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Designing for the long term: a risk-based approach to stormwater management at mine closure

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Abstract

Effective stormwater and waterway design is fundamental to achieving safe, stable and sustainable mine closure outcomes. As operational controls are progressively removed, closure landscapes must perform over extended design lives, often in the presence of residual geotechnical, environmental and public safety risks. This paper presents a structured, risk-based framework developed for rehabilitation of the Hazelwood mine site to guide the selection of design life and minimum design flow events for surface water infrastructure.

The framework integrates corporate risk matrices with hydrologic and geomorphic design processes to ensure that stormwater assets are proportionate to the consequence of failure. Consequence categories – including public safety, environmental harm, cost, legal and reputational impacts – are linked to likelihood thresholds over defined design life criteria, such as operational and post-closure phases. These likelihood thresholds are translated into annual exceedance probability (AEP) design events, enabling consistent and transparent derivation of minimum design criteria across diverse landform and drainage settings.

A spatial classification of 'surface water management unit types' was developed based on discharge location (internal pit, internal terminal, or external receiving waters of the Latrobe catchment) and underlying material (e.g. ash, coal, overburden, in situ soils). This classification directly informs consequence ratings for erosion-related failure and, in turn, the required design event. The approach aligns with Australian Rainfall and Runoff (ARR) guidance, including climate change adjustments to rainfall intensity (Ball et al. 2019).

Testing across multiple design domains, illustrated through the West Field Western Batter (WFWB) domain worked example, demonstrated that the framework improves consistency and defensibility of closure designs without imposing unnecessary conservatism. By explicitly linking risk appetite to hydraulic performance criteria, the methodology supports transparent trade-offs between capital cost, long-term maintenance and residual risk. The framework provides a scalable model for other mine sites transitioning to closure, offering regulators and operators a practical pathway to risk-informed, climate-resilient water management.

Keywords: *mine closure, risk-based design, stormwater management, waterway rehabilitation, erosion risk, design life, flood hydrology, climate change adaptation.*

1 Introduction

Following the operational closure of Hazelwood mine in March 2017, ENGIE Hazelwood commenced planning for relinquishment of the site and future alternate land uses. That process involves significant rehabilitation obligations and will ultimately seek to leave the site in a form that is safe, stable, sustainable and non-polluting (ENGIE Hazelwood 2025).

Mine closure requires stormwater and waterway systems to transition from actively managed operational controls to passive, long-term landscape features. At Hazelwood mine, closure landforms include engineered batters and drainage networks that must remain stable under a range of frequent and extreme rainfall run-

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off conditions while limiting exposure and mobilisation of problematic materials (e.g. ash, coal, overburden) to receiving waterways (Figure 1).

A risk-based approach to the design of these systems must therefore balance safety and environmental protection with constructability, cost and long-term maintenance.

This paper presents a risk-based framework to select design life and minimum design flow events for closure waterways at Hazelwood. The method aligns corporate risk concepts (consequence, likelihood and acceptable residual risk) with hydrologic design by translating likelihood bands over defined design lives into annual exceedance probability (AEP) events.

