

# Cowal Gold Operations

Monitoring Programme for Detection of any Movement of  
Lake Protection Bund, Water Storage and Tailings Structures  
and Pit Void Walls



## COWAL GOLD OPERATIONS

### MONITORING PROGRAMME FOR DETECTION OF ANY MOVEMENT OF LAKE PROTECTION BUND, WATER STORAGE AND TAILINGS STRUCTURES AND PIT-VOID WALLS



#### Revision Status Register

Section/Page/ Annexure	Revision Number and Document Number	Amendment/Addition	Distribution	DP&E Approval Date
NA	LPBMP01-L (Oct 2003) Document No.00685133	Original Monitoring Programme for the Detection of any Movement of the Lake Protection Bund, Water Storage and Tailings Structures and Pit-Void Walls (LPBMP).	DMR and DIPNR	October 2003
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## **PREFACE**

This Monitoring Programme for the detection of any movement of the Lake Protection Bund, Water Storage and Tailings Structures and Pit-Void Walls (LPBMP) has been prepared to meet the requirements of Condition 4.5(c) of the Cowal Gold Mine Development Consent. Where there is any conflict between the provisions of this LPBMP and the applicable statutory requirements (i.e. licences, permits, consents and relevant laws) the statutory requirements are to take precedence.

In accordance with Development Consent Condition 9.1(c), this LPBMP is to be revised/updated annually, or as otherwise directed by the Secretary, in consultation with the relevant government authorities.

Relevant current regulatory guidelines are appended to this LPBMP to provide guidance to Evolution Mining (Cowal) Pty Limited (Evolution) employees and its contractors. It is the responsibility of Evolution to ascertain whether these guidelines have been updated since the production of this LPBMP, and to conform with any new versions of these guidelines as required by Development Consent Conditions.

Similarly, it is the responsibility of Evolution to refer to the latest versions of statutory instruments, guidelines or any Australian Standards that are referenced in this LPBMP, but have not been appended.

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## 1 INTRODUCTION

The Cowal Gold Operations (the CGO) is located approximately 38 kilometres (km) north-east of West Wyalong, New South Wales (NSW) (Figure 1). Evolution Mining (Cowal) Pty Limited (Evolution) is the owner and operator of the CGO. Evolution acquired the CGO from Barrick (Cowal) Pty Ltd (Barrick) in July 2015.

Development Consent (DA 14/98) for the CGO (including the Bland Creek Palaeochannel Borefield water supply pipeline) was granted by the NSW Minister for Urban Affairs and Planning under Part 4 of the NSW *Environmental Planning and Assessment Act, 1979* (EP&A Act) on 26 February 1999. Development Consent (DA 2011/64) for the operation of the Eastern Saline Borefield was granted by the Forbes Shire Council on 20 December 2010.

The NSW Minister for Planning granted approval to modify Development Consent (DA 14/98) for the *Cowal Gold Mine Extension Modification* under Section 75W of the EP&A Act on 22 July 2014. The *Cowal Gold Mine Extension Modification* involves the continuation and extension of open pit mining and processing operations for an additional operational life of approximately 5 years (i.e. to 2024).

On 7 February 2017, Development Consent (DA 14/98) was again modified by the NSW Minister for Planning under Section 75W of the EP&A Act to allow continued operations at the existing CGO for a further 8 years (i.e. to 2032) to allow an additional 1.7 million ounces of gold production. The general arrangement of the approved CGO is provided in Figure 2.

A copy of the Development Consent (DA 14/98) for the CGO (as modified on 7 February 2017) is available on Evolution's website ([www.evolutionmining.com.au](http://www.evolutionmining.com.au)).

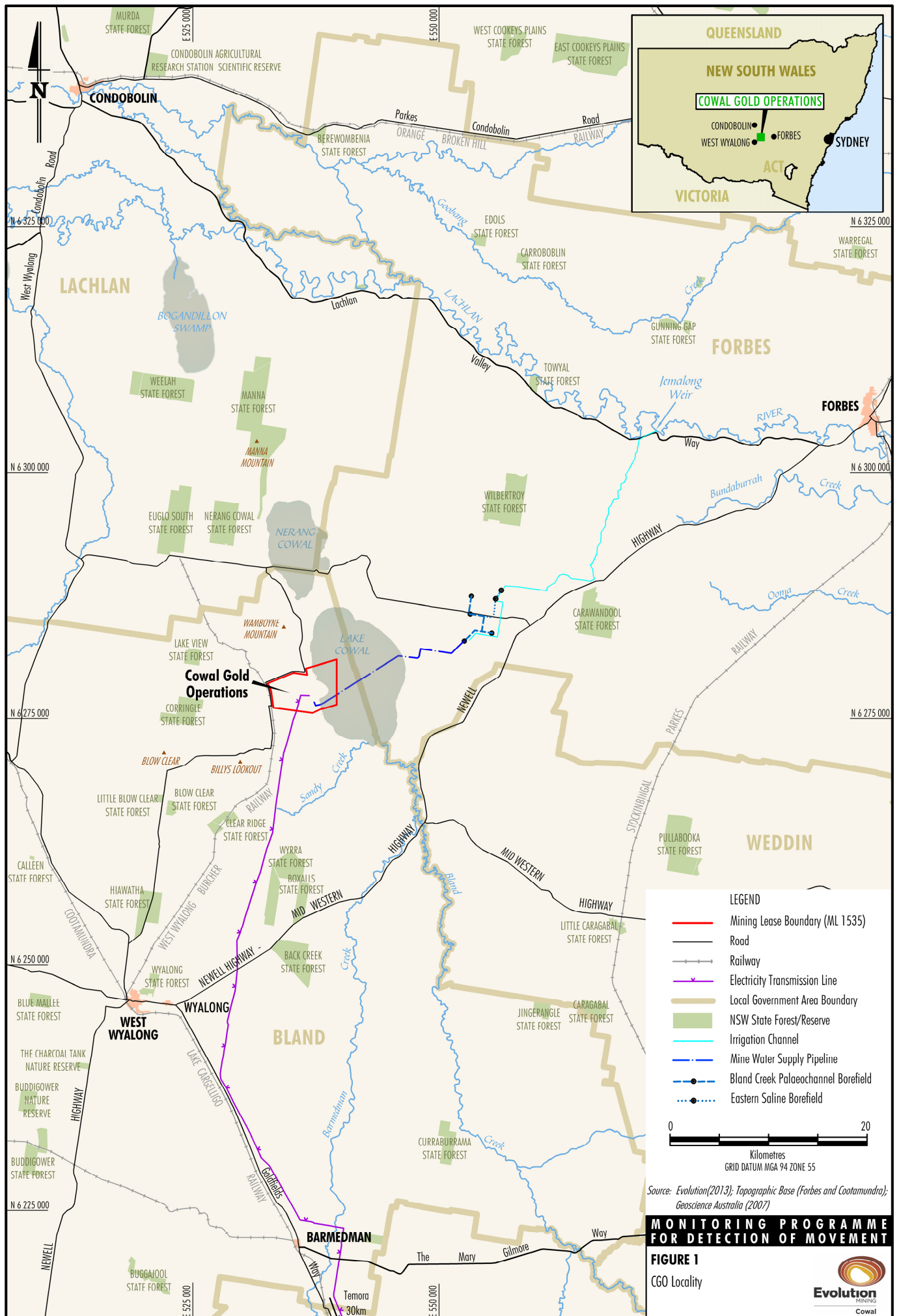
The CGO's Monitoring Programme for the Detection of any Movement of the Lake Protection Bund, Water Storage and Tailings Structures and Pit-Void Walls (LPBMP) was originally approved in October 2003, with a subsequent addendum dated April 2015 prepared to the satisfaction of the NSW Department of Planning and Environment (DP&E). This revised LPBMP has been prepared to reflect the Development Consent as modified on 7 February 2017 and supersedes the former LPBMP and supporting addendum.

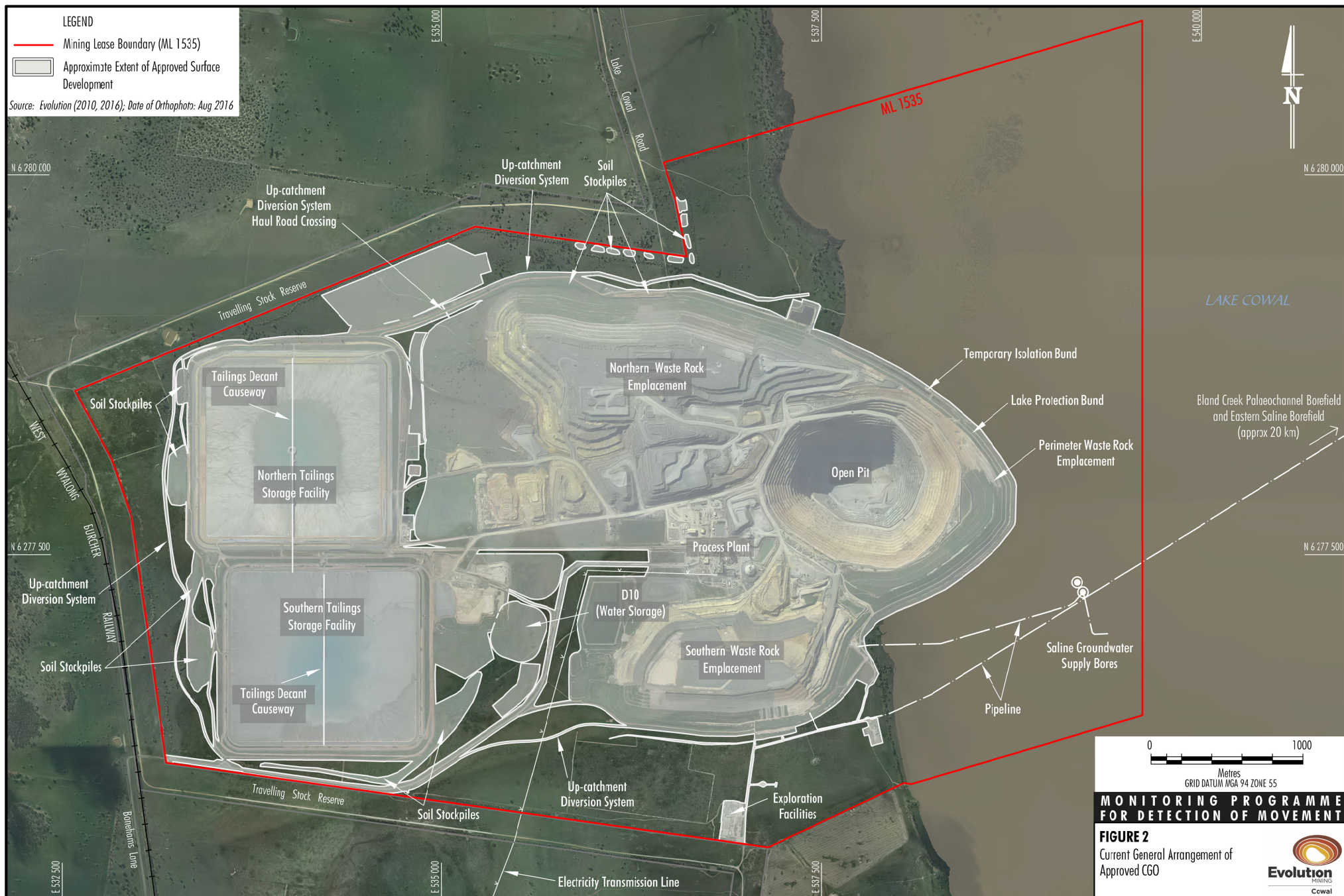
### 1.1 OBJECTIVES AND SCOPE

#### **Objectives**

The primary objective of this LPBMP is to establish a monitoring programme for the CGO that complies with Consent Condition 4.5(c) by providing for:

- the detection of any movement of the lake protection bund, water storage and tailings structures and pit-void walls during the life of the mine, with particular emphasis on monitoring after any seismic events as required by Consent Condition 4.5(c).





## **Scope**

This LPBMP has been prepared to reflect the modified Development Consent approved by the NSW Minister for Planning on 7 February 2017 under Section 75W of the EP&A Act.

In accordance with the requirements of Development Consent Condition 4.5(c), the DP&E, Division of Resources and Geoscience (DRG) (within the DP&E) and NSW Department of Primary Industries – Water (DPI-Water) have been consulted during preparation of this LPBMP. In correspondence dated 14 August 2017, DPI-Water advised that following review of the revised LPBMP they were satisfied with the proposed revisions.

The LPBMP is structured as follows:

- Section 1: Outlines the objectives and scope of the LPBMP and the relevant consent conditions.
- Section 2: Identifies the relevant statutory requirements and guidelines for monitoring for the detection of any movement of the lake protection bund, tailings structures, water storages and pit-void walls.
- Section 3: Describes the typical seismicity of Lake Cowal and West Wyalong.
- Section 4: Identifies the methodologies behind the design of the lake protection bund, tailings structures, water storages and pit-void walls.
- Section 5: Outlines the monitoring programme comprising stability monitoring, visual assessment and survey assessment.
- Section 6: Identifies procedures to be undertaken in the event of detection of any movement of the lake protection bund, tailings structures, water storages and pit-void walls.
- Section 7: Summarises stakeholder consultation and complaints receipt.
- Section 8: Outlines the reporting requirements for the annual review and incidents related to the lake protection bund, tailings structures, water storages and pit-void walls monitoring.
- Section 9: Outlines auditing and review requirements.
- Section 10: Lists the references cited in this LPBMP.

## 2 STATUTORY REQUIREMENTS

### 2.1 DEVELOPMENT CONSENT CONDITION

This LPBMP has been prepared in accordance with the requirements of Development Consent Condition 4.5(c). The requirements of Development Consent Condition 4.5(c) is outlined below.

#### **4.5 Water Monitoring**

- (c) *The Applicant shall prepare and implement a monitoring program for the detection of any movement of the Lake protection bund, water storage and tailings structures and pit/void walls during the life of the mine, with particular emphasis on monitoring after any seismic events prior to commencement of construction works, in consultation with DPI (Water) and DRE, and to the satisfaction of the Secretary.*

Development Consent Condition 4.5(c) is addressed in Sections 5 and 6.

### 2.2 CONDITIONS OF AUTHORITY ML 1535

The DRG has requirements that relate to soil stripping activities and rehabilitation as detailed in the Conditions of Authority for Mining Lease (ML) 1535. Relevant Conditions of Authority include:

#### **Mining Rehabilitation, Environmental Management Process (MREMP) Mining Operations Plan (MOP)**

- 25 (4) *The Plan [Mining Operations Plan] must present a schedule of proposed mine development for a period of up to seven (7) years and contain diagrams and documentation which identify:-*

...

- (k) *management plan for the construction and operation of the tailing dam;*
- (l) *environmental monitoring programme listing the location of monitoring points, frequency of monitoring and parameters to be monitored; and*

...

This condition is addressed in Sections 4.1.3 and 5.

#### **Annual Environmental Management Report (AEMR)**

26. (1) *Within 12 months of the commencement of mining operations and thereafter annually or, at such other times as may be allowed by the Director-General, the lease holder must lodge an Annual Environmental Management Report (AEMR) with the Director-General.*

- (2) *The AEMR must be prepared in accordance with the Director-General's guidelines current at the time of reporting and contain a review and forecast of performance for the preceding and ensuing twelve months in terms of:*

- (a) *the accepted Mining Operations Plan;*
- (b) *development consent requirements and conditions;*
- (c) *Environment Protection Authority and Department of Land and Water Conservation licences and approvals;*
- (d) *any other statutory environmental requirements;*
- (e) *details of any variations to environmental approvals applicable to the lease area; and*
- (f) *where relevant, progress towards final rehabilitation objectives.*

- (3) *After considering an AEMR the Director-General may, by notice in writing, direct the lease holder to undertake operations, remedial actions or supplementary studies in the manner and within the period specified in the notice to ensure that operations on the lease area are conducted in accordance with sound mining and environmental practice.*
- (4) *The lease holder shall, as and when directed by the Minister, cooperate with the Director-General to conduct and facilitate review of the AEMR involving other government agencies and the local council.*

This condition is addressed in Section 8.1.

## **2.3 GUIDELINES**

The following guidelines by the Dams Safety Committee (DSC) relate to seismic analysis, monitoring and management (Appendices A, B and C).

### ***Acceptable Earthquake Capacity for Dams (DSC3C)***

The Acceptable Earthquake Capacity for Dams guideline (DSC, 2010a) provides details on dam design in order to reduce the risk of dam failure due to seismic activity. These requirements are based on the 1998 Australian National Committee on Large Dams *Guidelines for the Design of Dams for Earthquakes* and are designed to ensure that proper consideration is given to adequate earthquake loading in the design and in the review of dam safety. Included are design criteria and loading requirements, methods for analysing designs of earthfill and rockfill dams and post earthquake procedures (including the requirement for a Dam Safety Emergency Plan). Requirements relevant to this LPBMP are discussed in Section 5.2.3.

### ***Operation and Maintenance for Dams (DSC2F)***

The *Operation and Maintenance for Dams* guideline (DSC, 2010b) provides details relevant to the operation and maintenance requirements for dams. Current DSC policy is for all tailings dams to have an Operation and Maintenance Manual, regardless of their Consequence Category. This LPBMP will be an integral part of the Operation and Maintenance Manual, which is to be prepared and used when mining operation commences.

