Failure impact assessment of a mine site flood levee in Australia

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SYNOPSIS. Coal production from the 200 million tonne Curragh North coal resource in Central Queensland commenced in late 2005. The mine is located on the eastern floodplain of the Mackenzie River, and requires a 22 km long flood levee before operations can proceed. The earthfill embankment will generally be 1 m to 5 m in height; however, in eight locations the height will be between 11 m and 15 m. Although the levee's primary function is to protect the mine from flooding it will also form part of the site water management plan, retaining run-off across the 31 km2 site.

Under the Queensland Water Act 2000, a dam is referable and requires licensing if there is a population at risk (PAR) below the dam. Five potentially affected low-lying homesteads were identified over a 50 km downstream reach of the flood plain. An assessment of maximum breach characteristics was made using the mine layout and the State of Queensland Department of Natural Resources and Mines (DNRM) Guidelines. The unsteady hydraulic modelling program HEC RAS was used to model the breach impact at the homestead locations for both sunny-day and flood events. The assessment concluded that the levee is non-referable and a costly dam safety management program is therefore not required.

THE CURRAGH NORTH OPEN-CUT COAL MINE PROJECT

Australia has more than 74 billion tonnes of identified black coal reserves of which over 95% is located in either New South Wales or Queensland. Most black coal in Queensland comes from Newlands, Blair Athol or the Bowen Basin, extending south from Collinsville to Blackwater and Moura. Although the majority of the world's coal reserves are recoverable by underground mining, in Queensland approximately half of the 31,420 million tonnes of identified *in-situ* black coal resources is open cut coal. In 2004 the State of Queensland produced 169 million tonnes of saleable black coal.[1]

[1] Australian Coal Association website: www.australiancoal.com.au

The Curragh mine is situated 200 km west of Rockhampton, 30 km north of the township of Blackwater within Queensland’s Bowen Basin. It is owned and operated by Wesfarmers Curragh Pty Ltd. In 2004 the mine produced around 7 million tonnes of black coal. In 2004 Wesfarmers commenced development of the Curragh North coal site. This 200 million tonne resource will double the recoverable coal reserves currently available at Curragh and will extend the life of mining operations until at least 2025.[2]

A map showing the location of the Curragh North mine site is shown in Figure 1. The site is located on the eastern floodplain of the Mackenzie River, approximately 5 km downstream of the Bedford Weir.

Figure 1: Location of the Curragh North coal mine

THE FLOOD LEVEE

The floodplain in the vicinity of the mine site is subject to flooding during events in excess of the 10 year average recurrence interval (ARI) event. It is therefore proposed to protect the mine site from river flooding by constructing a perimeter levee which will surround the mine and prevent regular river inundation. The flood levee is designed to provide protection to the mine up to the 200 year ARI event.

A location plan for the flood levee and a typical section are shown in Figures 2 and 3 respectively. The levee is an earthfill embankment. It has a length of 22 km, with 12.5 km running along the river. Although the levee will generally be 1 m to 5 m in height; in eight locations significant gullies drain into the river and the height will be between 11 m and 15 m.

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[2] Wesfarmer’s website: www.wesfarmers.com.au

