Table 3.4 Holcim sampling results

Parameter	Turbidity	Reactive Phosphorus	Nitrate	pH	Salinity	Chemical Oxygen Demand
Units	NTU	mg/L	mg/L	-	µS/cm	mg/L
DGV	20	0.035 (TP DGV adopted)	0.6 (TN DGV adopted)	7.0-8.0	504 (median) 744 (80th percentile)	-
Eulomogo Creek Upstream						
Number of samples	20	20	20	20	20	20
Number of detects	20	20	20	20	20	20
Number of exceedances	1	20	6	2	12	-
Minimum concentrations	1.1	**0.072**	0.10	**6.8**	280	6
20th percentile concentration	2.0	**0.173**	0.18	7.3	358	19.4
Median concentration	4.1	**0.292**	0.45	7.6	**840**	42.6
80th percentile concentration	13.3	**0.430**	**0.77**	7.9	**1,352**	61.1
Maximum concentration	**87.1**	**0.836**	**3.93**	**8.1**	**2,150**	133.1
Eulomogo Creek Downstream						
Number of samples	41	41	41	41	41	0
Number of detects	41	41	40	41	41	-
Number of exceedances	6	41	24	6	38	-
Minimum concentrations	0.5	**0.077**	0.10	7.0	481	-
20th Percentile	2.1	**0.196**	0.20	7.5	**758**	-
Median concentration	4.9	**0.323**	**2.20**	7.7	**964**	-
80th percentile concentration	**21**	**0.369**	**2.20**	7.8	**1,256**	-

Table 3.4 Holcim sampling results

Parameter	Turbidity	Reactive Phosphorus	Nitrate	pH	Salinity	Chemical Oxygen Demand
Maximum concentration	**102**	**1.152**	**16.5**	**8.4**	**1,891**	-
Units	NTU	mg/L	mg/L	-	µS/cm	mg/L
DGV	20	0.035 (TP DGV adopted)	0.6 (TN DGV adopted)	7.0-8.0	504 (median) 744 (80^{th} percentile)	-
Macquarie River (downstream of Eulomogo Creek)						
Number of samples	26	26	24	27	26	26
Number of detects	26	26	24	27	26	26
Number of exceedances	3	26	**3**	1	3	-
Minimum concentrations	2.2	**0.077**	0.03	7.4	99	14.1
20^{th} percentile concentration	6.2	**0.095**	0.10	7.6	279	16.3
Median concentration	9.0	**0.15**	0.2	7.7	387	21.8
80^{th} percentile concentration	17.5	**0.247**	**0.4**	7.9	481	31.6
Maximum concentration	**59.6**	**0.748**	**1.1**	**8.1**	**849**	51.4
In Pit Dam						
Number of samples	45	45	45	45	45	45
Number of detects	45	45	45	45	45	44
Number of exceedances	1	45	40	**23**	42	-
Minimum concentrations	0.1	**0.088**	0.38	**6.3**	310	0.1
20^{th} Percentile	0.4	**0.194**	**1.5**	**6.6**	**814**	3.1
Median concentration	2.1	**0.292**	**4.2**	7.7	**919**	9.6

Table 3.4 Holcim sampling results

Parameter	Turbidity	Reactive Phosphorus	Nitrate	pH	Salinity	Chemical Oxygen Demand
80th percentile concentration	3.6	**0.438**	**6.1**	**8.0**	**1,007**	16.3
Maximum concentration	**23**	**0.729**	**10.6**	**9.0**	**1,260**	75.6
Units	NTU	mg/L	mg/L	-	µS/cm	mg/L
DGV	20	0.035 (TP DGV adopted)	0.6 (TN DGV adopted)	7.0-8.0	504 (median) 744 (80th percentile)	-
Pump 2 Storage Pond						
Number of samples	45	45	45	45	45	45
Number of detects	45	45	45	45	45	44
Number of exceedances	**5**	45	**16**	39	42	-
Minimum concentrations	1.9	**0.096**	**0.07**	7.0	77	1.0
20th percentile concentration	3.6	**0.185**	**0.10**	**8.1**	**705**	9.5
Median concentration	6.2	**0.259**	**0.32**	**8.4**	**817**	14.1
80th percentile concentration	14.7	**0.371**	**1.35**	**8.7**	**895**	20.3
Maximum concentration	**73**	**0.541**	**2.02**	**9.3**	**1,011**	62.4
Settling Pond						
Number of samples	45	45	45	45	45	45
Number of detects	45	45	45	45	45	45
Number of exceedances	20	45	34	19	36	-
Minimum concentrations	0.4	**0.113**	0.05	6.7	343	0.1
20th Percentile	1.7	**0.224**	0.55	7.2	**508**	6.9