### ***Emergency Management for Dams (DSC2G)***

The Emergency Management for Dams guideline (DSC, 2015) provides details relevant to emergency planning requirements for dams. The aim of this guideline is to maximise the continued viability and safety of the dam and minimise consequences to the community in the unlikely event of its failure.

### 3 SEISMIC EVENTS AT LAKE COWAL

#### 3.1 SEISMICITY OF THE CGO AREA

Lake Cowal is situated in the Lachlan Fold Belt geologic province, where earthquake activity has historically been moderate (Australian Geological Survey Organisation [AGSO], 1997). The most recent earthquake in West Wyalong was on 10 March 2016 and measured at the magnitude of 2.25 on the Richter scale (Geoscience Australia, 2017).

Table 1 presents a description of general effects of earthquakes of various Richter scale magnitudes (AGSO, 2003):

**Table 1**  
**Description of Richter Scale Magnitudes**

<b>Magnitude (Richter scale)</b>	<b>Typical Effects</b>
< 3.4	Recorded only by seismographs.
3.5 – 4.2	Felt by some people who are indoors.
4.3 – 4.8	Felt by many people and windows rattle.
4.9 – 5.4	Felt by everyone, while dishes break and doors swing.
5.5 – 6.1	Causes slight building damage with plaster cracking, and bricks falling.
6.2 – 6.9	Causes much building damage and houses move on their foundations.
7.0 – 7.3	Causes serious damage with bridges twisting, walls fracturing, and many masonry buildings collapsing.
7.4 – 7.9	Causes great damage and most buildings collapse.
> 8.0	Causes total damage with waves seen on the ground surface and objects are thrown in the air.

Source: AGSO (2003).

For the purposes of the Cowal Gold Project Environmental Impact Statement (EIS) (North Limited, 1998), AGSO were requested to provide an estimate of the characteristic earthquakes for the Lake Cowal regional area for a range of recurrence expectancy (Knight-Piesold Pty Limited [Knight-Piesold], 1997). This analysis is summarised in Table 2.

**Table 2**  
**Lake Cowal Seismic Analysis**

<b>Analysis Event Parameter</b>	<b>Event Recurrence Expectancy (Years)</b>		
	<b>500</b>	<b>5,000</b>	<b>&gt; 10,000</b>
Peak Horizontal Ground Acceleration (g)	0.08	0.13	0.3
RMS Horizontal Ground Acceleration (g)	0.03	0.05	0.12
Duration of Strong Motions (seconds)	3	3	4
Predominant Frequency of Strong Motion (Hertz)	5	5	4
Earthquake Magnitude (Richter scale)	5.5	5.5	6
Earthquake Epicentral Distance (km)	25	15	<10

Source: AGSO (1997).

A maximum credible earthquake is an earthquake whose magnitude will not be exceeded for an indefinite period of time. The maximum credible earthquake for Lake Cowal was recommended by AGSO (1997) as a magnitude of 6.0 on the Richter scale, with greater than 10,000 years event recurrence expectancy. This magnitude was used by Knight-Piesold (1997) to simulate dynamic loading on various structures (Section 4.2). Details of the dynamic models are outlined in Section 4.2.

A further Seismicity analysis undertaken in 2011 (Seismology Research Centre, 2011), assessed the Peak Ground Acceleration for a 500year recurrence for the mine site to be 0.062g, slightly lower than that calculated by Knight Piesold in 1997.

### **3.2 DETECTION OF SEISMIC EVENTS**

#### **3.2.1 Richter Scale Magnitude**

Geoscience Australia reports all earthquakes occurring in Australia and significant worldwide earthquakes on their website. Seismic observatories proximal to West Wyalong are located at Cobar, Canberra and Young. Data from three seismometers are utilised to determine the epicentre and magnitude of an earthquake.

The Geoscience Australia website will be checked monthly by the Environmental and Social Responsibility (ESR) Manager (or delegate) for seismic events during the previous month in the West Wyalong area. The website is updated daily and is located at <http://www.ga.gov.au/earthquakes/searchQuake.do>.

Whilst it is acknowledged that Consent Condition 4.5(c) (Section 2.1) states that all seismic events should be considered for this LPBMP, only events of a magnitude of equal to or greater than 4.3 on the Richter scale will trigger visual inspection of structures (Section 5.2.3). The magnitude of 4.3 on the Richter scale has been selected because it is usually the lowest magnitude resulting in physical movement (i.e. windows rattle) (Table 1). Events of a magnitude of less than 4.3 on the Richter scale are not considered to be significant. The ground movement that occurs as a result of an earthquake of a magnitude of less than 4.3 will be unlikely to result in any movement of structures (Table 1).

#### **3.2.2 Local Felt Intensity**

The 'Local Felt Intensity' will be estimated for significant seismic events in order to provide an immediate trigger for visual inspections. The 'Local Felt Intensity' will be estimated using the Modified Mercalli (MM) Intensity Scale.

The MM Intensity Scale is a scale that assigns numerical values to seismic events based on the actual observed effects on the immediate environment. Table 3 presents a description of the MM Intensity Scale including a comparison with Richter scale magnitudes.

The General Manager (or civil/structural engineer) will assign a 'Local Felt Intensity' value for seismic events based on observed effects detected on-site based on Table 3. The lower numbers on the scale relate to the manner in which the seismic event is felt by people, whilst the higher numbers are based on observed structural damage. Structural engineers will contribute information for assigning 'Local Felt Intensity' values of 8 and above (US Geological Survey, 2003).

'Local Felt Intensity' values of 5 or greater will trigger immediate visual inspections (Section 5.2.3). This value represents the lowest MM intensity which could conceivably have some discernible effect on the lake protection bund, water storage, tailings structures or pit-void walls (URS, pers. comm., 18 August 2003). Should any 'Local Felt Intensity' value be assigned by the General Manager (or civil/structural engineer), the Geoscience Australia website will be checked to verify that an event has occurred (Section 3.2.1).

**Table 3**  
**The Modified Mercalli Intensity Scale**

<b>Modified Mercalli (MM) Intensity</b>	<b>Richter Scale Magnitude<sup>1</sup></b>	<b>Witness Observations<sup>2</sup></b>
1	1 to 2	<p>Not felt , except under especially favorable circumstances. Under certain conditions, at and outside the boundary of the area in which a great shock is felt:</p> <ul style="list-style-type: none"> <li>• sometimes birds, animals, reported uneasy and disturbed;</li> <li>• sometimes dizziness or nausea experienced; and</li> <li>• sometimes trees, structures, liquids, bodies of water, may sway; doors may swing, very slowly.</li> </ul>
2	2 to 3	<p>Felt indoors by few, especially on upper floors, or by sensitive or nervous persons. Also, as in grade I, but often more noticeably:</p> <ul style="list-style-type: none"> <li>• sometimes hanging objects may swing, especially when delicately suspended;</li> <li>• sometimes trees, structures, liquids, bodies of water, may sway, doors may swing, very slowly;</li> <li>• sometimes birds, animals, reported uneasy and disturbed; and</li> <li>• sometimes dizziness or nausea experienced.</li> </ul>
3	3 to 4	<p>Felt indoors by several, motion usually rapid vibration. Sometimes not recognised to be an earthquake at first. Duration estimated in some cases. Vibration like that due to the passing of light or lightly loaded trucks or heavy trucks some distance away. Hanging objects may swing slightly. Movements may be appreciable on upper levels of tall structures. Rocked standing motor cars slightly.</p>
4	4	<p>Felt indoors by many, outdoors by few. Awakened few, especially light sleepers. Frightened no one, unless apprehensive from previous experience. Vibration like that due to the passing of heavy or heavily loaded trucks. Sensation like heavy body striking building or falling of heavy objects inside. Rattling of dishes, windows, doors; glassware and crockery clink and clash. Creaking of walls, frame, especially in the upper range of this grade. Hanging objects swung, in numerous instances. Slightly disturbed liquids in open vessels. Rocked standing motor cars noticeably.</p>
5	4 to 5	<p>Felt indoors by practically all, outdoors by many or most: outdoors direction estimated. Awakened many, or most. Frightened few, slight excitement, a few ran outdoors. Buildings trembled throughout. Broke dishes, glassware, to some extent. Cracked windows, in some cases, but not generally. Overturned vases, small or unstable objects, in many instances, with occasional fall. Hanging objects, doors, swing generally or considerably. Knocked pictures against walls, or swung them out of place. Opened, or closed, doors, shutters, abruptly. Pendulum clocks stopped, started, or ran fast, or slow. Moved small objects, furnishings, the latter to slight extent. Spilled liquids in small amounts from well-filled open containers. Trees, bushes, shaken slightly.</p>

**Table 3 (Continued)**  
**The Modified Mercalli Intensity Scale**

<b>Modified Mercalli (MM) Intensity</b>	<b>Richter Scale Magnitude<sup>1</sup></b>	<b>Witness Observations<sup>2</sup></b>
6	5 to 6	<p>Felt by all, indoors and outdoors.  Frightened many, excitement general, some alarm, many ran outdoors.  Awakened all.  Persons made to move unsteadily.  Trees, bushes, shaken slightly to moderately.  Liquid set in strong motion.  Small bells rang, church, chapel, school, etc.  Damage slight in poorly built buildings.  Fall of plaster in small amount.  Cracked plaster somewhat, especially fine cracks; chimneys in some instances.  Broke dishes.  Fall of knick-knacks, books, pictures.  Overturned furniture in many instances.  Moved furnishings of moderately heavy kind.</p>
7	6	<p>Frightened all, general alarm, all ran outdoors.  Some, or many, found it difficult to stand.  Noticed by persons driving motor cars.  Trees and bushes shaken moderately to strongly.  Waves on ponds, lakes, and running water.  Water turbid from mud stirred up.  Incaving to some extent of sand or gravel stream banks.  Rang large church bells, etc.  Suspended objects made to quiver.  Damage negligible in buildings of good design and construction, slight to moderate in well-built ordinary buildings, considerable in poorly built or badly designed buildings, adobe houses, old walls (especially where laid up without mortar), spires, etc.  Cracked chimneys to considerable extent, walls to some extent.  Fall of plaster in considerable to large amount, also some stucco.  Broke numerous windows, furniture to some extent.  Shook down loosened brickwork and tiles.  Broke weak chimneys at the roof-line (sometimes damaging roofs).  Fall of cornices from towers and high buildings.  Dislodged bricks and stones.  Overturned heavy furniture, with damage from breaking.  Damage considerable to concrete irrigation ditches.</p>
8	6 to 7	<p>Fright general, alarm approaches panic.  Disturbed persons driving motor cars.  Trees shaken strongly, branches, trunks, broken off, especially palm trees.  Ejected sand and mud in small amounts.  Changes: temporary, permanent; in flow of springs and wells; dry wells renewed flow; in temperature of spring and well waters.  Damage slight in structures (brick) built especially to withstand earthquakes.  Considerable in ordinary substantial buildings, partial collapse: racked, tumbled down, wooden houses in some cases; threw out panel walls in frame structures, broke off decayed piling.  Fall of walls.  Cracked, broke, solid stone walls seriously.  Wet ground to some extent, also ground on steep slopes.  Twisting, fall, of chimneys, columns, monuments, also factory stacks, towers.  Moved conspicuously, overturned, very heavy furniture.</p>

**Table 3 (Continued)**  
**The Modified Mercalli Intensity Scale**

<b>Modified Mercalli (MM) Intensity</b>	<b>Richter Scale Magnitude<sup>1</sup></b>	<b>Witness Observations<sup>2</sup></b>
9	7	<p>Panic general.</p> <p>Cracked ground conspicuously.</p> <p>Damage considerable in (masonry) structures built especially to withstand earthquakes.</p> <p>Threw out of plumb some wood-frame houses built especially to withstand earthquakes.</p> <p>Great in substantial (masonry) buildings, some collapse in large part; or wholly shifted frame buildings off foundations, racked frames.</p> <p>Serious to reservoirs; underground pipes sometimes broken.</p>
10	7 to 8	<p>Cracked ground, especially when loose and wet, up to widths of several inches; fissures up to a yard in width ran parallel to canal and stream banks.</p> <p>Landslides considerable from river banks and steep coasts.</p> <p>Shifted sand and mud horizontally on beaches and flat land.</p> <p>Changed level of water in wells.</p> <p>Threw water on banks of canals, lakes, rivers, etc.</p> <p>Damage serious to dams, dikes, embankments.</p> <p>Severe to well-built wooden structures and bridges, some destroyed.</p> <p>Developed dangerous cracks in excellent brick walls.</p> <p>Destroyed most masonry and frame structures, also their foundations.</p> <p>Bent railroad rails slightly.</p> <p>Tore apart, or crushed endwise, pipe lines buried in earth.</p> <p>Open cracks and broad wavy folds in cement pavements and asphalt road surfaces.</p>
11	8	<p>Disturbances in ground many and widespread, varying with ground material.</p> <p>Broad fissures, earth slumps, and land slips in soft, wet ground.</p> <p>Ejected water in large amount charged with sand and mud.</p> <p>Caused sea-waves ("tidal" waves) of significant magnitude.</p> <p>Damage severe to wood-frame structures, especially near shock centers.</p> <p>Great to dams, dikes, embankments, often for long distances.</p> <p>Few, if any (masonry), structures remained standing.</p> <p>Destroyed large well-built bridges by the wrecking of supporting piers, or pillars.</p> <p>Affected yielding wooden bridges less.</p> <p>Bent railroad rails greatly, and thrust them endwise.</p> <p>Put pipe lines buried in earth completely out of service.</p>
12	8 or greater	<p>Damage total, practically all works of construction damaged greatly or destroyed.</p> <p>Disturbances in ground great and varied, numerous shearing cracks.</p> <p>Landslides, falls of rock of significant character, slumping of river banks, etc., numerous and extensive.</p> <p>Wrenched loose, tore off, large rock masses.</p> <p>Fault slips in firm rock, with notable horizontal and vertical offset displacements.</p> <p>Water channels, surface and underground, disturbed and modified greatly.</p> <p>Dammed lakes, produced waterfalls, deflected rivers, etc.</p> <p>Waves seen on ground surfaces (actually seen, probably, in some cases).</p> <p>Distorted lines of sight and level.</p> <p>Threw objects upward into the air.</p>

Sources:

<sup>1</sup> Southern California Earthquake Data Center (2003).

<sup>2</sup> Michigan Technological University (2003).

## **4 DESIGN OF LAKE PROTECTION BUND, WATER STORAGE, TAILINGS STRUCTURES AND PIT/VOID WALLS**

### **4.1 DESCRIPTION OF LAKE PROTECTION BUND, WATER STORAGE, TAILINGS STRUCTURES AND PIT-VOID WALLS**

The following descriptions are extracts from the EIS (North Limited, 1998), Cowal Gold Mine Extension Modification Environmental Assessment (Barrick, 2013) and CGO Mine Life Modification Environmental Assessment (Evolution, 2016). The current general arrangement for the CGO is shown on Figure 2.

#### **4.1.1 Lake Protection Bund**

The lake protection bund is a low permeability embankment designed to prevent water inflow (during periods of high lake water levels) from the lake into the open pit development area over the life of the mine and over the long term.

The design of the lake protection bund has been formulated to meet the following objectives (North Limited, 1998):

- provision of a low permeability barrier between the open pit and Lake Cowal;
- development of a revegetated, low profile stable permanent landform; and
- revegetation of the embankment and remnant isolation bund as early as possible in the mine life to permit early re-establishment of the foreshore ecotone.

The lake protection bund will be located behind the temporary isolation bund (closer to the open pit). It will be constructed to Rating Level (RL) 208.25 metres (m). Below RL 207.75 m it will be built as a two-zone earth fill embankment and will meet specific engineering criteria for compaction to ensure that the required compaction densities are achieved (North Limited, 1998).

The lake protection bund will be constructed from suitable low salinity lake sediments sourced from within the open pit development area. Once the structure is constructed to its final height, topsoil (organic lake bed sediments previously stripped from the open pit development area) will be applied to the surface to provide a suitable growth medium for reformation of the foreshore habitat and ecotone (North Limited, 1998).

#### **4.1.2 Pit-Void**

The proposed mining method is a conventional open pit, occurring in stages as the pit is widened and progressively deepened. At the end of mining, the open pit would have a maximum depth of approximately -331 m Australian height datum (AHD) (i.e. approximately 540 m below the natural surface level) and a surface area of approximately 131 hectares (Evolution, 2017).

Set back from the void on three sides will be the revegetated slope of the mine waste rock emplacements, comprising the northern waste rock emplacement, southern waste rock emplacement and perimeter waste rock emplacement (Figure 2).

Based on findings of geotechnical investigations, and consistent with existing operations, the pit slope design criteria of the approved/extended open pit have been developed in consideration of maximising ore recovery, while maintaining factors of safety appropriate for operating conditions and the long-term stability of the lake isolation system. The geotechnical modelling and analysis undertaken to determine suitable pit slope design criteria considered historical slope performance and geotechnical data gained over previous and current studies for the existing open pit for both surficial (soil/highly weathered rock) and hard rock material.

Single benches will be used for the oxide rock, with berms approximately 9 to 10 m in width, batter angles at 45 degrees (°) and with an inter-ramp angle of 25°.