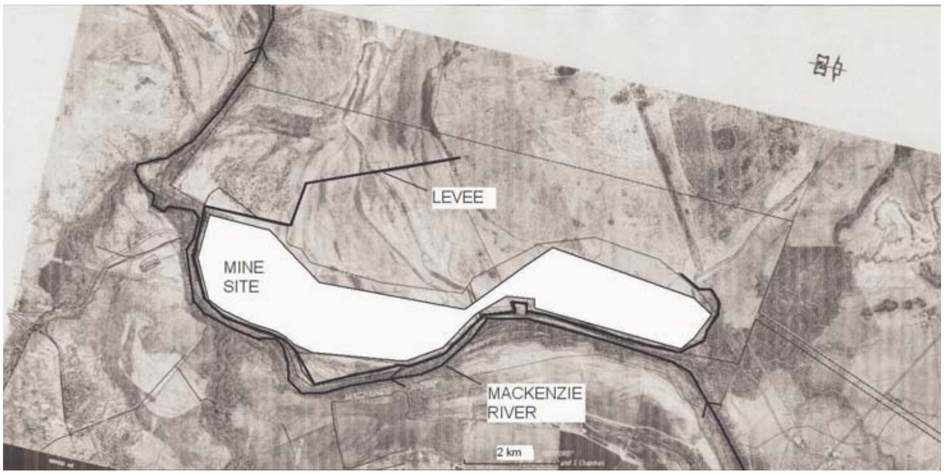

Figure 2: Curragh North mine site flood levee plan

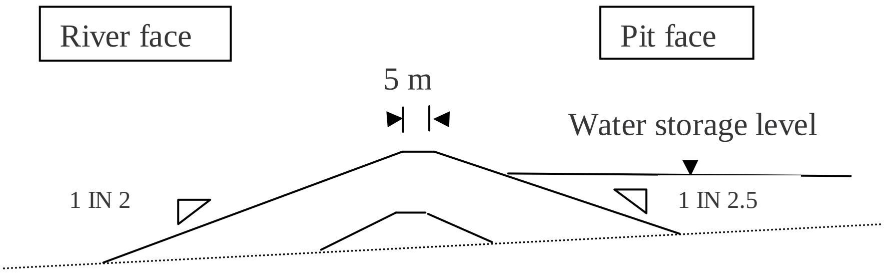

Figure 3: Curragh North mine site flood levee typical cross section

The levee will also form an important part of the mine water management system, as it will act to contain contaminated water from disturbed areas of the mine site, thereby minimising the frequency and volume of runoff to the receiving waters of the Mackenzie River. Water which is retained behind the levee will be harvested and used to satisfy mine site water demands.

WATER MANAGEMENT PHILOSOPHY

The philosophy behind the water management system is to retain as much runoff as possible within the levee system, throughout the 25-year life of the mine. Local runoff within the levee system is intended to be directed to a series of water storage dams via overland flow paths and drains.

IMPROVEMENTS IN RESERVOIRS

The water storage dams have been designed firstly to satisfy mine water demands and secondly to control contaminated runoff. They have been designed to comprise a lower level sump storage component and a higher level overflow storage component. The sump storage component will be excavated below the general ground levels inside the levee.

The concept of providing sump storage and overflow storage for the dams was adopted to minimise nuisance flooding, by storing runoff from minor and moderate events below the general ground level. This concept also assists in minimizing losses to evaporation and seepage, due to the reduced surface area of the excavated storage.

During major events, the sump storage will fill and water will spill out onto the overflow storage component. The overflow storage comprises the natural ground beyond the extent of the sump storage. The areal extent of the overflow storage will therefore be constrained by the flood levees, spoil dumps, pit protection bunds and the access road.

The overflow storage will enable retention of the majority of site runoff within the levee system, by providing large attenuating storage volumes above the natural ground level. During large storm events, this will mean that large areas of the mine site will be inundated for prolonged periods (several months).

THE NEED FOR A DAM FAILURE IMPACT ASSESSMENT OF THE CURRAGH NORTH FLOOD LEVEE

Under Australia's federal system of governance responsibility for dam safety falls under state legislation. Dam safety in Queensland is regulated by the Water Act 2000. Owners of dams are required to assess the impacts of dam failure on the safety of people living downstream by way of a dam failure assessment to determine whether the dam is referable.

Under the Act, the chief executive of the Department of Natural Resources and Mines (DNRM) is responsible for the regulation of referable dams in Queensland.

A failure impact assessment is required when a dam is or will be:

- 8 m in height and with a storage capacity > 500 Ml
- 8 m in height and with a storage capacity > 250 Ml and with a catchment area > 3 times the surface area of the dam at full supply[3]

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[3] Queensland Government Department of Natural Resources and Mines, Guidelines for Failure Impact Assessment of Water Dams, April 2002

The Curragh North flood levee will have a maximum height of 15.8m and could retain a maximum of 25,200 ML over its 2170 ha surface area. Therefore the Director of Dam Safety in the DNRM requested a failure impact assessment, assuming that the area inside the levee is filled by extreme rainfall to a level where additional runoff would discharge over the crest of the levee.