Table 3.4 Holcim sampling results

Parameter	Turbidity	Reactive Phosphorus	Nitrate	pH	Salinity	Chemical Oxygen Demand
Median concentration	13.7	**0.331**	**3.60**	7.9	**841**	14.1
80th percentile concentration	**220**	**0.514**	**5.05**	**8.2**	**999**	36.9
Maximum concentration	**646**	**0.766**	**6.92**	**8.6**	**1,080**	117.6
Units	NTU	mg/L	mg/L	-	µS/cm	mg/L
DGV	20	0.035 (TP DGV adopted)	0.6 (TN DGV adopted)	7.0-8.0	504 (median) 744 (80th percentile)	-
Immediately downstream of Settling Pond						
Number of samples	24	24	24	24	24	24
Number of detects	24	24	24	24	24	23
Number of exceedances	4	24	24	2	21	-
Minimum concentrations	1.1	0.140	**0.64**	7.2	353	3.1
20th percentile concentration	1.4	**0.279**	**3.59**	7.3	**809**	3.2
Median concentration	2.2	**0.364**	**3.89**	7.5	**989**	7.5
80th percentile concentration	19.5	**0.473**	**5.14**	7.8	**1,025**	20.2
Maximum concentration	**246**	**0.566**	**6.17**	**8.3**	**1,090**	40.4
The Well						
Number of samples	21	21	21	21	21	21
Number of detects	21	21	21	21	21	21
Number of exceedances	1	21	20	6	14	-
Minimum concentrations	0.4	**0.096**	0.3	**6.7**	358	1

Table 3.4 Holcim sampling results

Parameter	Turbidity	Reactive Phosphorus	Nitrate	pH	Salinity	Chemical Oxygen Demand
20th Percentile	1.0	**0.261**	**2.14**	**6.8**	442	4.0
Median concentration	1.8	**0.415**	**12.6**	7.2	**647**	9.7
80th percentile concentration	9.0	**0.668**	**20.3**	7.6	**861**	27.4
Maximum concentration	**21.8**	**1.056**	**27.8**	**7.9**	**1,086**	213.1

Table 3.5 EIS water quality results

	Units	LOR	DGV	Eulomogo Creek (upstream of site)	Eulomogo Creek (downstream of site)	In Pit Dam (East Pit)	Pump 2 Storage Pond (East Pit)	Settling Pond	Well	West Pit Pond
General water quality										
pH	-	0.01	7 - 8	**8.4**	**8.6**	**8.5**	**8.7**	**8.6**	**8.5**	**8.2**
Electrical Conductivity	µS/cm	1	504	**811**	**738**	**726**	**1,020**	**676**	**1,200**	464
Turbidity	NTU	0.1	20	3.1	2.5	13.8	4.8	15.6	0.3	10.5
Alkalinity										
Bicarbonate as $CaCO_3$	mg/L	1	-	164	246	236	328	237	367	108
Carbonate as $CaCO_3$	mg/L	1	-	6	24	20	40	<1	29	<1
Hydroxide as $CaCO_3$	mg/L	1	-	<1	<1	<1	<1	<1	<1	<1
Total alkalinity as $CaCO_3$	mg/L	1	-	170	270	256	368	237	396	108
Nutrients										
Ammonia	mg/L	0.01	-	<0.01	<0.01	**0.02**	<0.01	<0.01	<0.01	<0.01