Primary rock will be mined in multiple benches, with berms up to 13 m in width, batter angles between 65 to 90° and with an inter-ramp angle of 46 to 67° (variable according to open pit sector).

The berm widths and slope angles will continue to be reviewed and monitored through ongoing geotechnical studies and data collection during mine development.

At a final void level of RL 130 m, the surface area of the approved final void is approximately 3% greater as a result of the approved CGO Mine Life Modification (Evolution, 2016). For an equivalent final void water level, it is therefore expected that evaporation rates would be slightly higher and therefore the final void water level would be slightly lower than that predicted as part of the *Cowal Gold Mine Extension Modification* (Barrick, 2013). The void water is not predicted to spill and would be hydrogeologically isolated from and lower than water in Lake Cowal, even allowing for adverse future climate change predictions (Hydro Engineering & Consulting Pty Ltd [HEC], 2017).

The predicted maximum water volume held in the modified open pit in all simulated climatic sequences was 1,293 megalitres (ML) (HEC, 2017). However, the risk of such a large water volume is low (HEC, 2017). Model results indicate that there is only a 5% risk of exceeding a pit water volume of 574 ML, and a 50% risk of exceeding a pit water volume of 16 ML at any time during the remaining mine life (HEC, 2017).

A bund would be constructed around the perimeter of the final void which would be planted with an initial cover crop (to assist in stabilising the bund following construction) and native and/or endemic Eucalypt woodland species. The final void would be screened from public views on Lake Cowal Road by the tailings storage facilities and waste rock emplacements and would be fenced upon completion of mining. Signposted warnings to the public would also be placed along the fence.

#### **4.1.3 Tailings Structures**

The tailings disposal strategy for the CGO is to provide secure, long term storage within two dedicated storage facilities. The operating aims of the facilities will be to (North Limited, 1998):

- provide a temporary water storage area for groundwater from the open pit dewatering operation during construction and the first year of operation;
- maximise the dry density and long term strength of the storage structure;
- maximise water re-use from the structures; and
- minimise ponding.

The tailings structures will be located approximately 3.5 km west of the lake shoreline (Figure 2). The storages will be stage constructed throughout the mine life, by raising the height of the embankment in advance of the storage requirements (North Limited, 1998). An initial starter embankment will be built during the construction phase and will provide storage for the first one to two years of production. As the structures fill, the embankment will be raised in a series of upstream lifts (Evolution, 2016).

Initially tailings have been deposited peripherally via a spigotted ring main allowing for the controlled development or “build-up” at any point around the surface of the northern and southern tailings storage facilities.

The sub-aerial tailings depositional technique will promote the segregation of the coarse fraction on the perimeter and finer fraction towards the centre of the dam. The different particle settling rates will result in a tailings beach which slopes toward the centre. As a result, water contained within the tailings structure will drain towards a pond area and decant towers located in the centre of the structure, thus maximising the exposure of the tailings surface to air-drying and increasing in-storage tailings dry densities (North Limited, 1998).

The main engineering components required for the operation of the tailings structures are (North Limited, 1998):

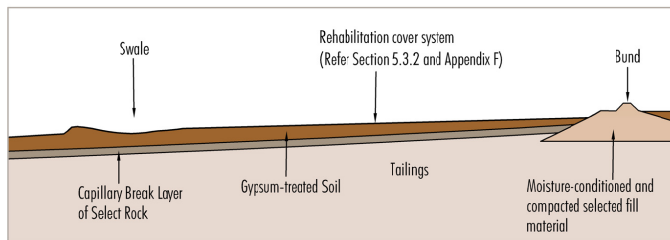
- starter embankment;
- upstream embankment lifts;
- low permeability storage floor blanketing *in situ*;
- storage floor underdrainage and recovery system;
- decant towers, associated pipelines and pumps;
- earth-fill causeway to the decant tower structure; and
- lined tailings water reclaim pond.

Materials required for construction will be pre-stripped from borrow areas within the footprint of the tailings structures and areas of the open pit. The types of construction materials required include (North Limited, 1998):

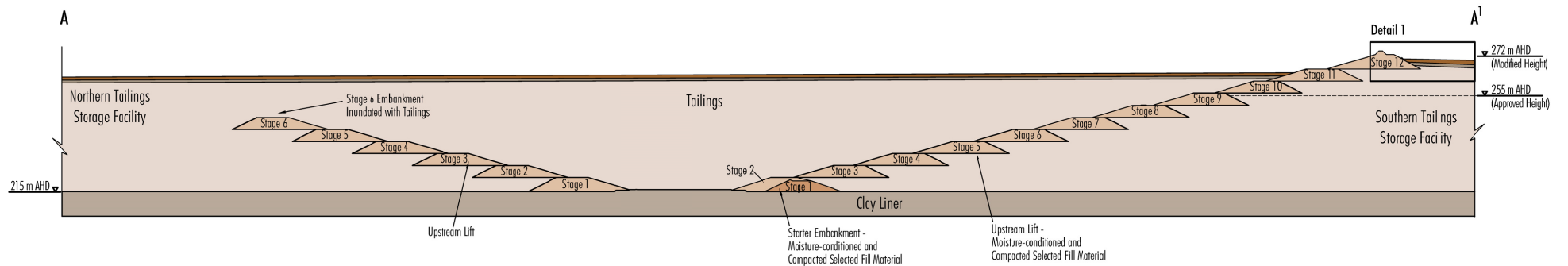
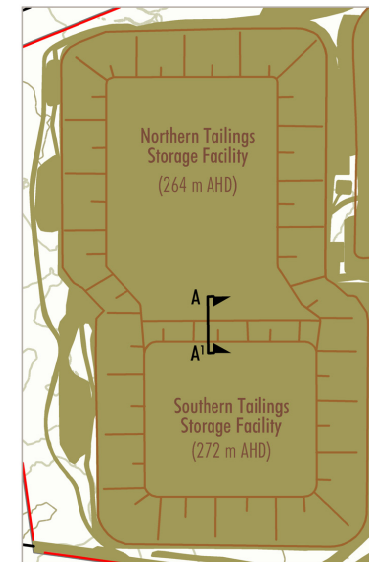
- clay fill - used for lining areas, the floor and embankment;
- rock fill - used for construction of the starter embankment and upstream lifts;
- filter material - used at the clay fill/rock fill interface; and
- rip rap - used for scour protection of outer embankment and spillway surfaces.

Tailings will also be deposited in the central section (i.e. between the northern and southern tailings storage facilities) until the tailings surface is level with the Stage 6 embankment of the northern tailings storage facility. Construction works will include (Evolution, 2016):

- construction of connector embankments between the northern tailings storage facility and southern tailings storage facility;
- construction of a low permeability basement layer and other seepage control measures; and
- extension of the existing northern tailings storage facility decant causeway into the new tailings storage area, prior to the point when tailings deposition in the new area overtops the Stage 6 northern tailings storage facility embankment.



DETAIL 1



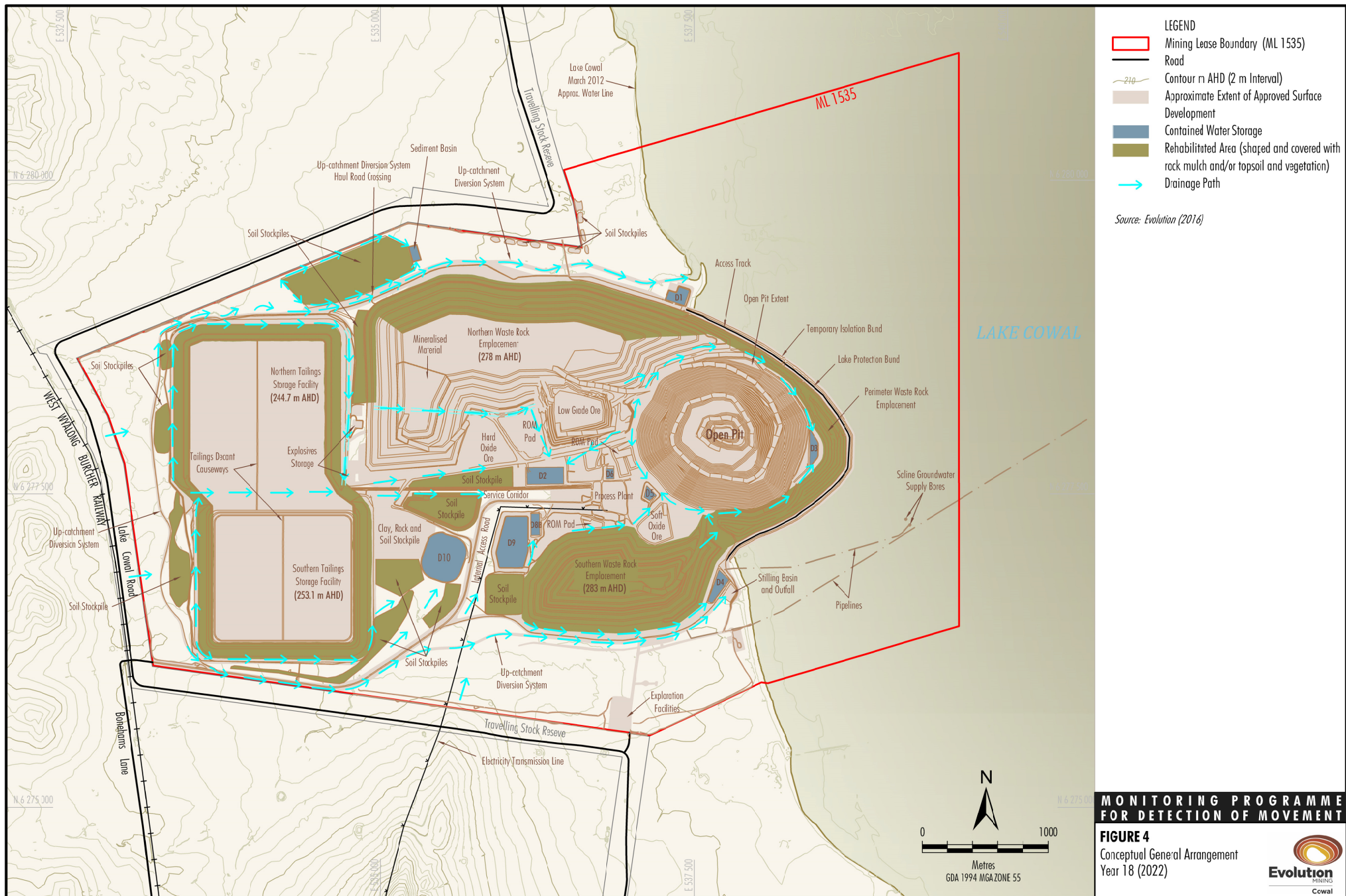
Source: AECOM (2016)

# MONITORING PROGRAMME FOR DETECTION OF MOVEMENT

FIGURE 3

Conceptual Cross-section of  
Central Tailings Storage Facility Area





Following construction of the connector embankments, tailings would be deposited into the central section and the northern tailings storage facility simultaneously.

The northern tailings storage facility and central section will then act as one continuous area for tailings deposition (Figure 3), with the existing decant causeway for the northern tailings storage facility extended to the northern face of the southern tailings storage facility embankment (Figure 4). The approximate final heights of the northern and southern tailings storage facilities will increase to approximately 264 m AHD and 272 m AHD, respectively.

To maintain suitable geotechnical factors of safety appropriate for operating conditions and long-term stability, a rock buttress cover will be constructed on the outer slopes of the TSFs' embankments once the final height has been reached. As the TSFs are filled, the embankments will continue to be raised in a series of upstream lifts. During operations, each upstream lift will also involve placement of an interim rock buttress on the outer slope of the lift. Once the final embankment is constructed, placement of the final rock buttress will occur.

For further description of the operation of tailings storages, refer to the CGO Site Water Management Plan (SWMP).

In accordance with Condition of Authority for ML 1535 25(4)(k), a management plan for the construction and operation of the tailing dam will be presented in the Mining Operations Plan.

#### **4.1.4 Water Storages**

The quantity of surface water runoff within the CGO area will be collected by a series of bunds and collection ponds. Runoff from the waste rock emplacement, open pit area and other disturbed areas will be collected during rainfall events and transferred to the process water pond (D6) or other retention ponds for re-use in the process plant or to satisfy other operational requirements.

The mine water management system includes some nine collection and containment storages which together provide for control of site water. The function, design criteria and approximate capacity of these contained water storages is summarised in Table 4. The location of these water storages is shown on Figure 2.

For further description of the operation of contained water storages, refer to the SWMP.

## **4.2 DYNAMIC STRUCTURAL ANALYSIS**

A dynamic structural analysis was undertaken by Knight-Piesold (1997) for the purposes of the EIS (North Limited, 1998). This analysis was undertaken for the lake protection bund, tailings storages and the open pit.

The modelling was undertaken using a finite difference computer model called Fast Lagrangian Analysis of Continua (FLAC). The design earthquake event, termed the maximum credible earthquake, of magnitude 6.0 on the Richter scale and recurrence interval of greater than 10,000 years (Section 3.2) was used to assess whether movement or failure will occur on the lake protection bund or tailings storages. Pells Sullivan Meynink Pty Ltd assessed the seismic stability of pit-void walls. The results of the dynamic structural analysis are outlined below.

#### 4.2.1 Lake Protection Bund

The behaviour of the lake protection bund under the maximum credible earthquake was modelled using FLAC. The lake protection bund was modelled using soil parameters typical of the sandy or silty clay material extracted as overburden alluvium from the open pit (as described in Section 4.1.1).

The analysis found that no significant deformations of the slopes of the lake protection bund are expected (Knight-Piesold, 1997). The lake protection bund may experience some deformations during the maximum credible earthquake of up to 30 millimetres (mm) in the area around its highest point, but they should not lead to a slope failure (Knight-Piesold, 1997).

**Table 4**  
**Contained Water Storages**

Storage Number	Catchment/Function	Design Criteria	Approximate Storage Capacity (megalitres)
D1 (Existing)	Runoff from the northern perimeter of the northern waste rock emplacement. Collected water is pumped to D6.	Runoff from contributing catchment resulting from a 1 in 100 year average recurrence interval (ARI) rainfall event of 48 hours duration	57
D2 (Existing)	Runoff/seepage from run-of-mine and low grade stockpile areas from the northern waste rock emplacement area, the batters of the northern tailings storage facility and other areas within the Internal Catchment Drainage System (ICDS). Collected water is pumped to D6 or D9.	Runoff from contributing catchment resulting from a 1 in 100 year ARI rainfall event of 48 hours duration	195
D3 (Existing)	Runoff from perimeter catchment surrounding the open pit and the perimeter waste rock emplacement areas. Collected water is pumped to D6.	Runoff from contributing catchment resulting from a 1 in 100 year ARI rainfall event of 48 hours duration	39
D4 (Existing)	Runoff from the southern perimeter of the southern waste rock emplacement. Collected water is pumped to D6 or D9.	Runoff from contributing catchment resulting from a 1 in 100 year ARI rainfall event of 48 hours duration	69
D5 (Existing and approved to be modified)	Process plant area drainage collection. Water is pumped to D6.	Runoff from a 1 in 1,000 year ARI storm of 48 hours duration	92
D6 (Existing)	Process water supply storage. Main source of process plant make-up water requirements.	1 in 1,000 year ARI storm of 48 hours duration above normal operating level	10
D8B (Existing)	Runoff from the southern waste rock emplacement, the batters of the southern tailings storage facility and other areas within the ICDS. Water is pumped to D9.	Runoff from contributing catchment resulting from a 1 in 100 year ARI rainfall event of 48 hours duration	43
D9 (Existing)	Process water supply storage. Storage for raw water. Water is pumped to D6. Some water used for tailings storage facilities lift construction.	1 in 1,000 year ARI storm of 48 hours duration above normal operating level	726
D10 (Approved but not yet constructed)	Process water supply storage. Storage for raw water. Water is pumped to D9.	1 in 1,000 year ARI storm of 5 days duration above normal operating level	1,500

Source: After Evolution (2016).

#### 4.2.2 Pit-Void Walls

The 1999 Cowal Gold Project Commissioner's report (Commissioners of Inquiry for Environment and Planning, 1999) included the following information relevant to seismic stability and geotechnical considerations for setback distances from the open pit.