In accordance with the DNRM Guidelines, the assessment included the analysis of two cases:

1. clear or 'sunny-day' failure with no flow in Mackenzie River
2. failure coincident with the peak discharge during each of several floods of increasing magnitude in the river

If the levee embankments proved to be referable, Wesfarmers would be required to undertake the preparation of a dam safety management programme in accordance with Queensland Dam Safety Management Guidelines. This programme would involve the assembly of available design and construction documents, the preparation of standing operating procedures, operation and maintenance manuals, an emergency action plan and a schedule of surveillance and reporting. A referable dam in Queensland requires a safety review, generally at not more than 20 year intervals.

ANALYSES OF FLOOD INUNDATION

A hydrology and groundwater report for the Curragh North Mine Site was carried out by Parsons Brinckerhoff Australia (PB) in 2003. Estimated peak flow rates at Bedford Weir, 5 km upstream of the mine site, are shown in Table 1 below:

Table 1: Estimated peak flow rates

ARI (years)	**Peak flow (m^3/s)**
5	2600
10	4000
20	5600
50	7600
100	9200
200	11000
1000	15000

In order to determine the potential Population at Risk (PAR) as a result of a dambreak of the mine site levee, aerial photographs of the floodplain extending 110 km downstream of the area were inspected to identify homesteads. A vehicle inspection of the floodplain at various locations within this reach was then undertaken. Nine homesteads were identified that may be affected by a breach of the Curragh North levee.

Using the steady state hydraulic modelling program HEC RAS and a model developed as part of the levee design flood levels for the design floods in Table 1 above were calculated at each of the nine identified homesteads. Four of the homesteads were located above the 1000 year ARI flood peak and will be immune from dambreak during any flood. For the remaining five homesteads the critical flood ARIs are between 10 years and 100 years.

DAMBREAK ESTIMATES

Basis of estimate

In accordance with the DNRM guidelines the maximum breach discharge, Q_{breach} was determined using the following empirical formula for a typical homogeneous earthfill embankment:

$$Q_{breach} = 2.5FV^{0.76}H^{0.1} \text{ m}^3/\text{s}$$

Where:
F = 1.3 = Factor of safety to account for the simplified nature of the assessment
V = volume of water released (in megalitres)
H = maximum depth of water in the storage (in metres)

The maximum volume of water that could theoretically be stored within the levee system corresponds to the lowest crest level along the embankments. The maximum depth of water is taken as being based on the level of the most critical gully bed. For a sunny-day failure, this is the volume on which the breach discharge estimate is based.
For a concurrent river flood, the volume released from a breach will be the net volume stored above the river level at the breach location. The depth of water will be the difference between river level and crest level.

Sunny-day failure

For the sunny-day scenario a discharge hydrograph was developed for the peak discharge with an area equivalent to the corresponding storage volume released. Table 2 below summarises the breach discharge.

Table 2: Breach parameters for sunny-day failure

Depth (m)	Volume (ML)	Qbreach (m3/s)	Breach development time (min)
15.7	41360	13810	100.0

The dambreak wave pulse along the river and floodplain was modelled using an unsteady HEC RAS model. The flood wave envelope remained within the river channel, well below the ground level at any of the five critical homesteads. There is therefore no PAR from a sunny dam failure of the levee.

Concurrent flooding failure

Under the DNRM Guidelines there is a PAR for a dam breach that occurs concurrently with the peak of a flood if the incremental rise in the water level caused by the concurrent dambreak exceeds 300mm. The most critical case for each dwelling involves the flood which alone would just reach the ground level at the dwelling. Dam breach scenarios were calculated for various stages during the development of the mine. Table 3 below shows the flood levels, depths and estimated storage volumes upon which concurrent flooding dambreak discharge estimates were based.