Table 3.5 EIS water quality results

	Units	LOR	DGV	Eulomogo Creek (upstream of site)	Eulomogo Creek (downstream of site)	In Pit Dam (East Pit)	Pump 2 Storage Pond (East Pit)	Settling Pond	Well	West Pit Pond
Oxidised Nitrogen	mg/L	0.01	-	0.6	0.2	2.33	3.8	0.74	1.26	1.52
Total Kjeldahl Nitrogen	mg/L	0.1	-	0.3	0.3	0.5	0.5	0.7	0.2	0.3
Nitrite	mg/L	0.01	-	0.02	<0.01	0.01	0.03	<0.01	<0.01	0.01
Nitrate	mg/L	0.01	-	0.58	0.2	2.32	3.77	0.74	1.26	1.51
Total nitrogen	mg/L	0. 1	0.6	**0.9**	0.5	**2.8**	**4.3**	**1.4**	**1.5**	**1.8**
Total phosphorus	mg/L	0.01	0.035	<0.01	0.01	**0.14**	0.03	**0.07**	**0.04**	**0.07**
Inorganics										
Cyanide	mg/L	0.004	0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Inorganics										
Calcium	mg/L	1	-	33	34	28	15	26	78	22
Chloride	mg/L	1	-	164	62	58	68	52	164	49
Fluoride	mg/L	0.1	-	0.2	0.4	0.4	0.4	0.5	0.5	0.5
Sodium	mg/L	1	-	57	73	77	177	78	75	38
Magnesium	mg/L	1	-	39	29	28	14	20	66	16
Potassium	mg/L	1	-	6	9	7	14	8	4	5
Sulphate as SO_4	mg/L	1	-	8	23	22	52	23	38	28
Ionic Balance										
Anions	meq/L	0.01	-	8.19	7.62	7.21	10.4	6.68	13.3	4.12
Cations	meq/L	0.01	-	7.49	7.49	7.23	9.96	6.54	12.7	4.2

Table 3.5 EIS water quality results

	Units	LOR	DGV	Eulomogo Creek (upstream of site)	Eulomogo Creek (downstream of site)	In Pit Dam (East Pit)	Pump 2 Storage Pond (East Pit)	Settling Pond	Well	West Pit Pond
Ionic Balance	%	0.01	-	4.46	0.88	0.14	1.95	1.06	2.46	0.87
Dissolved metals										
Arsenic	mg/L	0.001	0.013	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001
Barium	mg/L	0.001	-	0.032	0.026	0.003	<0.001	<0.001	0.01	0.001
Beryllium	mg/L	0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	mg/L	0.0001	0.00006	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium (III+VI)	mg/L	0.001	0.00001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	mg/L	0.001	0.0014	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Dissolved metals										
Copper	mg/L	0.001	0.001	0.001	0.001	0.001	<0.001	**0.002**	<0.001	<0.001
Lead	mg/L	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.001	1.2	0.02	0.074	<0.001	<0.001	<0.001	0.001	<0.001
Mercury	mg/L	0.0001	0.00006	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel	mg/L	0.001	0.008	0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	mg/L	0.01	0.005	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	mg/L	0.01	0.006	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	mg/L	0.005	0.0024	<0.005	<0.005	**0.010**	**0.007**	<0.005	<0.005	<0.005

4 Existing water management

This chapter describes the functionality and key characteristics of the existing water management system. Section 4.1 describes the existing system and water balance results are provided in the Water Addendum (Water RtS Appendix A). The information presented in this chapter is referenced in Chapter 5 which describes the proposed water management system and includes commitments for some modifications to the existing system to improve environmental performance.

4.1 System description

4.1.1 Overview

The existing water management system receives inflows from:

- runoff from the quarry area;
- runoff from the eastern watercourse catchment; and
- groundwater inflows into quarry pits.

The system provides water for operational uses which include process plant and haul road dust suppression. Discharges from the water management system occur due to sedimentation dam overflows and dewatering quarry pits. The functionality of the existing water management system is diagrammatically described in Figure 4.1 and the system layout is shown in Figure 4.2. Key aspects of the water management system are discussed in detail in Sections 4.1.2 to 4.1.7.