*Work carried out by Pells Sullivan Meynink Pty Ltd (PSM) involving a series of parametric analyses for a range of groundwater conditions and a seismic loading of 0.08 g has shown that the pit slopes will have adequate stability for the anticipated conditions.*

*The analyses show that the factor of safety is greater than 1.3 for the highest slope sector and that the critical circle is within approximately 40 m of the pit rim. The closest distance from the pit rim to the toe of the lake protection bund in this sector is 160 m.*

Further, the Commissioner reported that:

*During the Commission of Inquiry, criteria were set requiring a civic engineering approach to the stability of the transported cover-soft material surrounding the final pit void.*

*In response to these criteria PSM carried out a series of stability analyses to establish the location of the back scarp based on the most critical failure geometry for a factor of safety of 1.5 for each of the pit design sectors. A factor of safety of 1.5 is the normal civil engineering criteria applied in assessing the long term stability of large embankment dams.*

*From these analysis, PSM established a setback line around the pit smoothed on the basis of the geological conditions. The setback line was taken into account when the preliminary design of the lake protection bund was prepared to ensure that no portion of the bund footprint encroached within the line. The minimum distance between the bund toe and the setback line is 20 m.*

*In view of the inherent stability of the lake protection bund (Section 4.2.1) and the protection it provides the lake will be unaffected in the extremely remote event of a wall failure of the final void extending as far as the setback line (Knight Piesold, pers. comm., 1998).*

Further to the original approval of the CGO, changes were approved to the open pit geometry and factors of safety further considered, as discussed in the Mod 11 EA below (Barrick, 2013):

*Based on findings of geotechnical investigations, and consistent with existing operations, the pit slope design criteria of the extended open pit have been developed in consideration of maintaining factors of safety appropriate for operating conditions and the long-term stability of the lake isolation system. The geotechnical modelling and analysis undertaken to determine suitable pit slope design criteria considered historical slope performance, and geotechnical data gained over previous and current studies for the existing open pit for both surficial (soil/highly weathered rock) and hard rock material.*

#### 4.2.3 Tailings Structures

The behaviour of the tailings structures under the maximum credible earthquake was modelled using FLAC. The tailings structures were modelled for the end of the operation period, which is considered to be the most important stage in the life of the storage because the embankment has reached its highest point and the porewater pressures within the storage are at their highest level (Knight-Piesold, 1997). Dynamic loading to simulate the maximum credible earthquake was applied to the model. The model found that the maximum horizontal displacement during the maximum credible earthquake will be up to 70 mm whilst the maximum vertical displacement will be up to 50 mm (Knight-Piesold, 1997). The model showed that although some deformations are expected, they will not lead to dam failure (Knight-Piesold, 1997).

## **5 MONITORING PROGRAMME FOR DETECTION OF MOVEMENT**

### **5.1 OPEN PIT STABILITY MONITORING**

The following monitoring/recording measures will be used to monitor and assess pit wall stability:

- a radar slope monitoring system (for selected walls of the pit), capable of detecting sub-millimetric movements, and with alarming capability to warn of increasing movement rates;
- a prism monitoring system which includes placement of prisms on each bench of the open pit at approximately 50 m intervals and data analysis software;
- monitoring of pore water pressure in the open pit walls, using a number of vibrating wire piezometers;
- development of a hydrogeological database to record the results of the open pit dewatering programme; and
- weekly geotechnical engineering team inspections.

Survey of slope design is conducted once slope construction is complete to confirm consistency with design criteria. Survey/topographical results are compiled weekly for analysis by the Geotechnical Department.

#### ***Geotechnical Analysis and Review of Ongoing Open Pit Development***

Analysis of pit stability involves review of weekly monitoring results, inspection reports and survey results by the Senior Geotechnical Engineer and Senior Mining Engineer.

Weekly geotechnical reports are prepared which include targeted Trigger Action Response Plans (TARPs) for relevant trigger events. Trigger events include tension crack movements, prism movement, radar deformation/wall movement and visual inspection observations (e.g. rockfalls, bench cracking). Levels of trigger events are also defined within the TARP including first indication of instability (Trigger Level 1), onset of movement (Trigger Level 2), continuous movement (Trigger Level 3) and failure imminent (Trigger Level 4). Each TARP includes contingency measures, planned response procedures (including evacuation control procedures), required reporting and role responsibilities relevant to each trigger event and trigger level.

Slope design parameters are developed for each pit sector which are reviewed and incorporated into the pit/mine design developed by the Senior Mining Engineer. Any open pit design changes must be in accordance with Evolution's open pit design standards/guidelines.

A periodic review of slope design parameters and their effects on phased pit designs, lithology and groundwater is undertaken by the Senior Geotechnical Engineer. Revised pit/mine plans and the final pit design are developed based on the outcome of this review and modelled geology. Potential risk areas are identified and investigated during this review process. Long and short term mine designs are then developed to ensure compatibility with Evolution's open pit design standards/guidelines.

## **5.2 VISUAL ASSESSMENTS**

Visual assessments of the lake protection bund, tailings structures, water storages and pit-void walls will be undertaken routinely (i.e. weekly), following review of surface and groundwater monitoring data and following seismic events to identify the initial signs of movement as described in the following sections.

### **5.2.1 Routine Visual Assessments**

Visual assessments of the lake protection bund, tailings structures, water storages and pit-void walls will be undertaken regularly (i.e. weekly) by a civil/structural engineer to detect/locate the presence of any cracks or other signs of failure or movement (e.g. slips, erosion, subsidence or seeps).

Previously observed cracks or other signs of failure will be visually assessed to monitor the extent of the crack or other sign of failure. Photographic records and/or measurements of the magnitude of the crack/failure will be taken, where necessary, as determined by the civil/structural engineer to determine if cracks or other signs of failure or movement are increasing in size.

Observations made during visual assessments, including photographic records and any measurements taken, will be detailed in a database and subsequently reported in the Annual Review (Section 8.1). Information recorded in the database will include:

- name, contact details, qualifications and experience of the person undertaking the assessment;
- the time and date that the assessment was undertaken;
- the location of the sign(s) of failure or movement (including position on the embankment/pit, where necessary); and
- a general description of observations made (e.g. suspected cause and impact of the movement).

This data would be used should movement of the lake protection bund, water storage, tailings storage or pit-void walls occur to assist in identifying the factors contributing to the movement.

A survey assessment (Section 5.3.2) will be undertaken should visual assessments indicate movement of the lake protection bund, tailings structures, water storages or pit-void walls.

### **5.2.2 Visual Assessments following review of Surface Water and Groundwater Monitoring Data**

Surface and groundwater monitoring will be carried out in accordance with current Surface Water, Groundwater, Meteorological and Biological Monitoring Programme (SGWMBMP).

Surface and groundwater monitoring results will be interpreted and reported as outlined in the SGWMBMP. Where interpretation reveals a connection of mine waters to local groundwater waters or surface waters via groundwater aquifers, a visual assessment will be carried out on the relevant water storage/tailings storage embankment to identify any signs of movement/failure.

Visual assessments of the lake protection bund, tailings structures, water storages and pit-void walls will be undertaken regularly (i.e. weekly) by a civil/structural engineer to detect/locate the presence of any cracks or other signs of failure or movement (e.g. slips, erosion, subsidence or seeps).

Previously observed cracks or other signs of failure will be visually assessed to monitor the extent of the crack or other sign of failure. Photographic records and/or measurements of the magnitude of the crack/failure will be taken, where necessary, as determined by the civil/structural engineer (to determine if cracks or other signs of failure or movement are increasing in size).

Observations made during visual assessments, including photographic records and any measurements taken, will be detailed in a database and subsequently reported in the Annual Review (Section 8.1). Information recorded in the database will include:

- name contact details, qualifications and experience of the person undertaking the assessment;
- the time and date that the assessment was undertaken;
- the location of the sign(s) of failure or movement (including position on the embankment/pit, where necessary); and
- a general description of observations made (e.g. suspected cause and impact of the movement).

This data would be used should movement of the lake protection bund, water storage, tailings storage or pit-void walls occur to assist in identifying the factors contributing to the movement.

A survey assessment (Section 5.3.2) will be undertaken should visual assessments indicate movement of the lake protection bund, tailings structures, water storages or pit-void walls.

### **5.2.3 Visual Assessments Following Seismic Events**

The Geoscience Australia website will be checked to determine Richter scale magnitudes of seismic events on a monthly basis, or after a suspected seismic event as described in Section 3.2.1. In addition, the magnitude of seismic events will be estimated on the MM Intensity Scale (Section 3.2.2). Visual assessments will occur immediately following the detection of seismic events of greater than 4.3 on the Richter scale and/or immediately following seismic events of greater than 5 on the MM Intensity Scale.

Visual assessments of the lake protection bund, tailings structures, water storages and pit-void walls will be undertaken regularly (i.e. weekly) by a civil/structural engineer to detect/locate the presence of any cracks or other signs of failure or movement (e.g. slips, erosion, subsidence or seeps).

Previously observed cracks or other signs of failure will be visually assessed to monitor the extent of the crack or other sign of failure. Photographic records and/or measurements of the magnitude of the crack/failure will be taken, where necessary, as determined by the civil/structural engineer to determine if cracks or other signs of failure or movement are increasing in size.

Observations made during visual assessments, including photographic records and any measurements taken, will be detailed in a database and subsequently reported in the Annual Review (Section 8.1). Information recorded in the database will include:

- name, contact details, qualifications and experience of the person undertaking the assessment;
- Richter scale magnitude and/or Local Felt Intensity of the seismic event;
- the time and date that the assessment was undertaken;
- the location of the sign(s) of failure or movement (including position on the embankment/pit, where necessary); and
- a general description of observations made (e.g. evidence of slippage into the lake).

This data would be used should movement of the lake protection bund, water storage, tailings storage or pit-void walls occur to assist in identifying the factors contributing to the movement.

Section 5.11.1 of the *Acceptable Earthquake Capacity for Dams* (Appendix A) (DSC, 2010a) states that there is considerable risk to the safety of a dam for some time after the earthquake event. Therefore, visual inspections following trigger level seismic events will continue until stability of the lake protection bund, water storage and tailings structures and pit-void walls is restored, as outlined in Section 5.11.2 of the *Acceptable Earthquake Capacity for Dams* (Appendix A) (DSC, 2010a). The stability status of the structure will be determined by the civil/structural engineer.

A survey assessment (Section 5.3.3) will be undertaken should visual assessments indicate movement of the lake protection bund, tailings structures, water storages or pit-void walls.

### **5.3 SURVEY ASSESSMENT**

Survey assessment of the lake protection bund, tailings structures, water storages and pit-void walls will be routinely undertaken at six monthly intervals or following visual assessments that indicate movement of a structure and/or following seismic events to determine and quantify any movement of these structures.

The following sections detail routine survey assessment, survey assessment undertaken following visual assessment and survey assessment undertaken following a seismic event.

#### **5.3.1 Routine Survey Assessment**

Survey assessment of the lake protection bund, tailings structures, water storages and pit-void walls will be routinely undertaken at six monthly intervals to determine and quantify any movement of these structures.

The survey assessment will be undertaken by an appropriately qualified surveyor. The locations of survey stations to be surveyed throughout the mine life will also be submitted to the DRG for approval prior to the initial survey. Survey stations will be constructed to minimise the effects of any non-mining ground movements (such as swelling or shrinking) on the survey stations. The length between survey stations will initially be 200 m for the lake protection bund, tailings storage and pit-void walls (URS, pers. comm., 15 August 2003). This length would allow for an appropriate number of monitoring points at each structure. The length between the stations for the water storages will be determined by the surveyor prior to the initial survey.

Surveys will commence following construction of the lake protection bund, with the tailings structures, water storages and open pit to be surveyed following commissioning of this infrastructure. The final void will be surveyed from the cessation of mining until lease relinquishment.

Surveys will be undertaken to identify any significant movement of the lake protection bund, tailings structures, water storages and pit-void walls. Significant movement will be defined as (URS, pers. comm., 15 August 2003):

- lateral movement greater than 20 mm since previous survey, or greater than 500 mm in total; and/or
- vertical movement greater than 20 mm since previous survey, or greater than 0.1% of total embankment height.

Trends in lake protection bund, tailings structures, water storages and pit-void walls movement identified by survey assessments will be analysed in order to identify significant movement and develop predictions of possible future trends in movement. Interpretation and the development of trends in survey assessment results will be undertaken by a civil/structural engineer. This appropriately qualified person will be determined in consultation with the DRG and/or the DSC.

Trends indicating movement inconsistent with predictions of the lake protection bund, tailings structures, water storages and pit-void walls will result in the DRG being contacted, as outlined in Section 6.

Surveys detecting any significant movement of the lake protection bund, tailings structures, water storages and pit-void walls will result in the DRG being contacted, as outlined in Section 6.

The results of the survey assessments will be detailed in a database and subsequently reported in the Annual Review (Section 8.1). Data recorded will include:

- name, contact details, qualifications and experience of the person undertaking the survey;
- the time and date that the survey was undertaken;
- survey stations/permanent markers used;
- a report of any indications of movement observed;
- a description of any trends in the movement of the lake protection bund, tailings structures, water storages or pit-void; and
- a general description of observations made.

This data will be used should significant movement of the lake protection bund, water storage, tailings storage or pit-void walls occur to assist in identifying the factors contributing to the movement.

### **5.3.2 Survey Assessment Following Visual Assessment**

Survey assessment of the lake protection bund, tailings structures, water storages and pit-void walls will be undertaken where visual assessment (Section 5.2 identifies movement of any of these structures.

The survey assessment will be undertaken by an appropriately qualified surveyor. The locations of survey stations to be surveyed throughout the mine life will also be submitted to the DRG for approval prior to the initial survey. Survey stations will be constructed to minimise the effects of any non-mining ground movements (such as swelling or shrinking) on the survey stations. The length between survey stations will initially be 200 m for the lake protection bund, tailings storage and pit-void walls (URS, pers. comm., 15 August 2003). This length would allow for an appropriate number of monitoring points at each structure. The length between the stations for the water storages will be determined by the surveyor prior to the initial survey.

Surveys will be undertaken to identify any significant movement of the lake protection bund, tailings structures, water storages and pit-void walls. Significant movement will be defined as (URS, pers. comm., 15 August 2003):

- lateral movement greater than 20 mm since previous survey, or greater than 500 mm in total; and/or
- vertical movement greater than 20 mm since previous survey, or greater than 0.1% of total embankment height.

Trends in lake protection bund, tailings structures, water storages and pit-void walls movement identified by survey assessments will be analysed in order to identify significant movement and develop predictions of possible future trends in movement. Interpretation and the development of trends in survey assessment results will be undertaken by a civil/structural engineer. This appropriately qualified person will be determined in consultation with the DRG and/or the DSC.

Trends indicating movement inconsistent with predictions of the lake protection bund, tailings structures, water storages and pit-void walls will result in the DRG being contacted, as outlined in Section 6.

Surveys detecting any significant movement of the lake protection bund, tailings structures, water storages and pit-void walls will result in the DRG being contacted, as outlined in Section 6.

The results of the survey assessments will be detailed in a database and subsequently reported in the Annual Review (Section 8.1). Data recorded will include:

- name, contact details, qualifications and experience of the person undertaking the survey;
- the time and date that the survey was undertaken;
- survey stations/permanent markers used;
- a report of any indications of movement observed;
- a description of any trends in the movement of the lake protection bund, tailings structures, water storages or pit-void; and
- a general description of observations made.

This data will be used should significant movement of the lake protection bund, water storage, tailings storage or pit-void walls occur to assist in identifying the factors contributing to the movement.

### **5.3.3 Survey Assessment Following Seismic Event**

The Geoscience Australia website will be checked to determine Richter scale magnitudes of seismic events on a monthly basis, or after a suspected seismic event as described in Section 3.2.1. In addition, the magnitude of seismic events will be estimated on the MM Intensity Scale (Section 3.2.2). Visual assessments (Section 5.2.3) will occur immediately following the detection of seismic events of greater than 4.3 on the Richter scale and/or immediately following seismic events of greater than 5 on the MM Intensity Scale. Should these visual assessments indicate that movement of the lake protection bund, tailings structures, water storages and pit-void walls may have occurred, a survey assessment will be carried out as described below.

The survey assessment will be undertaken by an appropriately qualified surveyor. The locations of survey stations to be surveyed throughout the mine life will also be submitted to the DRG for approval prior to the initial survey. Survey stations will be constructed to minimise the effects of any non-mining ground movements (such as swelling or shrinking) on the survey stations. The length between survey stations will initially be 200 m for the lake protection bund, tailings storage and pit-void walls (URS, pers. comm., 15 August 2003). This length would allow for an appropriate number of monitoring points at each structure. The length between the stations for the water storages will be determined by the surveyor prior to the initial survey.

Surveys will be undertaken to identify any significant movement of the lake protection bund, tailings structures, water storages and pit-void walls. Significant movement will be defined as (URS, pers. comm. 15 August, 2003):

- lateral movement greater than 20 mm since previous survey, or greater than 500 mm in total; and/or
- vertical movement greater than 20 mm since previous survey, or greater than 0.1% of total embankment height.

Trends in lake protection bund, tailings structures, water storages and pit-void walls movement identified by survey assessments will be analysed in order to identify significant movement and develop predictions of possible future trends in movement. Interpretation and the development of trends in survey assessment results will be undertaken by a civil/structural engineer. This appropriately qualified person will be determined in consultation with the DRG and/or the DSC.

Trends indicating movement as a result of a seismic event of the lake protection bund, tailings structures, water storages and pit-void walls will result in the DRG being contacted, as outlined in Section 6.

Surveys detecting any significant movement of the lake protection bund, tailings structures, water storages and pit-void walls will result in the DRG being contacted, as outlined in Section 6.

The results of the survey assessments will be detailed in a database and subsequently reported in the Annual Review (Section 8.1). Data recorded will include:

- name, contact details, qualifications and experience of the person undertaking the survey;
- Richter scale magnitude and/or Local Felt Intensity of the seismic event;
- the time and date that the survey was undertaken;
- survey stations/permanent markers used;
- a report of any indications of movement observed;
- a description of any trends in the movement of the lake protection bund, tailings structure, water storages or pit-void; and
- a general description of observations made.