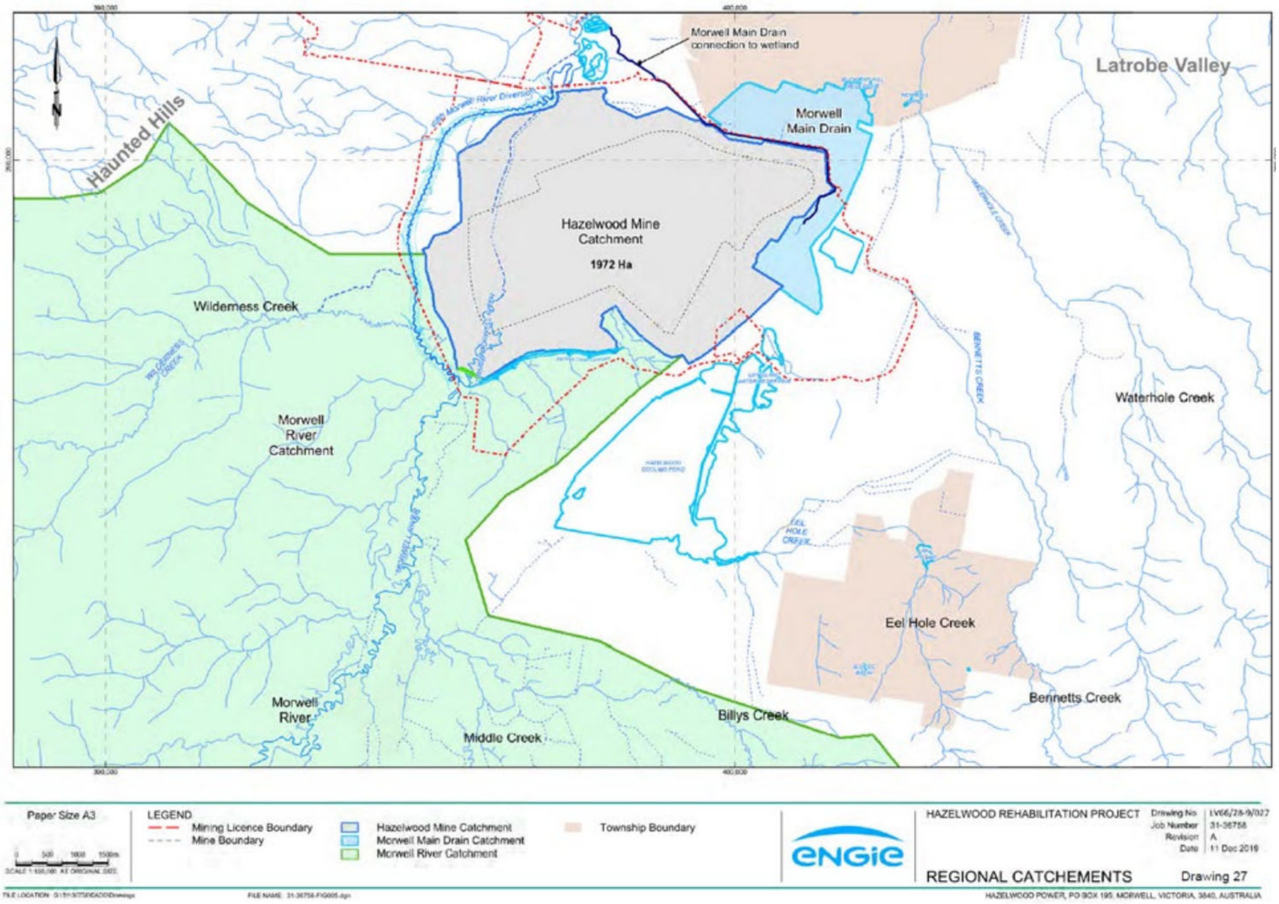


Figure 1 Waterways and catchments surrounding Hazelwood mine (source: ENGIE Hazelwood 2025)

2 Risk-based framework for closure waterway design

The framework supports consistent criteria across multiple designers and packages. It links an agreed risk tolerance to minimum hydraulic performance, using higher standards where failure consequences are severe (e.g. safety or critical infrastructure) and allowing less-conservative criteria where consequences are low and controlled adjustment is acceptable. A conceptual overview of the framework is provided in Figure 2.

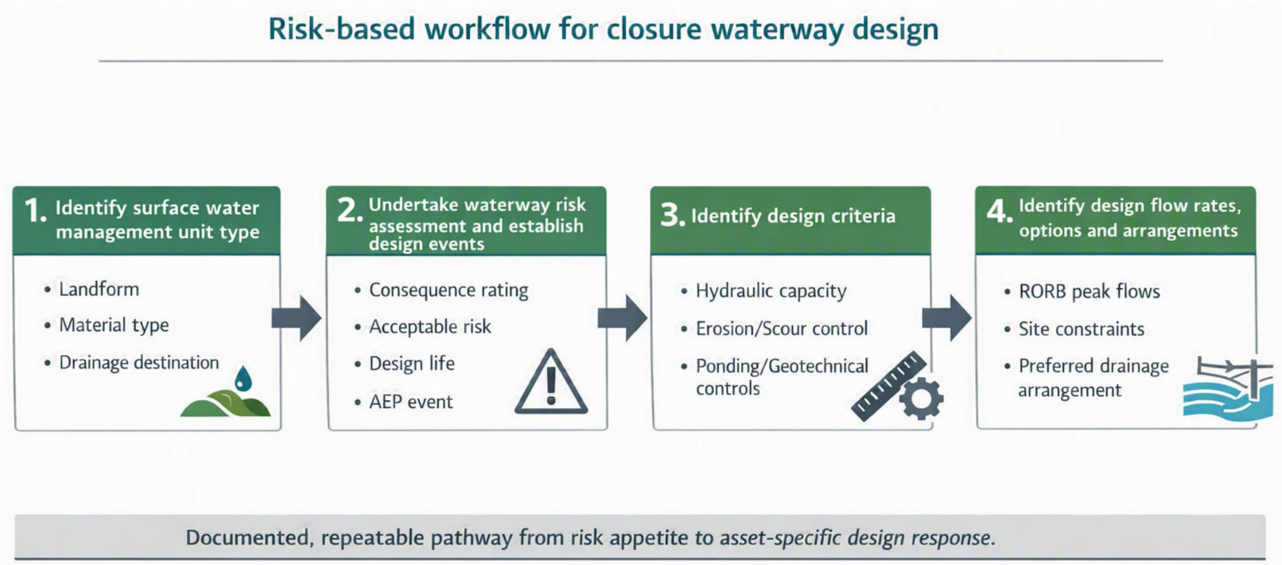


Figure 2 Risk-based workflow linking risk appetite to design events and waterway design checks for closure stormwater assets

2.1 Framework design objectives

Objectives considered in the framework used to guide the selection of design life and design events include:

- Establish a consistent approach to selection of the design life and design flow events for waterways across the site for the use of multiple designers for the purpose of the closure of the site.
- Recognise and reflect the inherent risks at the site and trade-offs between construction costs, risks and ongoing maintenance requirements.