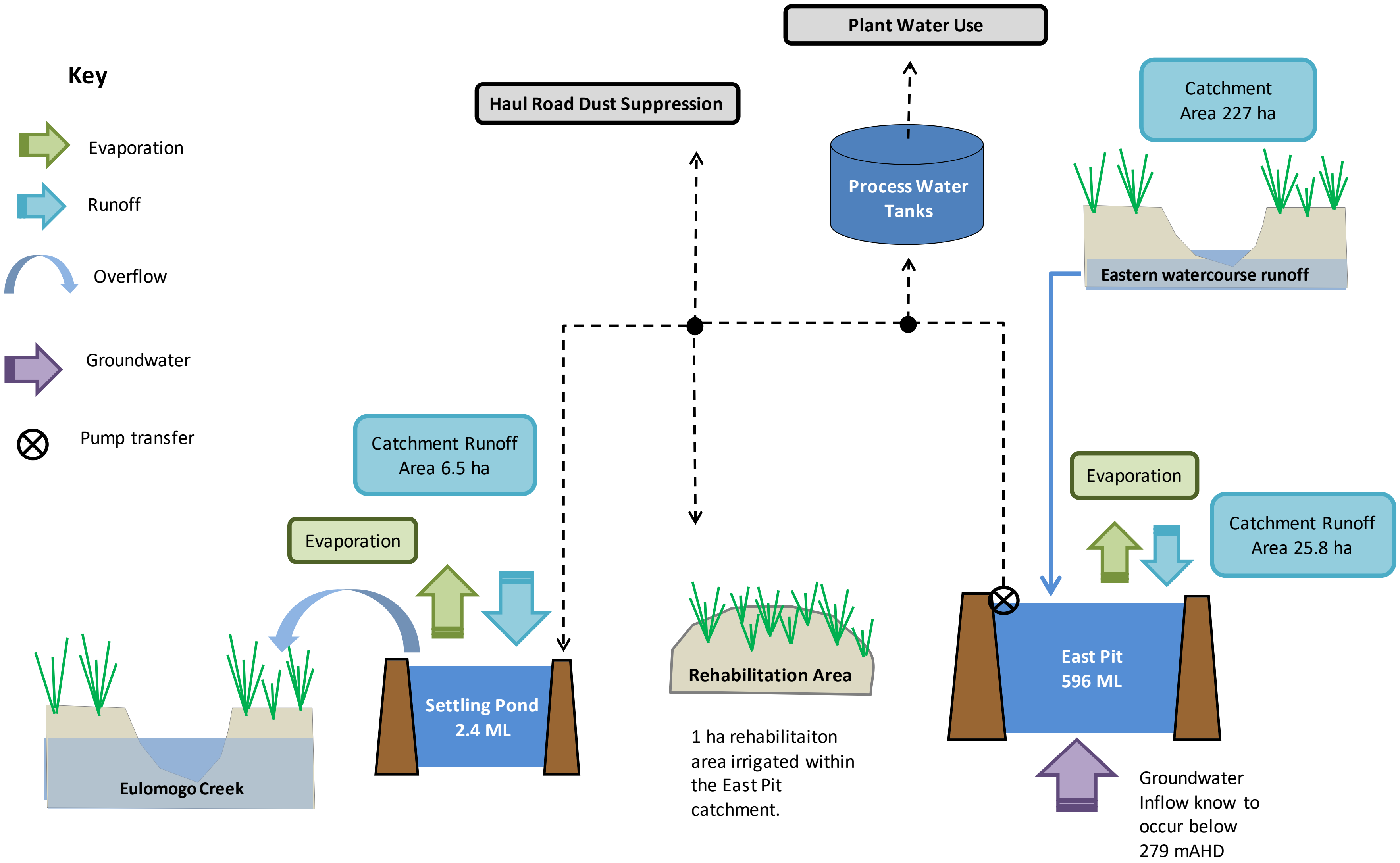

Figure 4.1 Existing water management system functionality