This data will be used should significant movement of the lake protection bund, water storage, tailings storage or pit-void walls occur to assist in assessing the extent and potential impacts of the movement.

## **6 PROCEDURES IN THE EVENT OF DETECTION OF MOVEMENT**

Should visual or survey assessments indicate any significant movement of the lake protection bund or water storage and tailings structures, Evolution will record this movement in the database and undertake further monitoring to verify and assess the extent and potential impacts of the movement .

Similarly, should trends in the movement of the pit-void (Section 5.3) indicate that significant or unexpected movement has occurred or may occur, as determined by an appropriately qualified person, Evolution will record this movement in the database and undertake further monitoring to verify and assess the extent and potential impacts of the movement.

As required by DRG (DMR, pers. comm., 2 June 2003) Evolution then will enter into discussions with DRG and DP&E to facilitate the undertaking of a risk assessment to devise ameliorative measures depending on the severity of the problem.

The general procedures in the event of detection of movement are summarised as follows:

1. Visual/survey assessment identified movement.
2. Movement assessed for significance in accordance with criteria:
  - lateral movement greater than 20 mm since previous survey, or greater than 500 mm in total; and/or
  - vertical movement greater than 20 mm since previous survey, or greater than 0.1% of total embankment height.
3. If the movement is deemed significant, Evolution will record the movement in the database and undertake further monitoring to verify and assess the extent and potential impacts of the movement.
4. DRG and DP&E will be informed of the significant movement to facilitate the undertaking of a risk assessment to devise ameliorative measures depending on the severity of the problem.

## 7 CONSULTATION AND COMPLAINTS RECEIPT

### 7.1 COMMUNITY ENVIRONMENTAL MONITORING AND CONSULTATIVE COMMITTEE

A Community Environmental Monitoring and Consultative Committee (CEMCC) has been set up for the CGO in accordance with Development Consent Condition 9.1(d). The condition is reproduced below:

#### 9.1 Environmental Management

(d) Community Environmental Monitoring and Consultative Committee

- (i) *The Applicant shall establish and operate a Community Environmental Monitoring and Consultative Committee (CEMCC) for the development to the satisfaction of the Secretary. This CEMCC must:*
- be comprised of an independent chair and at least 2 representatives of the Applicant, 1 representative of BSC, 1 representative of the Lake Cowal Environmental Trust (but not a Trust representative of the Applicant), 4 community representatives (including one member of the Lake Cowal Landholders Association);*
  - be operated in general accordance with the Guidelines for Establishing and Operating Community Consultative Committees for Mining Projects (Department of Planning, 2007, or its latest version).*
  - monitor compliance with conditions of this consent and other matters relevant to the operation of the mine during the term of the consent.*
- Note: The CEMCC is an advisory committee. The Department and other relevant agencies are responsible for ensuring that the Applicant complies with this consent.*
- (ii) *The Applicant shall establish a trust fund to be managed by the Chair of the CEMCC to facilitate the functioning of the CEMCC, and pay \$2000 per annum to the fund for the duration of gold processing operations. The annual payment shall be indexed according to the Consumer Price Index (CPI) at the time of payment. The first payment shall be made by the date of the first Committee meeting. The Applicant shall also contribute to the Trust Fund reasonable funds for payment of the independent Chairperson, to the satisfaction of the Secretary.*

...

As required by Development Consent Condition 9.1(d)(i), the CEMCC comprises an independent chair and representatives of the Bland Shire Council, Forbes Shire Council, Lachlan Shire Council, Lake Cowal Foundation, the Wiradjuri Condobolin Corporation, two Evolution representatives and four community representatives including one from the Lake Cowal Landholders Association.

The CEMCC will provide opportunities for members of the community to attend CEMCC meetings to discuss specific issues relevant to them. A landholder can make a request to the CEMCC regarding a particular issue, or the landowner can register a complaint in the complaints register. Landowners who register complaints may be invited to join in discussion of the issue at the next CEMCC meeting.

Items of discussion at these meetings will include mine progress, reporting on environmental monitoring, complaints, rehabilitation activities and environmental assessments undertaken.

## 7.2 COMPLAINTS REGISTER

A process for the handling of complaints is provided below in accordance with the requirements of the CGO's EPL and Development Consent conditions and to facilitate prompt and comprehensive responses to any community concerns.

As required by EPL Condition M6.1, a dedicated Community Complaints Line has been established (via phone [02] 6975 3454 or email [community.cowal@evolutionmining.com.au](mailto:community.cowal@evolutionmining.com.au)) that is available 24 hours, seven days a week for community members who have enquiries or who wish to lodge complaints in relation to Evolution's activities at the CGO.

A complaints register will be maintained by the CGO Environment and Social Responsibility Manager in accordance with EPL Condition M5 and will be made available on Evolution's website in accordance with Development Consent Condition 9.4(a)(v).

Information recorded in the complaints register with respect to each complaint will include:

- date of complaint;
- the method by which the complaint was made;
- nature of complaint; and
- response action taken to date (if no action was taken, the reasons why no action was taken).

An initial response will be provided to the complainant within 24 hours. Preliminary investigations into the complaint will commence within 48 hours of complaint receipt.

## **8 REPORTING**

### **8.1 ANNUAL REVIEW**

In accordance with Condition 9.1(b) of the Development Consent, Evolution will prepare an Annual Review to report on the environmental performance of the CGO by the end of July each year, or other timing as may be agreed by the Secretary of the DP&E. The Annual Review will be made publicly available on Evolution's website ([www.evolutionmining.com.au](http://www.evolutionmining.com.au)) in accordance with Development Consent Condition 9.4(a)(vii). The Annual Review will also address the Annual Environmental Management Report requirements of ML 1535 Condition of Authority 26.

The Annual Review will report on monitoring for the detection of any movement of the lake protection bund, tailings structures, water storages and pit-void walls. Monitoring results collected in accordance with Development Consent Condition 4.5(c) will be reported in the Annual Review.

### **8.2 INCIDENT REPORTING**

An incident is defined in the CGO Development Consent as a set of circumstances that causes or threatens to cause material harm to the environment, and/or breaches or exceeds the limits or performance measures/criteria of the Development Consent.

In accordance with Development Consent Condition 9.3(a) Evolution will immediately notify the Secretary of the DP&E and any other relevant agencies of any incident related to the CGO. Within seven days of the date of the incident, Evolution will provide the Secretary of the DP&E and any other relevant agencies with a detailed report on the incident, and any further reports that may be requested. In addition, in accordance with EPL 11912 Condition R2, Evolution will notify the Environment Protection Authority (EPA) (and all other relevant authorities) of incidents causing or threatening material harm to the environment immediately after the person becomes aware of the incident. Evolution will provide written details of the notification to the EPA within seven days of the date on which the incident occurred.

Evolution will maintain a record of/and report on any incidents related to the detection of any movement of the lake protection bund, tailings structures, water storages and pit-void walls. The form will be completed when recording incidents at the site.

## 9 AUDITING AND REVIEW

### 9.1 INDEPENDENT ENVIRONMENTAL AUDIT

An Independent Environmental Audit will be conducted in accordance with Development Consent Condition 9.2(a) and may include issues related to the lake protection bund, water storage, tailings structures or pit-void walls. The condition is reproduced below:

#### **9.2 Independent Auditing and Review**

##### **(a) Independent Environmental Audit**

(i) *By the end of July 2016, and every 3 years thereafter, unless the Secretary directs otherwise, the Applicant shall commission and pay the full cost of an Independent Environmental Audit of the development. This audit must:*

- Be conducted by a suitably qualified, experienced and independent team of experts whose appointment has been endorsed by the Secretary;*
- Include consultation with relevant regulatory agencies, BSC and CEMCC;*
- Assess the environmental performance of the development and assess whether it is complying with the requirements in this consent and any other relevant approvals (such as environment protection licences and/or mining lease (including any assessment, plan or program required under this consent);*
- Review the adequacy of any approved strategy, plan or program required under this consent or the abovementioned approvals; and*
- Recommend measures or actions to improve the environmental performance of the development, and/or strategy, plan or program required under this consent.*

*Note: This audit team must be led by a suitably qualified auditor, and include ecology and rehabilitation experts, and any other fields specified by the Secretary.*

(ii) *Within 3 months of commissioning this audit, or as otherwise agreed by the Secretary, the Applicant shall submit a copy of the audit report to the Secretary, together with its response to any recommendations contained in the audit report, and a timetable for the implementation of these recommendations as required. The applicant must implement these recommendations, to the satisfaction of the Secretary.*

This process provides a mechanism by which management and monitoring of the lake protection bund, water storage, tailings structures or pit-void walls at the CGO can be assessed against relevant Development Consent, mining lease and licence conditions, legislation and Australian Standards.

### 9.2 INDEPENDENT MONITORING PANEL

The Independent Monitoring Panel will, amongst other things, review the Independent Audit required by Development Consent Condition 9.2(b). In accordance with Development Consent Condition 9.2(b):

- (i) *The Applicant shall at its own cost establish an Independent Monitoring Panel prior to commencement of construction. The Applicant shall contribute \$30,000 per annum for the functioning of the Panel, unless otherwise agreed by the Secretary. The annual payment shall be indexed according to the Consumer Price Index at the time of payment. The first payment shall be paid by the date of commencement of construction and annually thereafter. Selection of the Panel representatives shall be agreed by the Secretary in consultation with relevant government agencies and the CEMCC. The Panel shall at least comprise two duly qualified independent environmental scientists and a representative of the Secretary.*

(ii) *The panel shall:*

- *provide an overview of the annual reviews and independent audits required by conditions 9.1(b) and 9.2(a) above;*
- *regularly review all environmental monitoring procedures undertaken by the Applicant, and monitoring results; and*
- *provide an Annual State of the Environment Report for Lake Cowal with particular reference to the on-going interaction between the mine and the Lake and any requirements of the Secretary. The first report shall be prepared one year after commencement of construction. The report shall be prepared annually thereafter unless otherwise directed by the Secretary and made publicly available on the Applicant's website for the development within two weeks of the report's completion.*

...

### **9.3 REVIEW OF THIS LPBMP**

In accordance with Condition 9.1(c) of the Development Consent, this LPBMP will be reviewed, within three months of the submission of:

- an Annual Review under Condition 9.1(b);
- an incident report under Condition 9.3(a);
- an audit under Condition 9.2(a);
- an Annual State of the Environment Report under Condition 9.2(b);
- the approval of any modification to the conditions of the Development Consent; or
- any direction of the Secretary under Condition 1.1(c).

Where this review leads to revisions of the LPBMP, then within four weeks of the review, the revised LPBMP will be submitted for the approval of the Secretary of the DP&E (unless otherwise agreed with the Secretary). The revision status of this LPBMP is indicated after the title page of this LPBMP.

This LPBMP will be made publicly available on Evolution's website ([www.evolutionmining.com.au](http://www.evolutionmining.com.au)), in accordance with Condition 9.4(a)(iii) of the Development Consent. A hard copy of the LPBMP will also be kept at the CGO.

Evolution may update this LPBMP periodically in the event of any significant alteration of on-site activities or control measures.

## 10 REFERENCES

- Australian Geological Survey Organisation (1997) *Lake Cowal Seismic Hazard Evaluation*. Prepared for Knight Piesold Pty Ltd.
- Australian Geological Survey Organisation (2003) *West Wyalong Earthquake History* obtained on 26 May 2003.
- Barrick (Cowal) Limited (2013) *Cowal Gold Mine Extension Modification Environmental Assessment*.
- Commissioners of Inquiry for Environment and Planning (1999) *Proposed Cowal Gold Project North Gold (WA) Limited. Report to the Minister for Urban Affairs and Planning*.
- Dams Safety Committee (2010a) *Acceptable Earthquake Capacity for Dams*.
- Dams Safety Committee (2010b) *Operation and Maintenance for Dams*.
- Dams Safety Committee (2015) *Emergency Management for Dams*.
- Evolution Mining (Cowal) Pty Limited (2016) *Cowal Gold Operations Mine Life Modification – Environmental Assessment*.
- Geoscience Australia (2017) *Geoscience Australia Earthquakes: Database*. Available at: <http://www.ga.gov.au/earthquakes/searchQuake.do>. Accessed on 29 June 2017.
- HydroEngineering & Consulting (2016) *Cowal Gold Operations Mine Life Modification Hydrological Assessment*.
- Knight-Piesold Pty Ltd (1997) *Geotechnical Studies Tailings and Waste Management Pre-assessment Process*. Attachment N4 to Appendix N of North Limited (1998) *Cowal Gold Project Environmental Impact Statement*. Prepared by Resource Strategies Pty Ltd.
- Michigan Technological University (2003) *Modified Mercalli Intensity Scale*. Available at: [www.geo.mtu.edu/UPSeie/Mercalli.html](http://www.geo.mtu.edu/UPSeie/Mercalli.html). Accessed 11/09/03.
- North Limited (1998) *Cowal Gold Project Environmental Impact Statement*. Prepared by Resource Strategies Pty Ltd.
- Seismology Research Centre (2011) *Cowal Tailings Storage Facility Seismic Hazard Assessment*. Prepared by Seismology Research Centre for Barrick Gold, dated July 2017, ref. 2011.07 ESS Seismicity Analysis Report
- Southern California Earthquake Data Center (2003) *Modified Mercalli Intensity Scale of 1931*. Available at <http://www.scecdc.scec.org/Module/s3act01m.html>. Accessed on 11/09/03.
- US Geological Survey (2003) *The Modified Mercalli Intensity Scale*. Available at: <http://neic.usgs.gov/neis/general/handouts/mercalli.html>. Accessed on 11/09/03.

## APPENDIX A

### ACCEPTABLE EARTHQUAKE CAPACITY FOR DAMS (DSC3C) (DSC, 2010a)

DSC3C

June 2010

## ACCEPTABLE EARTHQUAKE CAPACITY FOR DAMS

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## 1. INTRODUCTION

The *normal requirements* of the NSW Dams Safety Committee (DSC) are set out in its guidance sheets with its principal guidance sheet, *DSC Background, Functions and Operations - DSC1A*, outlining the DSC's general operations and authority.

The DSC has statutory functions under the *Dams Safety Act, 1978* to ensure that all prescribed dams in NSW are designed, constructed, maintained and operated to a standard where risks to the community are tolerably low. The level of risk is determined by the likelihood and consequences of failure. Earthquake (seismic) activity affecting dams is one of the risk elements that must be considered by dam owners.

Owners, and their professional advisers, have full responsibility for ensuring the seismic safety of their dams, each with their own individual and specific issues. However, the DSC also has a responsibility to draw owners' attention to any DSC requirements (see section 2.2), as well as general issues or findings that may provide guidance to assist owners to achieve *good practice* for the seismic safety management of dams.

The DSC Seismic Safety Goal and Key Requirements (Section 2) at the start of the sheet are a summary - the whole sheet is to be read for a proper understanding of DSC considerations on acceptable earthquake capacity for dams.

## 2. DSC SEISMIC SAFETY GOAL & KEY REQUIREMENTS

### 2.1 DSC Seismic Safety Goal

The DSC's goal regarding the seismic safety of prescribed dams is to ensure they are appropriately designed (e.g. have adequate stability) and managed to result in tolerable risks to community interests.

It is for the dam owner to determine how this goal (including DSC requirements) will be achieved and to demonstrate to the DSC that the goal is achieved or will be achieved following safety improvements. The following sheet sections aim to provide guidance to assist dam owners in achieving this DSC goal.

### 2.2 DSC Key Requirements

This section summarises the DSC requirements outlined in this sheet.

#### 5.1 General

Check all new or proposed significant, high and extreme Consequence Category dams for safety under seismic loadings. All existing extreme, high and significant Consequence Category dams are to be subject to an appropriate safety under earthquake study and its status reviewed at each 5 yearly surveillance report.

#### 5.2 Design Criteria

All extreme, high and significant Consequence Category dams are to withstand earthquake shaking for the appropriate Maximum Design Earthquake (MDE) from Table 5.3 of this sheet. For extreme and high Consequence Category dams, obtain seismic loadings from an

experienced seismologist who is familiar with the characteristics of earthquakes in Australia. In taking guidance from ANCOLD(1998), read the guidelines in conjunction with the paper Fell(2005).

#### **5.4 Design Analysis for Concrete Dams**

For extreme and high Consequence Category concrete dams, base the design on an accepted dynamic analysis.

#### **5.5 Design Analysis for Earthfill Dams**

For all extreme, high and significant Consequence Category embankment dams determine whether the dam or foundation is potentially subject to liquefaction and report the determination to the DSC. For extreme, high and significant Consequence Category earthfill dams carry out a staged stability analysis based on the procedure outlined in Section 6 of the ANCOLD earthquake guidelines.

#### **5.7 Design Analysis for Rockfill Dams**

Concrete faced rockfill dams of free-draining rockfill are often designed empirically on the basis of precedent performance. The DSC will accept such a design basis. Analyse dams of rockfill that are not free-draining, in a similar manner to earthfill dams and current best practice.

#### **5.8 Appurtenant Structures**

The design of appurtenant structures where they are relevant to dam safety shall be in accordance with Section 8 of the ANCOLD Guidelines.

#### **5.9 Defensive Measures**

For extreme, high and significant Consequence Category dams, particularly embankment dams employ appropriate defensive measures.