The key challenge is setting criteria that are defensible but practical. The framework addresses this by making design life and risk tolerance explicit and using a repeatable pathway to minimum design events, supporting consistent peer review and regulator engagement.

2.2 Acceptable levels of risk

A risk management framework was developed for the closure of the site that considers:

- the acceptability of risk
- definitions of consequence
- definitions of likelihood.

The acceptability of risk contained within this framework, adopted for the site, is summarised in Figure 3. The risks set out in Figure 3 comprise the likelihood and consequence of an event impacting on assets or values of interest. A maximum risk category of 'medium' has been adopted for the purpose of determining the AEP event across the site. This maximum risk rating has been identified based on the consequences of failure and agreed with ENGIE.

LIKELIHOOD \ CONSEQUENCE	INSIGNIFICANT	MINOR	MODERATE	MAJOR	CRITICAL
Rare	Low	Low	Medium	Medium	High
Unlikely	Low	Low	Medium	High	High
Possible	Low	Medium	Medium	High	Very High
Likely	Medium	Medium	High	Very High	Very High
Almost Certain	Medium	High	Very High	Very High	Very High

Figure 3 Risk assessment matrix (ENGIE Hazelwood 2025)

The consequence of an event occurring has been categorised by ENGIE based on the severity of impacts under the following themes:

- Public health and safety
- Environment
- Cost consequence
- Reputation
- Legal.

Within the site/ENGIE risk framework, consequence ratings describe the severity of impact if a hazard event occurs. For this paper, the following categories are applied:

- Insignificant
- Minor
- Medium
- Major
- Critical.

The likelihood of an event occurring that triggers an impact has been categorised by ENGIE into 5 categories:

- Rare
- Unlikely
- Possible
- Likely
- Almost certain.

The likelihood of an event occurring is a function of the design life of the proposed works. The likelihood of an event occurring increases with design life; that is, with increasing time there is an increased chance that an event will occur that impacts the asset or value of interest. That is the likelihood of an event occurring that exceeds design flow event increases with time, which could result in asset degradation, failure or damage to adjacent infrastructure. The probability categories adopted in the framework are set out in Table 1.

Table 1 Likelihood categories

Likelihood category	**1**	**2**	**3**	**4**	**5**
Description	Rare	Unlikely	Possible	Likely	Almost certain
Probability of occurrence over design life	<2%	2–20%	20–60%	60–98%	>98%

The risk framework adopted by ENGIE has been adapted for the purpose of the risk-based approach to identifying the design life and design flow events for waterway and drainage infrastructure.

2.3 Determining design life of waterway and drainage infrastructure

The design life of the landscape is a critical element in identifying the likelihood of a risk occurring. As design life increases, so does the likelihood of an event occurring. Two design time periods are associated with closure at the site: one covering the period over which the pit will be filled, and the second covering the longer-term life of the post-closure landscape, as follows:

- A 16-year minimum design life has been adopted for waterway and drainage infrastructure only intended to serve the period of mine filling.
- A 200-year post-fill phase long-term design life has been adopted based on waterway and drainage infrastructure consistent with previous, government-approved designs.

2.4 Determining design events

The design events to be adopted for the design of waterway and drainage infrastructure are based on:

- an acceptable level of risk
- the design life of infrastructure.

The design life of infrastructure has been used to calculate design events. AEP flow events have been calculated for both the 16-year fill phase and the 200-year design life based on the probability of occurrence included in the ENGIE-adopted risk framework.

The likelihood probabilities in Table 1 represent the cumulative probability of an event occurring over the design life. For example, a 0.1% AEP event has a probability of 99.9% of not occurring in any given year. The total probability of not occurring over a 200-year timeframe is 99.9%^200, which equals 81.8%. Therefore, the total probability of the event occurring at least once over the design life is 18.2%. This equates to an unlikely event (Table 1).

This process was adopted to identify the design event for each of the adopted likelihood ratings. The adopted design events for each likelihood rating for both a 16-year and 200-year design life based on acceptable 'medium' risk rating are set out in Table 2.

Table 2 Minimum design events for identified consequence categories

Risk category	Consequence rating	Maximum likelihood rating (for 'medium' risk)	Minimum design event	
			16-year design life	200-year design life
Medium	Critical	Rare	0.13% (770-year ARI)	0.01% (10,000-year ARI)
	Major	Unlikely	1.5% (66-year ARI)	0.11% (900-year ARI)
	Moderate	Possible	6% (16-year ARI)	0.5% (219-year ARI)
	Minor	Likely	23% (3.8-year ARI)	2% (50-year ARI)
	Insignificant	Almost certain	NA	NA

Note: ARI – annual recurrence interval. ARI values have been rounded to nearest suitable value currently available for modelling. NA = Not applicable, no design event required due to insignificant consequence.