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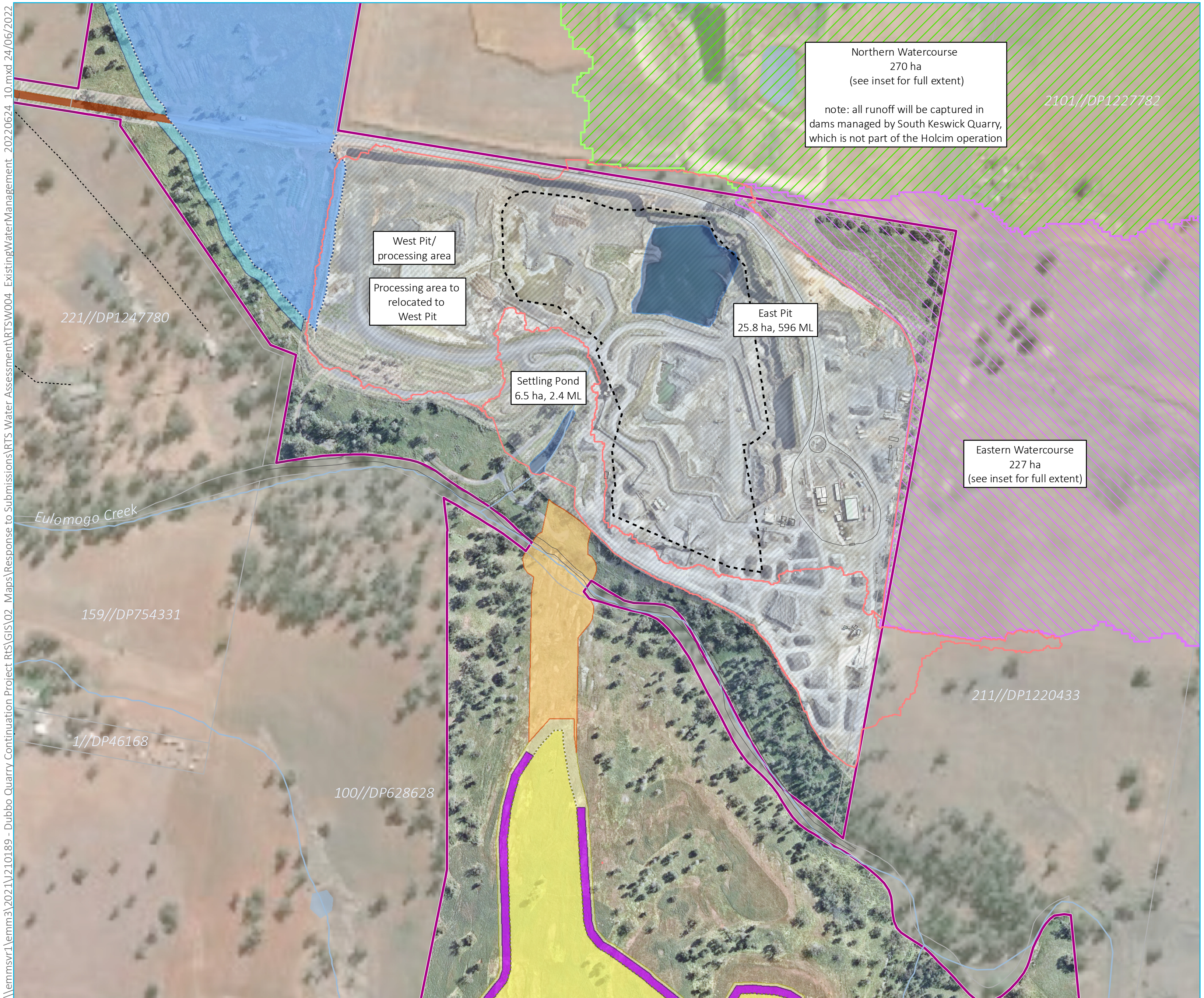