#### **5.10 Upstream Occurrences**

Consider the potential for reservoir rim landslides to be triggered by earthquake and for reservoir seiche and report on a qualitative assessment of the implications for the safety of all extreme, high and significant Consequence Category dams.

#### **5.11 Post Earthquake Procedures**

The DSC considers that there is a considerable risk to dam safety for some time after an earthquake an analysis of safety under the subsequent event should undertaken.

Dam owner's are required to have in place an effective Dam Safety Emergency Plan (DSEP) prepared in accordance with the DSC's guidance sheet on *Emergency Management for Dams (DSC2G)*.

#### **5.12 Summary**

The DSC will consider deviations from these requirements upon submission of a cogent and fully documented case. In particular, if Risk Assessment methodologies are used they should be in accordance with the ANCOLD Guidelines and follow the requirements of *Demonstration of Safety for Dams - DSC2D*.

### **3. BACKGROUND**

Australia is a landmass of comparatively low seismic activity. It is well removed from the tectonic plate margins which are the most seismically active parts of the earth's crust.

Nevertheless earthquakes of a magnitude with the potential to cause damage to structures do occur in Australia from time to time due to a gradual build up of intra plate stresses. Over recent decades the 1968 Meckering event (M6.9), the 1988 Tennant Creek events (largest M6.8) and the 1989 Newcastle event (M5.6) have confirmed the potential for damaging earthquakes. The symbol M refers to Richter magnitude, either  $M_L$  (based on records of local waves) or  $M_s$  (based on records of surface waves). The values are approximate since they vary in published sources. Overseas experience shows that very large earthquakes are possible in intraplate environments. A notable example is the New Madrid, Missouri event of 1812 (M8.3). Although exceptional intraplate events are rare they must be considered in dam safety given the potentially long life of dams and the very low risks of dam failure that are acceptable. If necessary, retrofitting of existing dams must be implemented to cater for such events. In Eastern Australia the present advice by seismologists is that the upper limit magnitude that could be expected is M7.5.

In Australia, the Newcastle event was significant in that, being located close to a major urban centre, it was the first earthquake to cause loss of life in this country. All three events in Australia mentioned in the preceding paragraph caused structural damage but again the Newcastle event was by far the most damaging, due to its location close to a large city, with a damage estimate totalling some \$1,000M in the prices of the day. In contrast, the Meckering and Tennant Creek events occurred in remote areas. It is important to note that the Newcastle Earthquake of 1989 was not an exceptional event. There are two other earthquakes exceeding M5 that have occurred in the Newcastle area in the past 130 years and there are two further events in the early 1840's which caused strong shaking in the Hunter Valley.

Understanding of Australian earthquakes has grown rapidly over the past two decades. Much is still being learned through improved monitoring of seismic events. Dam owners are thus encouraged to participate in the development and operation of seismic monitoring networks. The availability of additional data will assist in providing a more balanced decision making process in the design of new dams and assessment of existing dams.

Generally dams withstand earthquake shaking remarkably well. There are very few recorded instances of dam failure resulting from earthquakes, although many dams have suffered deformation and damages. For instance, the M8.0 Wenchuan earthquake of 12 May 2008 in China damaged over 1500 dams, some seriously, but no dam failed.

ICOLD (1995) has reported the results of a survey of dam failures among its national committees. Of 183 failures, at most 5 were related to earthquake. In comparison, 45 failed due to overtopping by flood. ICOLD give earthquake as the cause of failure or distress of:

- Embalse Aromos Dam, Chile, in 1985
- Lliu-Lliu Dam, Chile, in 1985

- Van Norman Dam, USA, in 1971

Liquefaction, presumably resulting from earthquake, was the cause of failure for:

- Sheffield Dam, USA IN 1925
- Niznhe Svirskaya Dam, USSR, in 1935

Note that “failure” by the ICOLD definition was an inability to retain water, and not necessarily release of the reservoir. The reservoir was not released in the case of Van Norman Dam, at least, because of a fortuitously low storage level when the earthquake occurred.

Reports of the performance of dams under earthquake shaking have also been provided by Seed (1981), Hinks and Gosschalk (1993) and USCOLD (1992). These sources show that there have been cases of damage, and some of failure. In summary, there have been:

- Some 20 to 30 failures of earth dams, most, perhaps all, involving liquefaction of cohesion less soils. Most also were low dams less than 20m high and did not result in loss of life. However, the failure of three tailings dams in Chile caused the loss of 254 lives.
- There have been no failures of rockfill dams
- There have been no failures of concrete dams

Concrete dams may be subject to severe cracking, movement and opening of joints which, if they do not cause failure, may render the dam unserviceable or may require major repairs.

To date there is no recorded failure of a large concrete dam as a result of earthquake shaking. However in September 1999, the Shih-Kung dam in Taiwan was severely affected by a nearby Richter 7.4 earthquake, which initiated movement in a fault line running under its gated spillway concrete section. One end of the spillway (6 gates) was sheared from the rest of the spillway (2 gates) and lifted over 9m. As such the construction of inelastic dams over known faults should be treated with extreme caution.

In 1971, the 113m Pacoima arch dam (near Los Angeles, California) experienced a M6.6 shock at 6.4km distance which resulted in a peak acceleration at the site of 1.2g. The dam suffered damage but did not fail and, after repairs, was returned to service. (Swanson and Sharma, 1979).

In 1967 the 103m high Koyna gravity dam in India suffered a near field M6.5 earthquake. Major cracking occurred but the dam did not fail. (Saini et al., 1972).

Embankment dams can suffer two main types of damage, depending on the nature of foundation or fill materials and the design and construction standards:

- major deformations, slumping and cracking; which could lead to failure from loss of freeboard or piping along cracks.
- liquefaction of either the foundation material or the dam fill.

In 1989 the M7.1 Loma Prieta earthquake damaged Austrian Dam in California. The 56m high earthfill dam suffered crest settlement up to 760mm with associated major cracking, including deep transverse cracks near the abutments and significant spillway damage. The separation of the embankment from the spillway wall was up to 300mm wide and 7.2m deep (Forster and MacDonald, 1998). The storage level was low at the time. No liquefaction was involved at this dam. The dam was repaired and returned to service. (Rodda et al., 1990).

In 1987 the 86m high Matahina Dam in New Zealand, an earth core rockfill structure, was strongly shaken by an earthquake of M6.3 centred some 23km away. The occurrence of delayed piping (over nine months after the earthquake), presumably triggered by this earthquake, may well have been fatal to the dam, had there not been intervention to arrest the process and make repairs. There was no liquefaction involved in this incident (Gillon and Newton, 1994). This experience indicates that enhanced surveillance after an earthquake needs to be maintained for a substantial period.

Coleman and Rogers Dams, Nevada, USA failed as a result of the Fallon earthquake, apparently at the interface between the concrete and the embankment structures (Ambrasseys, 1960). There was apparently no liquefaction involved.

Liquefaction can occur in saturated, loose, fine-grained cohesion less materials. The embankments of hydraulic fill or tailings dams may be subject to liquefaction. In Australia though, the main risk of liquefaction for dams, other than tailings dams, would relate to alluvial foundation materials that support dam embankments. This is because embankments in this country are traditionally constructed of either cohesive materials or rockfill; the hydraulic fill technique was never employed to any significant extent.

In 1971, the hydraulic fill embankment of the Lower van Norman Dam in California suffered a near disastrous failure due to liquefaction. A massive upstream slide occurred and the dam lost 9m height from its crest. It was only good fortune that the storage was 7.5m below full supply level at the time. If the storage had been at full supply level it seems certain that the dam would have failed. (Seed, 1982).

In 1925 the 11m high Sheffield Dam near Santa Barbara, California failed completely due to earthquake. It is believed the failure involved liquefaction. (Seed, 1982).

Free draining rockfill dams with a thin impervious element are regarded as inherently stable under earthquake shaking. This is particularly so for concrete faced rockfill dams and upstream sloping core rockfill dams which have a large mass of drained rockfill so that earthquake effects cannot cause reduced stability due to high pore pressures (Cooke, 1984). This is evidenced by the Cogoti Dam

(Chile), which in 1943 experienced ground accelerations estimated to be in the range 0.15g to 0.30g. This 159m high dam is a dumped rockfill structure with an impervious upstream facing of laminated concrete. The crest settled 280mm and there were minor rock slides on the 1.8H: 1V downstream face (Cooke, 1984).

However, Seed et al. (1985) pointed out that modern concrete faced compacted rockfill dams had not yet been subjected to strong earthquake shaking (over 0.20g) and their performance remained untested. Since then in 1994, Cogswell Dam, a large concrete faced compacted rockfill dam in Southern California, and Cogoti Dam (Chile), again in 1997, have been subjected to strong earthquake shaking (over 0.25g) with minimal distress (i.e. minor settlement).

In the Wenchuan M8.0 earthquake of May 2008, the 156m high Zipingpu concrete faced rockfill dam was subjected to severe shaking, being only 17km from the epicentre. The peak ground acceleration was 0.5g and the peak acceleration at the dam crest was 2.0g. The crest immediately settled 684mm and within a few days the settlement had reached 744mm. The crest was displaced 200mm downstream and the face slabs were severely damaged. However, the dam did not fail and was judged safe by the post-earthquake review team (Xu Zeping, 2008).

In 1984 the Leroy Anderson Dam (California) experienced a peak ground acceleration of 0.40g. The 72m high earth core rockfill dam (dumped and sluiced rockfill) sustained two systems of longitudinal cracks which apparently resulted from differential settlement between the core and the shells. The crest settled 15mm and moved 9mm downstream. (Bureau et al., 1985).

Earthquakes can trigger reservoir rim slides that in turn could lead to dam failure by creating a wave that overtops the dam. Earthquakes can cause a seiche in the reservoir that can overtop the dam as occurred at Hebgen Dam (USCOLD, 1992). Outlet towers, bridges and other appurtenant structures have failed due to seismic loading; such failures do not usually endanger the dam, but could result in an uncontrolled loss of storage.

#### **4. DSC APPROACH TO SEISMIC RISK IN DAMS**

In compiling this guidance sheet the DSC has been conscious of the following factors:

- Available data suggests that there is a low probability of failure under seismic loading for well designed and constructed dams on sound foundations. Nearly all cases of dam failure due to earthquake seem to be related to the liquefaction of saturated, cohesionless material, although incidents have occurred that point to the potential for failure where there is no possibility of liquefaction.
- Relative to the situation in other, more earthquake prone countries, seismic design methodology for dams is reasonably well developed in Australia but there are few highly experienced practitioners.

- Much of the design methodologies in use in Australia has been developed for the United States but have some application to Australian conditions despite the differing characteristics of seismic events in the two countries.

With the potential low probability of failure due to earthquake in mind, the DSC has set its minimum requirements given in this sheet. They allow a phased approach to ensure that designers give proper consideration to adequate earthquake loading, both in design of new dams and when reviewing the safety of existing dams.

The DSC endorses the 1998 ANCOLD *Guidelines for the Design of Dams for Earthquakes* as the basis for the DSC's requirements, except that aspects dealing with risk assessment should be modified in accordance with the *ANCOLD Guidelines on Risk Assessment - 2003*. The ANCOLD guidelines should be read in conjunction with Fell (2005) which outlines some later developments.

The ANCOLD earthquake guidelines contain a comprehensive list of methodologies and reference documents to assist dam owners. The DSC's overall requirement is that the degree of analysis adopted should reflect the consequences of failure, the type of dam, the local seismicity and the nature of the foundations.

Designers are invited to submit alternative approaches to these requirements if they consider the latter to be inappropriate in particular circumstances. The DSC will carefully consider any cogent and well documented case supporting the use of alternative approaches.

## **5. DSC SEISMIC REQUIREMENTS FOR DAMS**

### **5.1 General**

- 5.1.1 Check all new or proposed significant, high and extreme Consequence Category dams for safety under seismic loadings. The DSC notes that in most cases the concurrent occurrence of significant flood and earthquake events is of too low a probability to be considered.
- 5.1.2 The DSC has no requirements regarding the design of low Consequence Category dams for earthquake loading.
- 5.1.3 All existing extreme, high and significant Consequence Category dams are to be subject to an appropriate safety under earthquake study and its current status reviewed at each 5 yearly surveillance report (unless the DSC requests otherwise.)

### **5.2 Design Criteria**

- 5.2.1 All extreme, high and significant Consequence Category dams are to withstand earthquake shaking, without an uncontrolled loss of storage due to partial or complete failure of the dam, for the appropriate Maximum Design Earthquake (MDE) from Table 5.3 of this sheet. Considerable damage in such an event would be acceptable.
- 5.2.2 The DSC requires all dams to meet these standards but will consider studying alternative standards based on appropriate risk assessment. However, in such cases, the dams are also required to meet the provisions of Section 5.11 'Post Earthquake procedures' of this sheet.

5.2.3 The DSC has no requirements for earthquake stability of new or existing outlet towers, bridges and ancillary works unless their failure would result in uncontrolled loss of storage or would threaten dam failure. Where the DSC has requirements each case would be treated on its merits and consistent with the requirements of Section 5.8.

**5.3 Design Loadings** 5.3.1 For extreme and high Consequence Category dams, obtain seismic loadings from an experienced seismologist who is familiar with the characteristics of earthquakes in Australia.

5.3.2 The following dam safety levels are required to be achieved:

**Table 5.3 - Maximum Design Earthquakes**

Consequence Category	Earthquake Annual Exceedance Probability (AEP)
Extreme	<1 in 10,000
High A	1 in 10,000
High B	1 in 5,000
High C	1 in 1,000
Significant	1 in 500

**Notes:**

1. Consequence Categories as per ANCOLD "Guidelines on Consequence Assessment" and DSC3A.
2. This dam safety level is to be achieved with the reservoir at Full Supply Level.
3. For extreme Consequence Category dams, the owner is to demonstrate that the design safety level is appropriate to the consequences of failure.
4. If loss of life is expected the AEP shall not exceed 1 in 5000.

The DSC may consider, on a case by case basis, any proposals by the owners of existing dams for lower dam safety levels.

5.3.3 A deterministic approach to design loadings will be considered by the DSC subject to the identification of and comprehensive analysis of all potentially active faults local to the dam.

**5.4 Design Analysis for Concrete Dams** 5.4.1 For extreme and high Consequence Category concrete dams, base the design on an accepted dynamic analysis method (for gravity dams the method given in the ANCOLD Guidelines for Design of Dams for Earthquake - Section 7 is acceptable) and carry out a deformation analysis such as a Newmark type analysis (Newmark 1965 and as subsequently modified).

5.4.2 For significant Consequence Category concrete dams carry out as a minimum a pseudo-static analysis.

<b>5.5 Embankment Dams Susceptible to Liquefaction Failure</b>	5.5.1	For all extreme, high and significant Consequence Category embankment dams determine whether the dam or foundation is potentially subject to liquefaction and report the determination to the DSC.
	5.5.2	For dams subject to liquefaction the DSC will accept an established empirical approach as a basis for establishing safety. The approaches provided in the ANCOLD guidelines are acceptable to the DSC, subject to the advice given in Fell (2005).
<b>5.6 Design Analysis for Earthfill Dams</b>	5.6.1	For extreme, high and significant Consequence Category earthfill dams carry out a staged stability analysis based on the procedure outlined in Section 6 of the ANCOLD earthquake guidelines and summarised in the flow chart of Figure 32. For extreme and high Consequence Category dams the appropriate methodology shall be selected from initial screening through to dynamic, non-linear methods. The DSC notes the importance of well designed and constructed filters and the provision of substantial freeboard in improving the safety of dams under earthquake loads.
<b>5.7 Design Analysis for Rockfill Dams</b>	5.7.1	Concrete faced rockfill dams of free-draining rockfill are often designed empirically on the basis of precedent performance. The DSC will accept such a design basis. Analyse dams of rockfill that are not free-draining, in a similar manner to earthfill dams and current best practice. The DSC endorses the references listed in this document and in the ANCOLD Guidelines for Design of Dams for Earthquakes.
	5.7.2	Rockfill dams that are not free draining or other rockfill dams shall be treated in a similar manner for earthfill dams.
<b>5.8 Appurtenant Structures</b>	5.8.1	The design of appurtenant structures where they are relevant to dam safety shall be in accordance with Section 8 of the ANCOLD Guidelines. Give particular attention to structures, mechanical components and electrical fittings on the superstructure of concrete dams. Such elements are often fragile and may be subjected to accelerations many times greater than the peak ground acceleration. Their failure may leave the dam vulnerable, especially in the case of spillway gate operating equipment.
<b>5.9 Defensive Measures</b>	5.9.1	For extreme, high and significant Consequence Category dams, particularly embankment dams, employ appropriate defensive measures. These are measures that are not amenable to direct quantitative analysis but which are known to significantly improve safety under seismic loading. Examples are listed in Section 5.2 & 7.2 of the ANCOLD, 1998, Guidelines.
<b>5.10 Upstream Occurrences</b>	5.10.1	Consider the potential for reservoir rim landslides to be triggered by earthquake and for reservoir seiche and report on a qualitative assessment of the implications for the safety of all extreme, high and significant Consequence Category dams.

