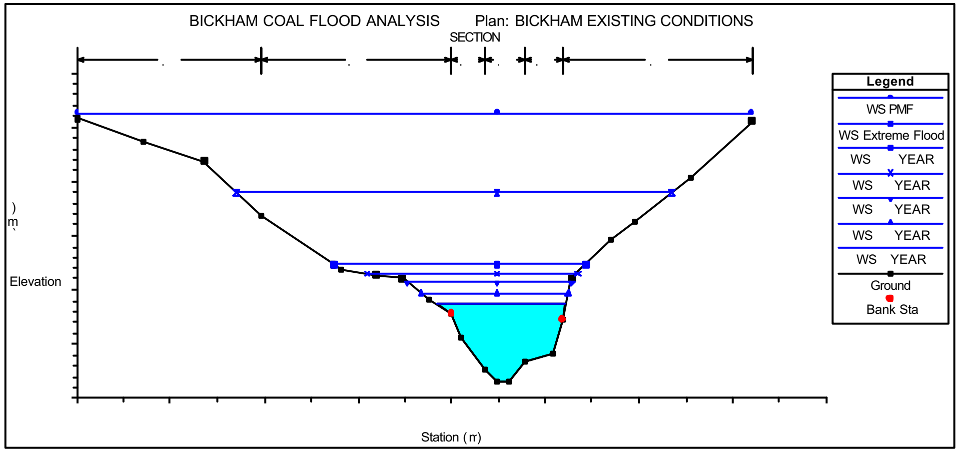
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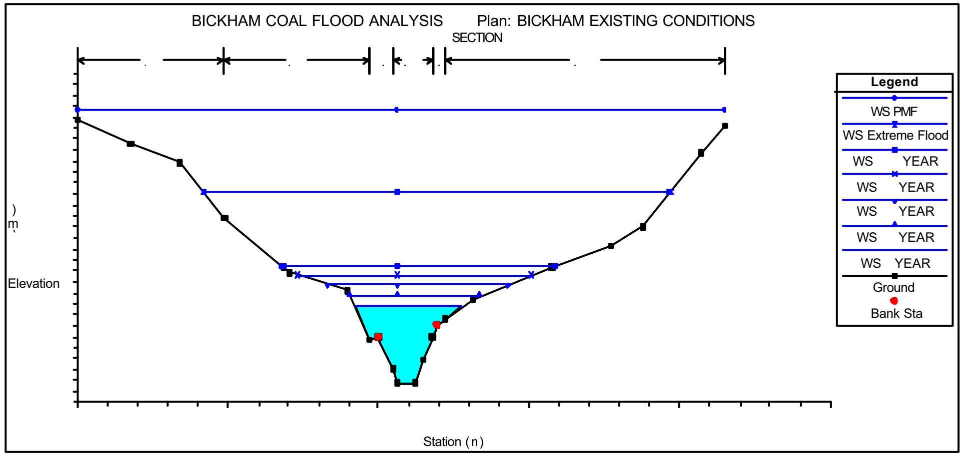
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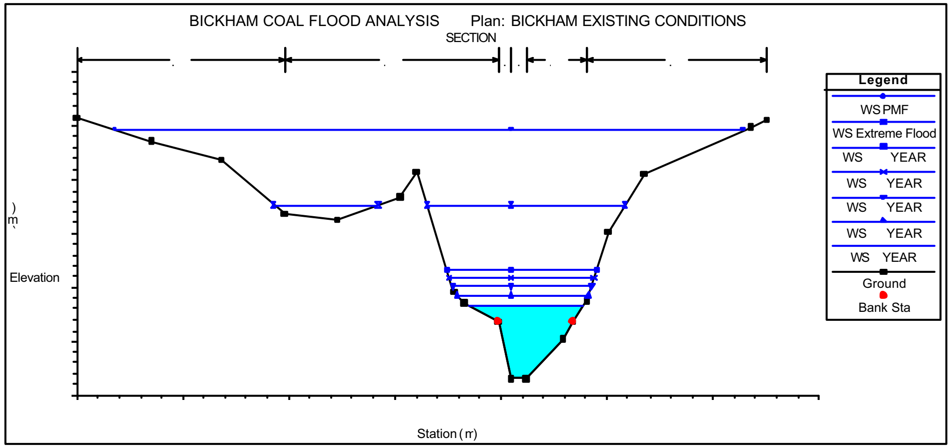
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APPENDIX B
FIGURES