2.4.1 Spatial classification of surface water management unit types

The consequence of a waterway failure can be critical. The mechanisms of failure can be diverse. The potential consequences of failure are set out in the ENGIE risk framework and include impacts on values such as:

- public safety and health
- the environment
- economic assets
- reputation.

The processes that lead to these outcomes can be associated with:

- flood inundation
- erosion
- contaminated seepage.

Erosional impacts can be driven by:

- surface flows
- subsurface processes.

Erosion consequences are assigned using 'surface water management unit types' defined by discharge setting (pit, internal terminal, or offsite receiving waters) and underlying material (e.g. ash, coal, overburden, in situ soils) (Alluvium Consulting 2019a) as shown in Figure 4.

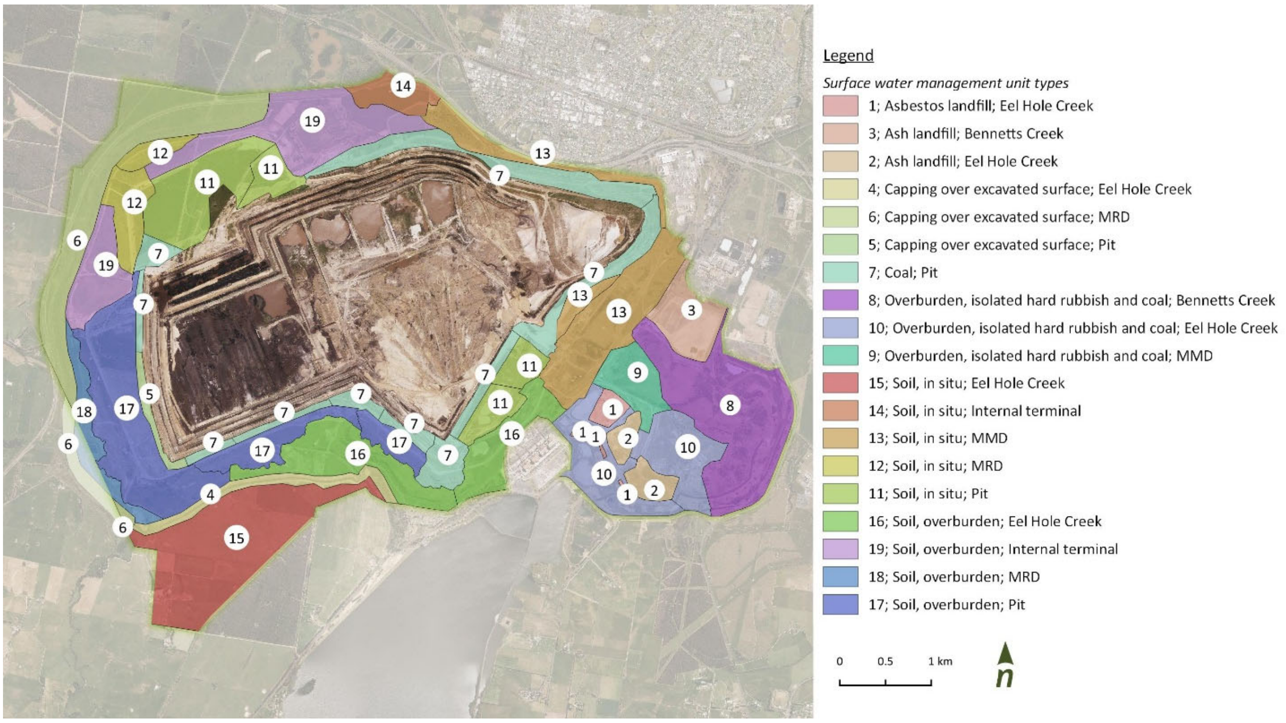


Figure 4 Example surface water management units adopted for the consequence assessment (Alluvium Consulting 2019b)

This logic is applied using the site landform, materials model and drainage connectivity, providing a consistent map-based input to minimum event selection. These types have been used as input to the risk assessment for the purpose of identifying consequence categories (Table 3) and the minimum design event applicable to that unit type.

Table 3 Surface water management unit types and consequence ratings for erosion processes

Management unit ID	Management unit type	Consequence rating for erosion impacts on the environment	Comment
1	Asbestos landfill; Eel Hole Creek	Major	
2	Ash landfill; Bennetts Creek	Major	
3	Ash landfill; Eel Hole Creek	Major	
4	Capping over excavated surface; Eel Hole Creek	Moderate	
5	Capping over excavated surface; pit	Moderate	Damage to chutes into pits is the driver of the moderate rating (i.e. cost)
6	Capping over excavated surface; MRD	Moderate	
7	Coal; pit	Moderate	Damage to chutes into pits is the driver of the moderate rating (i.e. cost)
8	Overburden, isolated hard rubbish and coal; Bennetts Creek	Moderate	
9	Overburden, isolated hard rubbish and coal; MMD	Moderate	
10	Overburden, isolated hard rubbish and coal; Eel Hole Creek	Moderate	
11	Soil, in situ; pit	Minor	
12	Soil, in situ; MRD	Major	Driven by the consequence of erosion of waterways leading to levee damage
13	Soil, in situ; MMD	Major	Driven by the consequence of erosion of Morwell Main Drain leading to road damage and potential fatalities
14	Soil, in situ; internal terminal	Minor	
15	Soil, in situ; Eel Hole Creek	Moderate	
16	Soil, overburden; Eel Hole Creek	Moderate	