## 5.11 Post Earthquake Procedures

5.11.1 The DSC considers that there is a considerable risk to dam safety for some time after an earthquake event. This risk may arise from the vulnerability of the dam or its foundations weakened by an earthquake and subject to post quake shock at normal reservoir level, a following flood event, the initiation of piping, the initiation of slope instability or the inability to operate the dam to the required standards.

Where analysis indicates that an extreme, high or significant Consequence Category dam will be damaged during an earthquake to an extent that makes it more vulnerable to a subsequent flood or earthquake, during the period before repairs can be completed, an analysis of safety under the subsequent event should be undertaken. The maximum magnitude of the subsequent event should be selected having regard to the overall probability of occurrence of the two events. An important consideration in such analyses is the ability to draw the reservoir down and to maintain it at a lowered level.

5.11.2 Dam owner's are required to have in place an effective Dam Safety Emergency Plan (DSEP) prepared in accordance with the DSC's guidance sheet on *Emergency Management for Dams - DSC2G*. In reference to dam owners' actions after a near field seismic event, the DSEP shall specify:

- Inspection by an experienced dams engineer;
- Reporting of the incident to the DSC;
- Visual inspection and monitoring of instrumentation from the event until stability is restored;
- Guidelines detailing procedures for managing all feasible subsequent events;
- Guidelines for remedial action;
- Requirement for drawdown of the reservoir until reviewed by appropriately expert persons;

The plan shall consider, but not be limited to the implications of:

- Loss of freeboard;
- Damage to the core or impermeable membrane;
- Operation of gates;
- Operation of outlet works;
- Liquefaction effects in the foundation;
- Major instability;
- Soil strain softening.

## 5.12 Summary

The DSC's aim at this time is to ensure that designers responsibly assess the safety of dams under seismic loading using the best information on loading currently available in Australia together with widely accepted methods of engineering analysis. It is recognised that earthquake safety for dams, is a complex subject, and that designers should be allowed substantial flexibility within the

constraints set out in the preceding sections. It is also recognised that, in many cases, loadings other than seismic will be critical for design and that in such cases dam owners should not be required to incur the costs involved in unnecessarily sophisticated analyses.

The DSC will consider deviations from these requirements upon submission of a cogent and fully documented case. In particular, if risk assessment methodologies are used they should be in accordance with the relevant ANCOLD Guidelines.

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## APPENDIX B

### OPERATION AND MAINTENANCE FOR DAMS (DSC2F) (DSC, 2010b)

DSC2F

June 2010

## OPERATION AND MAINTENANCE FOR DAMS

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## 1. INTRODUCTION

The *normal requirements* of the DSC are set out in its guidance sheets with its principal guidance sheet, *DSC Background, Functions and Operations - DSC1A*, outlining the DSC's general operations and authority. The DSC considers that effective and ongoing operation and maintenance programs are essential to ensure the continued viability and safety of a dam and its appurtenant structures. Accordingly, this guidance sheet is provided for the guidance and direction of dam owners, and their consultants, in the operation and maintenance of their dams.

## 2. OPERATION AND MAINTENANCE

The Operation and Maintenance (O&M) Manual for a dam is designed to collect together the background data and complete, accurate and current operating instructions for the dam and its appurtenant structures. Procedures for preparing appropriate manuals are outlined in the *ANCOLD (Australian National Committee on Large Dams) Guidelines on Dam Safety Management - 2003*. Additional information will be found in the references and publications cited in the ANCOLD Guidelines.

O&M Manuals should be prepared by appropriately qualified and experienced personnel including specialists such as Civil, Mechanical, and Electrical engineers as required by the type and complexity of the dam and its equipment.

The DSC requires the owners of all EXTREME, HIGH and SIGNIFICANT Consequence Category dams, and all prescribed tailings dams, to have an effective O&M Manual prepared for their dams. These manuals are to be regularly upgraded (at least every 5 years). The DSC recommends that owners of other dams in NSW should have appropriate O&M Manuals prepared for their dams to maximise their ongoing viability and safety. Owners of prescribed dams shall incorporate in their O&M Manuals a formal incident reporting system. The process shall be both internal and to the DSC (See DSC2A and DSC2B).

Owners of prescribed dams are to ensure that there are appropriately trained and experienced personnel available to operate and maintain their dams in accordance with their O&M Manuals.

Owners of EXTREME, HIGH and SIGNIFICANT Consequence Category Dams, and all prescribed tailings dams, are required to have training plans in place for their staff and ensure that their staff have attended a recognised course in dam safety. Further, those owners shall have a policy of ongoing staff education to include, as a minimum, refresher courses at regular intervals (i.e. 5 yearly for Extreme and High A Consequence Category dams ranging out to 10 yearly for Significant Consequence Category dams) to ensure they are kept up to date with latest developments in surveillance practices and maintain their knowledge of surveillance procedures.

### **3. RECORDS TO BE KEPT BY DAM OWNERS**

**T**he DSC requires, in conjunction with the requirements of the State Records Act 1998, that dam owners have an effective long-term archiving system to maintain appropriate records (ie design reports, construction reports and records, work-as-executed drawings, inspection and surveillance reports, safety reviews, O&M Manual, DSEP etc) of the operation and maintenance planning for their dams. This background information is particularly important when reviewing or upgrading dams.

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## APPENDIX C

### EMERGENCY MANAGEMENT FOR DAMS (DSC2G) (DSC, 2015)



**DSC2G**

June 2010  
(updated August 2015)

# **EMERGENCY MANAGEMENT FOR DAMS**

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## 1. INTRODUCTION

The *normal requirements* of the NSW Dams Safety Committee (DSC) are set out in its guidance sheets with its principal guidance sheet, *DSC Background, Functions and Operations (DSC1A)*, outlining the DSC's general operations and authority.

The NSW Dams Safety Committee (DSC) considers that a vital part of a dam owner's dam safety management program is the provision of effective emergency management plans for a dam to maximise the continued viability and safety of the dam and minimise consequences in the unlikely event of its failure. Dam owners, and their professional advisers, have full responsibility to determine, and put in place appropriate emergency management actions to ensure the ongoing safety of their dams. The purpose of this guidance sheet is to provide the owners of prescribed, or proposed, dams with general advice on good dam emergency management practice, along with specific advice on their responsibilities and the requirements of the DSC in this area.

The DSC Emergency Management Goal and Key Requirements (Section 2) at the start of the sheet are a summary - the whole sheet is to be read for a proper understanding of DSC considerations on emergency management for dams.

## 2. DSC EMERGENCY MANAGEMENT GOAL & KEY REQUIREMENTS

### 2.1 DSC Emergency Management Goal

The goal of the DSC for prescribed dams is to ensure that dam owners apply appropriate standards and planning for emergency management in order to achieve and/or maintain tolerable risks to community interests.

It is for the dam owner to determine how the goal will be achieved and to demonstrate to the DSC that the goal is achieved or will be achieved following appropriate action(s). The following sections of this sheet aim to provide guidance and direction to assist the owner in the achievement of the DSC's goal.

### 2.2 DSC Key Requirements

This highlighted section summarises the DSC requirements outlined in this sheet (under relevant section headings).

### **3. BACKGROUND**

Dam owners should comply with the *ANCOLD Guidelines on Dam Safety Management*.

### **4. DAM SAFETY EMERGENCY PLANS**

The DSC requires a quality controlled DSEP to be prepared for prescribed dams where persons may be at risk downstream if the dam failed. Dam owners must consult the SES State Headquarters during the preparation of draft DSEPs (see Figure 1 for process and Appendix B for helpful checklist to be completed and submitted with each DSEP).

A "Summary Information Sheet for Emergency Agencies" is to be included in conjunction with the emergency Notification Flowchart in each DSEP (refer Section 6 and Appendix A).

Table 1 briefly outlines some defining conditions and likely SES responses for each dam failure alert level (ie white, amber or red).

DSEP distribution arrangements are set out in Section 4.3.

DSEPs are to include provisions for prompt notification to the DSC's Executive Engineer of any actual or potential emergency which may have implications for dam safety.

Owners of Extreme and High Consequence Category dams (excluding retarding basins) are to have in place automatic telemetered monitoring of the storage level in their dams (and preferably rainfall and seepage as well). Owners of Extreme and High Consequence Category retarding basins are to have in place automatic telemetered monitoring of rainfall at a location near the basin in lieu of, or in addition to, monitoring of basin storage level.

The DSC also requires the owners of remotely located Extreme and High Consequence Category embankment dams to consider the practicalities of installing telemetered tailwater/seepage monitoring devices to maximise warning times of potential piping incidents at these dams. The installation of these devices is mandatory for all new Extreme and High Consequence Category embankment dams.

The DSC requires DSEPs to be updated annually, and to be reviewed and tested at least every 5 years.

### **6. EMERGENCY MANAGEMENT CONTACT PROCEDURES**

The SES, DSC and the NSW State Emergency Operations Controller (SEOCON) have agreed to a protocol to assist owners and operators of prescribed dams when determining the emergency management contact procedures for inclusion in a DSEP. The SES 24-hour contact number is to be stressed (contact the SES State Headquarters to obtain the appropriate emergency contact number). The arrangements are in the generic flow chart, and notes on its use, in Appendix A to this sheet.

### **7. DAMBREAK STUDIES**

The DSC requires that dambreak studies, using appropriate methods and parameters, are arranged by prescribed dam owners for any existing or proposed prescribed dam where loss of life, or other significant threat to the community's interests could result from dam failure. This dambreak information is to be provided to the SES State Headquarters to assist with emergency planning.

### **8.0 RECORDS TO BE KEPT BY DAM OWNERS**

The DSC requires that dam owners maintain appropriate records of their emergency planning for their dams.

### 3. BACKGROUND

The DSC has statutory functions to ensure that all prescribed dams do not impose an intolerable level of danger to the community's interests. In regard to proper dam emergency management practices, the DSC produced its Information Sheet DSC12 in 2001 giving guidance and direction to prescribed dam owners in this area.

However, there have been significant changes to emergency management approaches and practices in recent years and the DSC has produced this guidance sheet to supersede DSC12. It has been prepared to outline and clarify the procedures and processes the DSC considers necessary to ensure proper emergency management planning is in place for NSW dams. In this regard, the DSC has had significant input to, and has adopted in principle, the 2003 Australian National Committee on Large Dam's (ANCOLD) '*Guidelines on Dam Safety Management*' as its requirements for dam owners. Consequently, it is the DSC's policy that dam owners should normally comply with these ANCOLD guidelines unless otherwise indicated in this or other guidance sheets.

### 4. DAM SAFETY EMERGENCY PLANS

#### 4.1 Introduction

Dam Safety Emergency Plans (DSEPs) outline the required procedures to:

- Protect a dam in the event of an emergency which may threaten its security;
- Notify the State Emergency Service (SES) during potential dam failure emergencies; and
- Provide relevant information to assist the SES in its emergency planning for areas affected by dam flooding.

A DSEP outlines the required actions of owners and their personnel at dams in response to a range of possible emergency situations. The DSC considers that trained and experienced dam operators are a valuable "dam safety" resource, particularly in emergencies, and their value is enhanced when they are readily available to attend the dam site for emergency actions. The DSEP, and on-call trained staff, have particular importance for those dams with controlled spillways (i.e. gates, fuseplugs). Accordingly, owners of significant, and higher consequence category, dams should carefully consider the appropriateness of their staffing arrangements, particularly for emergency situations.

The DSC requires, as distinct from ANCOLD's suggestion, that the DSEP forms an important, yet separate, adjunct to the O&M Manual for a dam and should be rigorously implemented by dam owners in conjunction with the O&M Manual.

## 4.2 Preparation

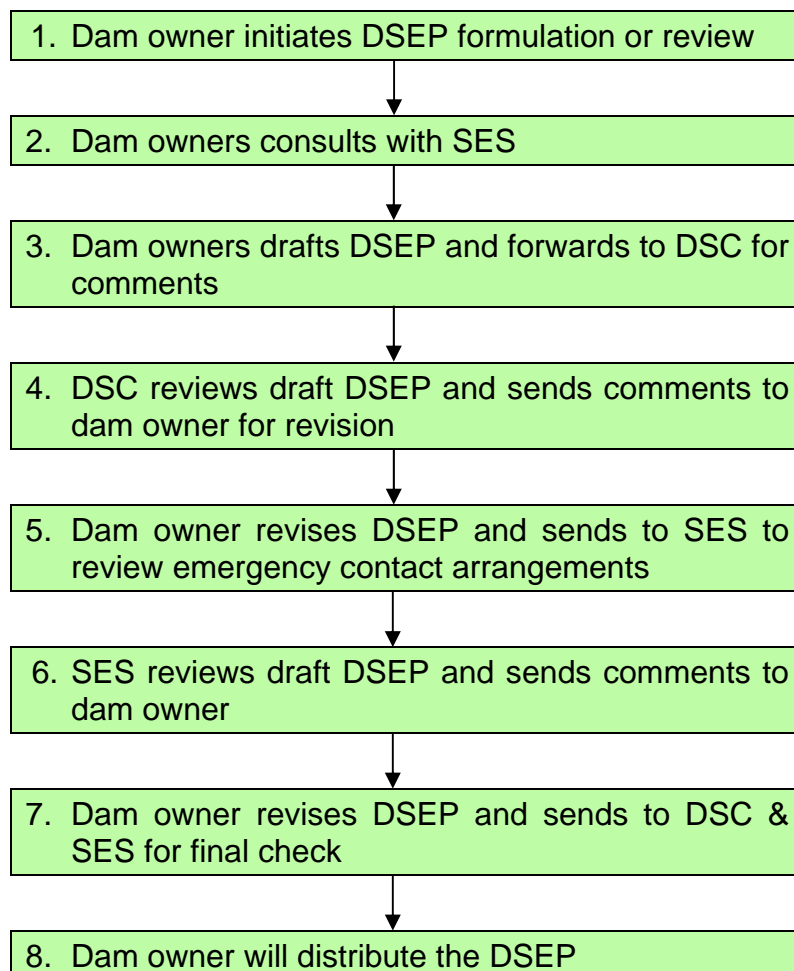
### 4.2.1 General Requirements

The DSC requires a quality controlled DSEP, with associated dambreak warning procedures, to be prepared for prescribed dams where persons may be at risk downstream if the dam failed. Appendix B provides a helpful checklist of items to be undertaken to complete an effective DSEP. This checklist is to be completed and attached to the final DSEP submitted to the DSC.

General procedures for preparing appropriate DSEPs are outlined in Section 8 of the ANCOLD *'Guidelines on Dam Safety Management'*, while DSC requirements for associated dambreak analysis studies are outlined in Section 7 of this sheet.

The DSC considers the key steps outlined in Figure 1 are required to ensure a proper quality control process of review, external consultation and approval for the provision of effective DSEPs for dams.

**Figure 1 - Key Steps in DSEP Formulation and Review**



The extent and content of DSEPs will vary between dams depending on local conditions. Dam owners must consult the SES, through its State Headquarters at Wollongong, at an early stage during the preparation of draft DSEPs to:

- Jointly determine dam failure alert levels (i.e. white, amber and red)
- Jointly determine appropriate warning protocols for downstream populations at risk (particularly warning arrangements for non-itinerant persons immediately downstream of dams); and
- Confirm notification arrangements.

If the SES is unable to warn downstream populations due to time/resource constraints, then the dam owner will be required to establish alternate appropriate measures such as improved warning systems, including gauges, sensors and associated telemetry and notification systems. In particular, several owners of dams with significant deficiencies have installed Dam Failure Warning Systems in order to provide advance notice of conditions under which failure could occur.

For prescribed dams, where non-itinerant persons could be at risk (i.e. all Extreme and High Consequence Category dams), the DSEP is required to include dambreak inundation information (e.g. mapping, depths, timing) and emergency authority notification arrangements. In the context of this sheet non-itinerant persons include:

- residents in dwellings, hotels, motels, boarding houses, hospitals, caravan parks, established camping grounds and the like; and
- persons occupying places of work, schools, day care centres and the like, including workplaces of limited duration such as mines or construction sites.

DSEP requirements for dry flood retarding basins will mainly reflect responses to flood threats only.

For prescribed dams, where only itinerant persons (e.g. campers, bushwalkers, fishermen etc) may be at risk (i.e. Significant Consequence Category dams), the DSC requires that owners also prepare a DSEP to minimise risk to itinerant persons and to be in line with prudent dam operation practice to maximise the safety of their dam, having regard to the consequences of dam failure and value of the dam as an asset. However, these DSEPs may not need to include such aspects as dambreak analysis, inundation mapping or emergency authority warning but will need procedures to maximise the safety of itinerant persons. Where it is practicable to warn and evacuate itinerant persons, appropriate provisions are to be included in the DSEP.

#### 4.2.2 Summary Information Sheet

A “Summary Information Sheet for Emergency Agencies” is to be included in conjunction with the Notification Flowchart in each DSEP. This sheet is to contain short summaries of the following topics:

- Background Information (e.g. dam owner, location, dam type & size, availability of dam data, Consequence Categories, safety status and nature of deficiency);
- Alert Levels Background (e.g. defining conditions and reasoning for alert levels of white, amber, and red - see Table 1);
- Notification Protocols (e.g. owner's actions, notifier's advice, content and quality of warning messages, availability of relevant Bureau of Meteorology warnings and stream gauges, emergency response requirements);
- Consequences of dam failure (including number of dwellings and depth and timing of flooding in the dambreak inundation area); and
- Flood Plan name.