Table 3: Concurrent flooding dambreak discharge estimates

Concurrent Event (ARI-year)	Flood level RL (m)	Storage depth (m)	Storage volume (ML)	Q_{breach} (m^3/s)	Breach development time (min)	Concurrent flood flow (m^3/s)	Q_{total} (m^3/s)
10	124.4	3.8	30800	9565	108	4000	13565
15	124.8	3.4	30320	9355	108	5300	14655
20	125.0	3.2	30040	9235	109	5600	14835
50	126.0	2.2	27120	7530	110	7600	15100
100	126.4	1.9	24200	7420	109	9200	16620

The HEC RAS model was run with a constant flow rate equal to the peak flow during the critical floods for each of the homesteads. The dambreak hydrographs from Table 3 above were then routed through the model. Table 4 below shows the incremental flood levels at each of the homesteads during the critical flood.

Table 4: Incremental flood levels at critical ARIs for each homestead

Homestead	Concurrent event (ARI – year)	Homestead floor level RL (m)	Flood level (RL (m)	Dambreak level RL(m)	Incremental flood rise (mm)
Bingegang	100	117.91	117.90	118.06	160
Greenacres	15	112.54	112.82	113.05	230
Bundaleer East	20	109.92	109.50	109.60	100
Parker Creek	10	107.55	107.69	107.95	260
Honeycomb	50	109.06	109.21	109.36	150

The maximum incremental flood rise is 260 mm at Parker Creek homestead. The incremental rise in water level during a dambreak is therefore less than 300mm in all cases and under the DNRM Guidelines there is no PAR.

Sensitivity tests

The DNRM Guidelines require that sensitivity tests are carried out on the parameters used for the dam failure assessment. The effect of a variation in the following parameters was therefore investigated:

- Floodplain width
- Roughness values
- Breach development time

Variations in the floodplain width were investigated due to the limited accuracy of the DTM available. Cross sections within the HEC RAS model were widened arbitrarily by 2000m. This caused a decrease in the peak levels, for both the dambreak scenarios and the flood alone. This led to a slight increase in the incremental flood rise for the first two homesteads and a slight decrease for the homesteads further downstream. The results were not significant.

Sensitivity analysis was carried out for a 50% increase and a 50% decrease in Manning’s n value. For the 50% increased roughness value there is no incremental flood rise. For the 50% decreased roughness value the flood rise is 0.6m. The roughness values used in the principal analyses were derived by calibration of the steady state model during the sizing of the flood levee. Values significantly less than these are therefore considered highly unlikely.

The dambreak hydrographs used in the principal analyses were assumed to be triangular. The DNRM Guidelines also describe a methodology for determining breach development time based on the volume of material eroded. Routing these alternative DNRM hydrographs through the HEC RAS model was found to have no significant effect on incremental flood levels.

The trends indicated by the sensitivity tests therefore confirmed that there is no PAR along the Mackenzie River due to a dam breach of the Curragh North mine levee. It will therefore not be necessary for Wesfarmers to undertake the preparation of a dam safety management program in accordance with Queensland Dam Safety Management Guidelines

CONCLUSIONS

The 22 km perimeter levee at the Curragh North mine site provides protection from inundation by the Mackenzie River during flooding events and contains contaminated runoff from the mine site for use during mine operations.

A dam failure assessment has been carried out on the levee in accordance with the Queensland Water Act 2000 using the DNRM guidelines. For the sunny-day scenario it was found that the flood wave envelope remained within the river channel and therefore there is no PAR. For a dam breach that occurs concurrently with the peak of a flood the maximum incremental rise at the homesteads was 260mm, which is within the allowable rise of 300 mm under the Guidelines. A robust sensitivity analysis was carried out on the floodplain width, the assumed channel roughness and the breach development time confirming that there is no PAR. Wesfarmers is therefore not required to undertake the preparation of a dam safety management program in accordance with Queensland Dam Safety Management Guidelines.