Management unit ID	Management unit type	Consequence rating for erosion impacts on the environment	Comment
17	Soil, overburden; pit	Minor	
18	Soil, overburden; MRD	Moderate	
19	Soil, overburden; internal terminal	Minor	

*Note this table is an indication of the consequence of erosion processes. It does not cover all potential processes such as dispersion, geotechnical failure, etc.

2.4.2 Recommended workflow approach for designers

The ENGIE risk framework has been developed to identify the minimum design flow event for the assessment and design of waterways and drainage infrastructure across the site, based on erosion and ponding risks.

The following tasks are required to identify the design flow events:

- Identify surface water management unit type (Figure 4).
- Identify the consequences on assets and values of interest based on the processes at work (found within the Hazelwood Declared Mine Rehabilitation Plan – ENGIE Hazelwood [2025]), and determine the highest consequence rating
- Establish minimum design events based on the consequence of events, assuming a maximum allowable risk rating of 'medium' for waterway designs using Table 2 for 'medium' risk.
- Identify the design flow rates, options and arrangements.

The design event table (Table 2) can be used to identify the minimum design event appropriate to any consequence rating based on a maximum risk of 'medium'.

3 Case study and worked example

3.1 West Field Western Batter domain

This case study represents drainage descending the steep West Field Western Batter (WFWB) domain batters into the pit (draining to pit; Figure 5a). ENGIE Hazelwood provided computer-aided design (CAD) files of the WFWB base design updated landforms, including existing contours and proposed batter re-profiling within the WFWB domain (Figure 5b). The surface profile created from these data forms the basis of the design strategy, including identification of relevant catchment areas and generation of design flows.

(a) (b)

Figure 5 (a) Aerial view of Hazelwood mine showing the extent of the WFWB domain; (b) WFWB base design updated landform (Alluvium Consulting 2024)

The following is a list of tasks undertaken to assess waterway risk and develop the design in accordance with the framework (Section 2):

- Task 1 - Identify surface water management unit type.
- Task 2 - Undertake waterway risk assessment and establish design events.
- Task 3 - Identify design criteria.
- Task 4 - Identify design flow rates, options and arrangements.

The following sections provide an outline of the design tasks listed above.

3.1.1 Identify surface water management unit type

The surface water management unit types associated with each waterway design tested for WFWB catchments using Figure 4 are:

- 5 - capping over excavated surface; pit
- 7 - coal; pit
- 17 - soil, overburden; pit.

3.1.2 Undertake waterway risk assessment and establish design events

The risk assessment in Table 4 was undertaken as part of framework development, based on Tables 2 and 3. Two hazard profiles were identified for the site: erosion of waterways (batter chutes and drains) and geotechnical failure. The consequences associated with these hazards vary and assessment was predominantly based on remediation cost following failure.

The cost to rehabilitate waterway erosion for batter chutes or structure repair above RL 45 will typically be in the \$100–500k category ('moderate' consequence), below RL 45 will typically be in the \$50–100k category ('minor' consequence), as advised by ENGIE.

The cost to rehabilitate waterway erosion for catch drains above and below RL 45 will typically be in the \$50–100k category ('minor' consequence). The cost to rehabilitate waterway erosion for swale drains above and below RL 45 will typically be in the \$50–100k category ('minor' consequence).

The cost to rehabilitate geotechnical failure will typically be in the \$500k–\$5M category ('major' consequence).

Based on the consequence and acceptable risk score, the required likelihood of occurrence has then been set to ensure an acceptable risk of 'low' or 'medium' is achieved based on Table 2. This includes:

- For a 'minor' consequence, the design requires the following target design events:
    - below RL 45: 23% (3.8-year ARI) to obtain maximum acceptable risk score of 'medium'
    - above RL 45: 2% (50-year ARI) to obtain maximum acceptable risk score of 'medium'.
- For a 'moderate' consequence, the design requires the following target design events:
    - below RL 45: no Moderate consequence identified
    - above RL 45: 0.5% (219-year ARI) to obtain maximum acceptable risk score of 'medium'.
- For a 'major' consequence, the design requires the following target design events:
    - below RL 45: 1.5% (66-year ARI) to obtain maximum acceptable risk score of 'medium'
    - above RL 45: 0.11% (900-year ARI) to obtain maximum acceptable risk score of 'medium'.

However, due to the significant risk and size of the design event required (0.11% AEP, 900-year ARI) for the geotechnical failure from ponding or crossing a burn-hole, a key design criterion is that drainage is to be free draining (no ponding) to avoid crossing burn-holes.