#### 4.2.3 Emergency Service Notifications

An emergency service notification flowchart is to be included in each DSEP (refer Section 6 and Appendix A).

The primary contact in the event of alerting emergency services for dam failure is the SES State Operations Communications Centre (OCC). The alerts must be provided by telephone, preferably by an actual person relaying a message (rather than an automated message). The SES cannot receive SMS, and considers it an unreliable technology for life threatening situations.

It is essential that each alert is communicated to the SES through its OCC. However, subsequent liaison between the dam owner and an appropriate SES Operations Controller, at an SES Region or Local Headquarters (to be advised by the SES during DSEP preparation), will be established to ensure effective communication during an emergency situation.

Dam failure alerts (i.e. white, amber and red) are used to trigger emergency response actions. The conditions that define each of the alert levels are listed in each DSEP. Consequences and responses escalate as the alert level migrates from white to red. Table 1 briefly outlines some of the possible defining conditions and likely SES responses associated with each alert.

**Table 1 - Typical Dam Failure Alert Protocols**

<b>Alert Level</b>	<b>Typical Defining Conditions</b>	<b>SES Response</b>	<b>SES Warning Product</b>
White	Structural defect detected (e.g. crack, piping) or heavy rainfall event.	Notification of support agencies. Monitoring at-risk areas downstream. Check operational readiness.	This is a preliminary alert to assist the SES in its preparations and is not a public alert.
Amber	Failure possible if storage continues rising or structural defect not fixed.	Warn downstream population at risk to prepare to evacuate.	SES Evacuation Warning.
Red	Failure imminent or occurred.	Evacuation of downstream population.	SES Evacuation Order.

These alert levels relate specifically to the warning and evacuation tasks to be performed by emergency managers with respect to communities at risk downstream. As far as possible, these alert levels should be set to maximise the amount of warning time available. When preparing DSEPs dam owners should liaise closely with the SES to ascertain the warning requirements for its flood operating procedures which is dependent, amongst other things, on the population at risk and emergency services resources.

Some DSEPs will require alert levels that proceed directly from White to Red if adequate time does not exist between the three alert levels to both warn and evacuate the downstream population at risk. The decision to omit the Amber Alert Level in these cases, and the general setting of Alert Levels, must be undertaken in consultation with the SES.

It is also essential that dam owners notify all appropriate personnel, including the SES, when the dam failure emergency is over, or if the dam failure alert was a false alarm. The SES will issue the "All Clear" to the community at risk where appropriate.

### 4.3 Distribution

DSEP distribution arrangements are to be as follows:

- One controlled copy to the DSC;
- Controlled copies to SES headquarters at Wollongong for internal distribution (Number of copies to be advised by the SES State Headquarters which retains one and distributes others to relevant SES Regions and local Units);
- Controlled copies to State Emergency Operations Centre for internal distribution (Number to be advised by SEOC related to number of Regional Emergency Management Offices involved); and
- DSEPs and their annual updates are to be distributed in both paper and electronic format (i.e. CD in flap of paper copy).

#### 4.4 Monitoring and Alert Systems

It is to be noted that, pursuant to Sections 18, 21 and 22 of the Dams Safety Act, 1978, the DSC has functions in relation to potential or actual emergencies at prescribed dams. Consequently DSEPs are to include provisions for prompt notification to the DSC's Executive Engineer of any actual or potential emergency, which may have implications for the safety of the particular dam or its storage.

The DSC's policy is that the owners of Extreme and High Consequence Category dams (excluding retarding basins) have in place automatic telemetered monitoring of the storage level in their dams (and preferably rainfall and seepage as well) to:

- Keep dam owner personnel apprised of this key surveillance information;
- Assist in the early detection of incidents at dams;
- Provide maximum warning times for any emergency response required in relation to these incidents.

This policy has been varied for owners of Extreme and High Consequence Category retarding basins, who are to have in place automatic telemetered monitoring of rainfall *at a location near the basin in lieu of, or in addition to, monitoring of basin storage level.*

*The DSC also requires the owners of remotely located Extreme and High Consequence Category embankment dams to consider the practicalities of installing telemetered tailwater/seepage monitoring devices to maximise warning times of potential piping incidents at these dams. The installation of these devices is mandatory for all new Extreme and High Consequence Category embankment dams.*

#### 4.5 Testing

For DSEPs to remain effective it is imperative that they be regularly updated and tested. In this regard, the DSC requires DSEPs to be updated annually, and to be reviewed and tested at least every 5 years with actions in this regard to be reported in Surveillance Reports for each dam (see DSC2C). When dam owners plan any DSEP testing they must contact the SES early to arrange appropriate SES involvement.

### 5. FLOOD EMERGENCY PLANS

Under the emergency management legislation in NSW (i.e. the State Emergency and Rescue Management Act, 1989 and the State Emergency Service Act, 1989) the SES is the combat agency for floods, including floods affected by dams. Within this role the SES's main responsibility, which relates to its interactions with dam owners and managers, is to plan for, and respond to, flood emergencies. SES planning is conducted at local, regional and State levels. Each flood plan prepared by the SES is a sub-plan to the Disaster Plan (DISPLAN) at the relevant level and is endorsed by the relevant Emergency Management Committee.

For Extreme and High Consequence Category prescribed dams having a significant deficiency in safety, the SES has agreed with the DSC that its local flood plans will contain specific arrangements for dealing with dam failure, usually in the form of a Dam Failure Annex in the Local Flood Plan. In this regard, the DSC regularly updates the SES on the deficiency status of prescribed dams in NSW through interaction on the DSC's Emergency Management Sub-Committee.

The implementation of Dam Failure Annexes in Local Flood Plans has proceeded for dams with significant deficiencies on a priority basis determined by the SES and the DSC. The priority is determined by the degree of deficiency and the consequences of failure. When a dam's deficiency is rectified, the SES will then review the appropriateness of the existing dam failure emergency response arrangements.

Dam owners have a responsibility to assist the SES in their task of flood emergency planning in order to protect the community as well as to minimise the owner's liability for damages from a dam failure.

Owners are to provide the SES with copies (both hard copy and electronic) of their DSEPs (including dambreak studies and associated relevant information) as they are implemented to provide necessary information for SES purposes, and also to provide any requested assistance to the SES to enable formulation of effective emergency response arrangements for the areas downstream of dams.

## **6. EMERGENCY MANAGEMENT CONTACT PROCEDURES**

The SES, DSC and the NSW State Emergency Operations Controller (SEOCN) have agreed to a protocol to assist owners and operators of prescribed dams when determining the emergency management contact procedures for inclusion in a DSEP. The contact procedures are intended to be followed when the owner/operator of a dam needs to activate the State's emergency management arrangements due to a potential or imminent failure of the dam or one of its control structures that could result in flooding of downstream communities. In this regard the importance and priority for contacting the SES 24 hour contact number is to be stressed (contact the SES State Headquarters to obtain the appropriate emergency contact number). Note that this is a dedicated number for dam failure emergencies only.

The arrangements have been developed in consultation with the NSW SES, the Emergency Management Sub-Committee of the DSC, and the State Emergency Operations Controller (SEOCN) and are represented in the generic flow chart, and notes on its use, in Appendix A to this sheet.

It has been further agreed that the SES will review emergency management contact arrangements in each DSEP submitted to the DSC and will sign-off on the emergency management contact arrangements on behalf of the Emergency Management agencies involved.

## 7. DAMBREAK STUDIES

### 7.1 General

The DSC requires that dambreak studies, using appropriate methods and parameters, are arranged by prescribed dam owners.

The dambreak studies are required for any existing or proposed prescribed dam where loss of life, or other significant threat to the community's interests, including to the environment, could result from dam failure. Dambreak studies are to be undertaken for all Extreme, High and Significant Consequence Category dams (see DSC3A for definition of consequence categories). For new dams, the studies are to be undertaken in the design phase, to be completed six months prior to the commencement of construction or modification of a dam.

The cases to be examined in the study are, as a minimum, those set out in the DSC's guidance sheet on 'Consequence Categories for Dams' - DSC3A, for assessment of consequences (i.e. sunny day dambreak and flood dambreaks from acceptable flood capacity up to PMF).

Reports on these studies are to be submitted to the DSC setting out:

- Cases examined;
- The input data; and
- The methodology used and the results including;
  - the extent of flooding;
  - flood travel times; and
  - flood water velocities, downstream of the dam, as related to residences, properties, infrastructure and environmentally sensitive areas.

The dambreak study should examine effects to a point downstream where there is no longer a significant incremental threat to the interests of the community, including to the environment.

The study report needs to outline the basis of dam breach modelling. For example, with long embankment dams having large storage volumes, the potential for outflow discharges, much greater than those given by empirical formulae based on failure data, needs to be considered. For such dams, the possibility of multiple breach locations upon overtopping, especially if the crest surface is of uneven level, should also be considered.

For flood related failure cases, consideration is to be given to a feasible range of antecedent flooding conditions downstream immediately prior to dam failure. This can be a particularly significant aspect where a dam is located on a stream, which joins a main stream with a relatively much larger catchment, not far downstream. If the large stream is at normal stage, the dambreak flood may remain within the banks and not affect towns on the alluvial terraces. But, if the main stream is close to bank full stage, the dambreak flood may affect towns on the terraces. Careful attention needs to be given to the likelihood of such scenarios.

See also Sub-section 8.5 of Nathan, R.J. and Weinmann, P.E., Book VI, The Estimation of Large to Extreme Floods, NCWE (Eds), Australian Rainfall and Runoff - A Guide to Flood Estimation, Volume 1. The report of a dambreak study is to state what consideration has been given to antecedent flooding.

The scale and quality of inundation mapping needs to be appropriate to the potential severity of the flooding impacts. Where dwellings are at risk, base mapping would typically be at a scale of 1:10,000 with a contour interval of 2m or better accuracy. Ortho photomaps can be particularly valuable to the emergency authorities but flood extents displayed on any maps should be transparent so that essential details are not obscured.

The Dambreak Study provides essential information for downstream emergency planning and also provides a basis for a conclusive assessment of the dam's Flood and Sunny Day Consequence Categories.

## **7.2 Information Required by the SES to Assist in Emergency Planning**

A complete copy of the Dambreak Study report is to be provided to the SES State Headquarters including the following information for emergency planning:

- The number of dwellings at risk for each scenario modelled (note that this is more useful to the SES than potential loss of life estimates);
- The access routes affected for each scenario modelled; and
- Travel time information and rate of rise (preferably to the start of the flood reaching the population rather than just the time to peak to enable consideration of timing for alert levels).

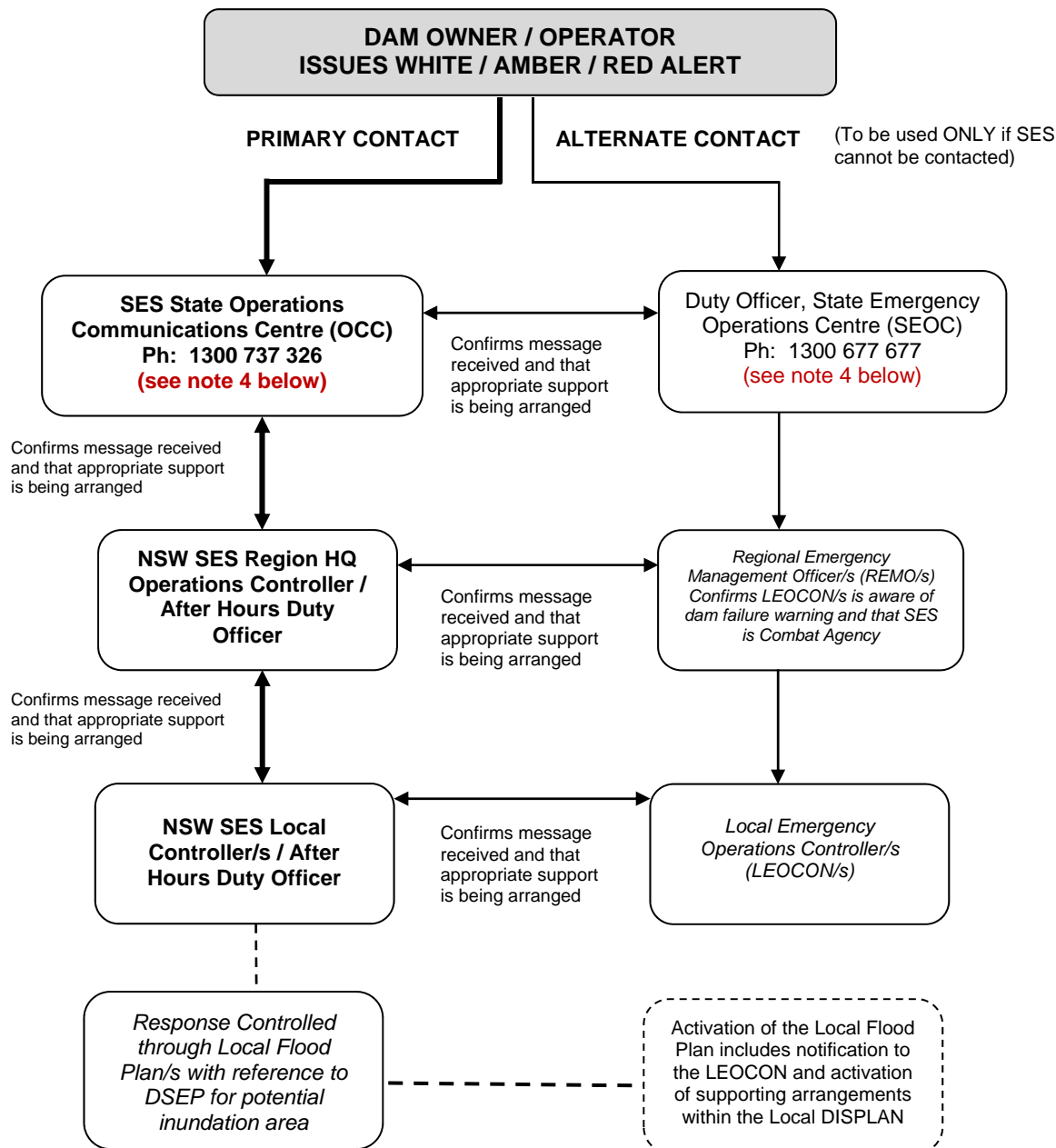
Where possible, the relevant GIS layers showing flood extents and other key information should also be provided. In addition it would be useful for emergency managers if flood cross-sections are provided at key locations such as flood gauges, bridges and major infrastructure (i.e. roads, railways, power facilities).

## **8. RECORDS TO BE KEPT BY DAM OWNERS**

The DSC requires, in conjunction with the requirements of the State Records Act 1998, that dam owners maintain appropriate records of their emergency planning for their dams including the results of emergency exercises and any dam incidents, responses and subsequent actions by dam owners.

# APPENDIX A

## Notification Arrangements for Potential Dam Failure



### Notes:

1. Dam owners should only contact the SEOC if the SES State Operations Communications Centre (OCC) cannot be contacted.
2. The first priority for notification is to contact the next SES HQ or the next level of EOC down the flowchart. The second notification should always be across the flow chart to confirm the message is received. If the first priority notification fails or is not picked up for any reason, the second priority notification should be made before any further attempts to contact the first priority (this is why an alternate or backup system of contracts is in place).
3. The triple zero (000) number for emergency services should not be used unless contact cannot be made with SES or the SEOC, as it is likely the triple zero (000) operators will have difficulty dealing with the very unusual case of potential or actual dam failure.
4. Dam owners must contact the SES State Headquarters during the preparation of the DSEP to check any changes in the appropriate emergency contact numbers.

# APPENDIX B

## CHECKLIST FOR FORMULATING DAM SAFETY EMERGENCY PLANS (DSEPs)

DSC Form D17

The following checklist covers the minimum items to be included in DSEPs submitted to the NSW Dams Safety Committee (DSC) by dam owners and their consultants. Please tick against each item to indicate completion of the item in, or in conjunction with, the DSEP, and enclose the signed form with the copy of the DSEP submitted to the DSC. Please note that DSEPs which do not address all relevant items may not be accepted.

- ☐ Owner to provide cover letter summarising actions to date.
- ☐ Coverage of each of the Sections outlined in Chapter 8.5 of ANCOLD Guidelines on Dam Safety Management.
- ☐ Summary Information Sheet including:
  - Background dam information;
  - Alert Levels background;
  - Notification protocols; and
  - Associated Flood Plan name.
- ☐ Emergency Services Notification Flowchart.
- ☐ Detailed information on monitoring and alert systems.
- ☐ Dambreak information including:
  - Cases studied;
  - Inundation mapping;
  - Flood depths;
  - Timing of flood events; and
  - PAR and LOL.
- ☐ SES consultation
- ☐ Copy of dambreak information provided to SES
- ☐ An IBM compatible CD, or equivalent, containing a Microsoft Word format file of the text and a PDF of the entire report including drawings and photos.

**Checklist completed by:** Name and position .....

Signature .....

This Guidance Sheet is one of a series available from our Website at:

<http://www.damsafety.nsw.gov.au>

In order to read this file you need a Portable Document Format (PDF) reader. A free PDF reader is available from <http://www.adobe.com/>

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