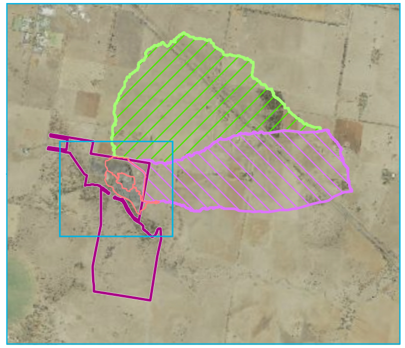

KEY

- Project area
- Existing project infrastructure
- The Eastern Watercourse - 277 ha
- The Northern Watercourse - 270 ha
- Indicative existing disturbance area
- Existing water management dam
- East pit (extraction boundary)
- Catchment boundary
- Bund wall
- Existing access road
- Western extension area
- Western disturbance area
- Haul road disturbance area
- Southern extension area
- Southern disturbance area
- Watercourse/drainage line
- Vehicular track
- Cadastral boundary (data does not align with surveyed site boundary)

Existing water management system layout

Dubbo Quarry Continuation Project
Surface Water Assessment
Figure 4.2

Source: EMM (2020, 2022); DFSI (2017); Nearmap (2020); ASGC (2006)

0 150 300 m
GDA 1994 MGA Zone 55
N

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4.1.2 Existing storages

The water management system includes two key water storages (refer to Figure 4.2). A summary of the key characteristics of each storage is presented in Table 4.1 (overleaf). Photographs of each storage are provided as Photograph 4.1 and Photograph 4.2. It is noted that these photographs were taken on 9 June 2020, nine weeks after significant rainfall that occurred in July 2020.

Photograph 4.1 East Pit/In Pit Dam (looking west)

Photograph 4.2 Settling Pond (looking south-west)

Table 4.1 Existing water management storages

Storage	Description/function	Contributing catchment area	Groundwater inflows	Volume	Overflows to
In Pit Dam (East Pit)	The In Pit Dam is the main storage within the East Pit that receives runoff from: • the East Pit extraction area; • office/workshop areas and stockpile areas surrounding the East Pit; • the West Pit/processing area; • a small clean water catchment to the east of the pit; and • the Eastern watercourse. Water is extracted from the in pit dam for haul road dust suppression.	25.8 ha – quarry area (inclusive of East Pit and West Pit) 227 ha – Eastern watercourse 252.8 ha - total	Groundwater inflows are known to occur when the water levels are below 279 m AHD, 9 m above the pit floor. Inflow regimes have been estimated by EMM, however, limited information is currently available to inform the groundwater exchange (refer the Water Addendum for further information). Anecdotal evidence from the quarry manager confirms it to be substantial when the pit has been fully dewatered to enable extraction.	596 ML	Settling Pond
Settling Pond	The Settling Pond receives runoff from the site office and stockpile areas and immediate surrounds. The pond also receives any water that is dewatered from the East Pit following wet weather conditions, or overflows from the East Pit, should this ever occur. When full, the pond overflows to Eulomogo Creek and is the quarry's only discharge location.	2.2 ha – processing and quarry area	No groundwater inflows are known to occur.	2.4 ML	Eulomogo Creek

4.1.3 Site water use

4.1.4 Operational uses

The quarry operation uses process water for haul road dust suppression and dust suppression within the processing plant. Table 4.2 provides annual water use estimates that have been provided by Holcim.

Table 4.2 Process water uses

Process water use	Description	Annual water use
Haul road dust suppression	The site operates a 13 kL water cart which completes approximately 15 loads a day.	Between 68 and 74 ML/year for wet and dry years, respectively.
Dust suppression within the processing plant	Water is used for conveyor and stockpile dust suppression within the plant. Two 50 kL process water tanks are filled every 2 days on average for process water use.	Constant at 18 ML/year.

The operation has not historically experienced water shortages as groundwater inflows into the In Pit Dam/East Pit have generally met or exceeded operational water requirements.

4.1.5 Amenities

Water for amenities use is sourced from rainwater tanks near the site office. The tanks are topped up using water sourced from the In Pit Dam when close to empty. The volume of water used in amenities is small relative to operational water use and is, therefore, not considered in the water balance. Potable water (ie for drinking) is trucked in.