Table 4 shows the required likelihood and associated design events (AEP) for each surface water management unit type required to bring the risks into an acceptable risk category ('medium'). The risks are broken into the fill phase (16-year design life) and post-fill phase (200-year design life).

Table 4 Risk assessment for WFWB domain draining to pit

ID	Hazard	Description	Consequence of occurrence	Maximum acceptable risk score	Target likelihood of occurrence	Design event AEP (ARI)	Design criteria recommendation
Management unit type: capping over excavated surface draining to pit							
Fill phase (waterways/drains below RL 45)							
1	Erosion of waterways (batter chutes, catch drains and swale drains)	Erosion of waterway/drains without contaminant exposure	Minor	Medium	Likely	23% (3.8-year ARI)	Design to ensure no scour potential up to the design threshold event = 23% (3.8-year ARI).
2	Geotechnical failure	Ponding of water leading to geotechnical failure of pit batters	Major	Medium	Unlikely	1.5% (66-year ARI)	Due to the significant risk and size of the design event required (1.5% AEP, 66-year ARI) for the geotechnical failure from ponding and waterway crossings of burn-holes, a key design criterion is that drainage is to be free draining (no ponding). Where design capacity is not achievable (due to site constraints), waterways to be lined with concrete matting or equivalent.
Post fill phase (waterways/drains above RL 45)							
3	Erosion of waterways (batter chutes)	Erosion of batter chutes without contaminant exposure	Moderate	Medium	Possible	0.5% (219-year ARI)	Design to ensure no scour potential up to the design threshold event = 0.5% (219-year ARI).
4	Erosion of waterways (catch drains and swale drains)	Erosion of catch drains without contaminant exposure	Minor	Medium	Likely	2% (50-year ARI)	Design to ensure no scour potential up to the design threshold event = 2% (50-year ARI). In areas where design capacity cannot meet design threshold event (due to site constraints), drain to be lined with concrete matting or equivalent.

ID	Hazard	Description	Consequence of occurrence	Maximum acceptable risk score	Target likelihood of occurrence	Design event AEP (ARI)	Design criteria recommendation
5	Geotechnical failure	Ponding of water leading to geotechnical failure of pit batters	Major	Medium	Unlikely	0.11% (900-year ARI)	Due to the significant risk and size of the design event required (0.11% AEP, 900-year ARI) for the geotechnical failure from ponding, a key design criterion is that drainage is to be free draining (no ponding). Where design capacity not achievable (due to site constraints), waterways to be lined with concrete matting or equivalent.
			Management unit type: soil, overburden; draining to pit				
			Fill phase (waterways/drains below RL 45)				
6	Erosion of waterways (batter chutes, catch drains and swale drains)	Erosion of waterway/drains without contaminant exposure	Minor	Medium	Possible	23% (3.8-year ARI)	Design to ensure no scour potential up to the design threshold event = 23% (3.8-year ARI).
7	Geotechnical failure	Ponding of water leading to geotechnical failure of pit batters	Major	Medium	Unlikely	1.5% (66-year ARI)	Due to the significant risk and size of the design event required (1.5% AEP, 66-year ARI) for the geotechnical failure from ponding and waterway crossings of burn-holes, a key design criterion is that drainage is to be free draining (no ponding). Where design capacity not achievable (due to site constraints), waterways to be lined with concrete matting or equivalent.
			Post fill phase (waterways/drains above RL 45)				
8	Erosion of waterways (batter chutes)	Erosion of waterway/drains without contaminant exposure	Moderate	Medium	Possible	0.5% (219-year ARI)	Design to ensure no scour potential up to the design threshold event = 0.5% (219-year ARI).

ID	Hazard	Description	Consequence of occurrence	Maximum acceptable risk score	Target likelihood of occurrence	Design event AEP (ARI)	Design criteria recommendation
9	Erosion of waterways (catch drains and swale drains)	Erosion of catch drains without contaminant exposure	Minor	Medium	Likely	2% (50-year ARI)	Design to ensure no scour potential up to the design threshold event = 2% (50-year ARI). In areas where design capacity cannot meet design threshold event (due to site constraints), drain to be lined with concrete matting or equivalent.
10	Geotechnical failure	Ponding of water leading to geotechnical failure of pit batters	Major	Medium	Unlikely	0.11% (900-year ARI)	Due to the significant risk and size of the design event required (0.11% AEP, 900-year ARI) for the geotechnical failure from ponding, a key design criterion is that drainage is to be free draining (no ponding). Where design capacity not achievable (due to site constraints), waterways to be lined with concrete matting or equivalent.
Management unit type: coal, draining to pit							
Fill phase (waterways/drains below RL 45)							
11	Erosion of waterways (batter chutes, catch drains and swale drains)	Erosion of waterway/drains leading to exposure of coal	Major	Medium	Unlikely	1.5% (66-year ARI)	Due to the significant risk and size of the design event required (1.5% AEP, 66 yr ARI) for the geotechnical failure from ponding and waterway crossings of burn holes, a key design criterion is that drainage is to be free draining (no ponding). Waterway to avoid crossing burn holes where possible. Where crossing of burn hole unavoidable or design capacity not achievable (due to site constraints, waterways to be protective lined with concrete matting or equivalent.
12	Geotechnical failure	Ponding of water leading to geotechnical failure of pit batters	Major	Medium	Unlikely	1.5% (66-year ARI)	

ID	Hazard	Description	Consequence of occurrence	Maximum acceptable risk score	Target likelihood of occurrence	Design event AEP (ARI)	Design criteria recommendation
			Post fill phase (waterways/drains above RL 45)				
13	Erosion of waterways (batter chutes)	Erosion of waterway/drains leading to exposure of coal	Moderate	Medium	Possible	0.5% (219-year ARI)	Design to ensure no scour potential up to the design threshold event = 0.5% (219-year ARI).
14	Erosion of waterways (catch drains and swale drains)	Erosion of waterway leading to exposure of coal	Minor	Medium	Likely	2% (50-year ARI)	Design to ensure no scour potential up to the design threshold event = 2% (50-year ARI). In areas where design capacity cannot meet design threshold event (due to site constraints), drain to be lined with concrete matting or equivalent.
15	Geotechnical failure	Ponding of water leading to geotechnical failure of pit batters	Major	Medium	Unlikely	0.11% (900-year ARI)	Due to the significant risk and size of the design event required (0.11% AEP, 900-year ARI) for the geotechnical failure from ponding, a key design criterion is that drainage is to be free draining (no ponding). Where design capacity not achievable (due to site constraints), waterways to be lined with concrete matting or equivalent.

3.1.3 Identify design criteria

The design criteria derived from the waterway risk assessment are defined in Table 5.

Table 5 WFWB surface water design criteria

Group	Criteria
Design life	Design life of assets proposed should be 16 years for the pit fill phase.
	Design life of assets proposed should be 200 years for the post-fill phase.
Design capacity	Waterway/drain design that are below the final fill level (RL 45 m AHD) should be based on ensuring stability up to the 23% AEP (3.8-year ARI - adopt 5-year ARI - standard output from ARR Data Hub; ARR Data Hub 2026).
	Waterways (batter chutes) that are above the final fill level (RL 45 m AHD) should be based on ensuring stability up to the 0.5% AEP (219-year ARI - adopt 200-year ARI - standard output from ARR Data Hub; ARR Data Hub 2026).
	Waterways (catch drains and swale drains) that are above the final fill level (RL 45 m AHD) should be based on ensuring stability up to the 2% AEP (50-year ARI - adopt 50-year ARI).

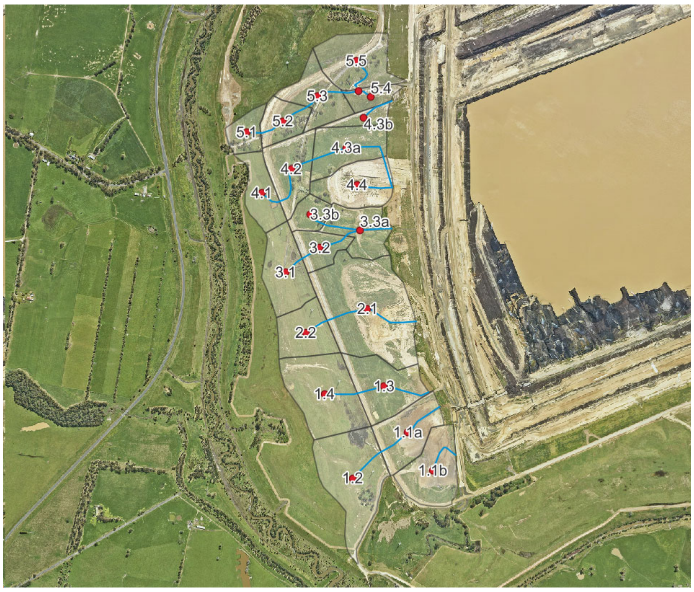
AHD – Australian height datum; ARR – Australian Rainfall and Runoff

3.1.4 Identify design flow rates, options and arrangements

For the WFWB catchment, hydrologic modelling was undertaken using RORB (v6.42), a run-off routing model that simulates attenuation and delay of a hydrograph to produce flood estimates at specified catchment locations (the asset being assessed). RORB calculates the peak flow rates for a range of design events.

A RORB model was built by delineating the major catchments into sub-areas based on the final landform with batter works (Figure 6Figure). A range of spill points were selected based on contour data, and the catchment behind it determined using the existing lidar data provided.

Figure 6 shows the resulting flows for the WFWB final landform under the various catchment conditions at which drainage spills into the pit.



Batter Drain	Design event (m^3/s)
ELCH1	1.45 0.5% AEP event
ELCH2	2.77 0.5% AEP event
ELCH3	2.91 0.5% AEP event
ELCH4	2.99 0.5% AEP event
ELCH5	4.46 0.5% AEP event
ELCH6	2.67 0.5% AEP event
ELCH7	3.60 0.5% AEP event
ELCH9	2.33 0.5% AEP event
ELCH8	0.34 0.5% AEP event
ELCH10	1.7 0.5% AEP event
ELCH11	3.06 0.5% AEP event

(a) (b)

Figure 6 WFWB drainage catchment plan and RORB structure (a) and RORB flows at key drainage asset locations (b) (Alluvium Consulting 2024)

Figure 6 completes the framework pathway summarised in Section 2 by converting the mapped unit types and consequence-based design events into asset-specific design checks. The RORB model identifies peak flows at key drainage assets, while Tables 4 and 5 define the applicable AEP criterion and design response. In this way, the framework moves from classification and risk assessment to practical design decisions: larger catchments or higher flows are checked against the relevant consequence-derived threshold to confirm whether standard earth-lined drainage is sufficient, or whether increased capacity, flatter alignment, protective lining, burn-hole avoidance or no-ponding/free-draining profiles are required.

4 Discussion

4.1 Broader application: translating the framework into design outcomes

The WFWB worked example demonstrates that the framework changes design outcomes in a measurable way, rather than simply providing a qualitative risk screening tool. Table 4 shows that drainage elements within the same domain are assigned different minimum design events depending on consequence, design life and failure mechanism. For example, erosion protection for fill-phase waterways below RL 45 is set at 23% AEP (3.8-year ARI), whereas post-fill batter chutes above RL 45 require 0.5% AEP (219-year ARI) and post-fill catch drains and swales require 2% AEP (50-year ARI). For geotechnical failure associated with ponding, the framework requires more stringent criteria again: 1.5% AEP (66-year ARI) during the fill phase and 0.11% AEP (900-year ARI) for the post-fill phase, with a design response of free-draining profiles rather than reliance on large conveyance capacity alone.

The worked example demonstrates the framework pathway described in Section 3.1.4 by converting mapped unit types and consequence-based design events into asset-specific design checks. The RORB model identifies catchment areas, routing structure and peak flows at key drainage asset locations, while Tables 4 and 5 define the applicable AEP criterion and design response. In practical terms, the framework converts a single landform and flow model into differentiated design requirements: lower-consequence, short-term drainage can be assessed against more frequent events, while higher-consequence or long-term assets are tested against rarer events and additional controls such as no-ponding/free-draining profiles, protective lining or burn-hole avoidance. This is the mechanism by which the framework improves consistency and transparency: the same consequence-to-event logic is applied to each asset, while the resulting design criteria remain proportionate to the specific hazard and receptor.

The worked example therefore provides practical evidence for the paper’s claims of improved consistency, transparency and defensibility. The design pathway is visible and repeatable: mapped unit types inform consequence ratings, consequence ratings determine acceptable likelihood, likelihood is translated into AEP design events, and the resulting events are applied to asset-specific design criteria. This makes the basis for design decisions clearer for designers, reviewers and regulators, particularly where different assets within the same landform require different levels of hydraulic performance.

4.2 Discussion: strengths, limitations and implementation

The framework’s key benefit is traceability: design events are derived from an agreed risk tolerance rather than implicit precedent. It can be applied consistently across individual assets, landform domains and broader drainage networks through the use of unit types and consequence-based design criteria.

Uncertainty remains inherent in closure hydrology because landforms, roughness and flow paths evolve over time. Sensitivity testing, robust detailing at outlets and control points, and explicit consideration of early vegetation performance can help manage this uncertainty.

The framework establishes minimum design criteria, but it does not replace engineering judgement. Higher design events may be warranted where consequences are greater, while any lower-event designs should be clearly justified and supported by documented residual risk management measures.

Embedding the method within project standards and design governance processes can support consistent application, clearer review pathways and more transparent regulatory engagement across a range of closure and rehabilitation settings.

5 Conclusion

The proposed risk-based approach provides a defensible basis for selecting design life and minimum design events for stormwater and drainage infrastructure in closure and rehabilitation settings. By translating likelihood bands over explicit design lives into AEP events, and linking consequences to mapped surface water management unit types, the framework makes the basis for design conservatism transparent and repeatable. Application to the WFWB domain demonstrates how the method differentiates design outcomes within a single landform: fill-phase waterways below RL 45 are assessed against 23% AEP (3.8-year ARI), post-fill catch drains and swales against 2% AEP (50-year ARI), post-fill batter chutes against 0.5% AEP (219-year ARI), and higher-consequence geotechnical ponding risks against 1.5% AEP (66-year ARI) in the fill phase and 0.11% AEP (900-year ARI) in the post-fill phase. These outputs show how the framework converts risk appetite into asset-specific design criteria, including scour protection, increased capacity, burn-hole avoidance and no-ponding/free-draining requirements where warranted. More broadly, the approach provides a transparent and transferable basis for risk-informed closure waterway design, subject to site-specific landform, materials, receptors and regulatory requirements.

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