Wastewater from on-site amenities is discharged to a septic tank located near the amenities block. The tank discharges to an absorption trench. The tank is periodically pumped out by an approved licensed contractor as required.

4.1.6 Operating principles

The existing water management system is operated using the following principles:

1. Operational water is extracted from the In Pit Dam/East Pit via pumps.
2. The water levels in the In Pit Dam/East Pit are managed to enable extraction from the pit. The following dewatering methods are applied on an as needed basis:
    a) Water is pumped to the 1 ha rehabilitation area that is located to the south of the West Pit/processing area. This is typically done to manage the accumulation of water in the pit.
    b) The pit is dewatered to the Settling Pond which overflows to Eulomogo Creek. This is typically done following significant wet weather events or when access to the pit floor is required.

4.1.7 Existing discharge methods

Discharges from the existing operation occur when the Settling Pond is full and overflows. This will typically occur when:

- runoff from the ponds contributing catchment area exceeds the available storage in the pond; and/or
- the In Pit Dam/East Pit is dewatered (via pumping into the Settling Pond).

Discharge regimes are discussed further in the Water Addendum (Water RtS Appendix A).

5 Proposed water management strategy

Holcim is proposing to integrate the water management systems for the two expansion areas with the quarry's existing water management system. This will require construction of new infrastructure, some modifications to existing infrastructure and new operating principles for the quarry.

This chapter describes the water management strategy for the proposed operations and is structured as follows.

- Section 5.1 describes the water management objectives that have been applied to develop the strategy.
- Section 5.2 describes the proposed strategy and includes information on existing system modifications and new controls.
- A summary of water balance model results is provided in the Water Addendum (Water RtS Appendix A).

It is noted that the proposed haul crossing of Eulomogo Creek is addressed separately in Chapter 6 and residual impacts are discussed in Chapter 7.

5.1 Water management objectives

Table 5.1 describes the water management objectives and associated management approach that have been applied to develop the water management strategy for the proposed operations.

Table 5.1 Water management objectives: proposed operations

Water management objective	Approach
1. Minimise groundwater inflows into existing and proposed quarry pits.	• The WEA and SEA pits will not be developed below the interpreted groundwater table. This will avoid any material groundwater inflows. Refer to Water Addendum (Water RtS Appendix A) for further information. • Further monitoring will be undertaken to allow for an improved understanding of groundwater inflow regimes into the East Pit (refer Water Addendum (RtS Appendix A)). • The East Pit will be allowed to partially fill and will be generally maintained at a water level that restricts groundwater inflows (as determined through monitoring). However, during dry periods, water in the In Pit Dam may be drawn down to a level that enables groundwater inflows to occur up to Holcim's existing WAL entitlement of 90 ML/year (see Chapter 8 for further detail).
2. Minimise controlled discharges from quarry pits	• As noted above, groundwater inflows into existing and proposed quarry pits will be minimised. This will reduce the volume of water that requires management. • Water collected in the sumps of the WEA and SEA pits will be pumped to the East Pit or managed in a way that does not require discharge of surplus water. The East Pit will provide a significant storage that can be utilised to minimise discharges and provide a reliable supply of water to the quarry. • Haul road dust suppression and irrigation of vegetated bunds will be undertaken to manage water surpluses. • Further monitoring will be undertaken to allow for the reliability of the water balance and water management system to be progressively improved. • If long-term water surpluses occur, Holcim will investigate alternative measures such as supplying water to nearby farming enterprises for beneficial use as irrigation water.

Table 5.1 Water management objectives: proposed operations

Water management objective	Approach
3. Provide industry best practice erosion and sedimentation controls for disturbance areas that do not drain to a pit sump.	• Existing and new sedimentation dams will be designed, constructed and operated in accordance with the methods recommended in *Managing Urban Stormwater: Volume 1* (Landcom 2004) and *Volume 2E* (DECC 2008). • The sedimentation dams will be dewatered to the East Pit within 5 days following the cessation of rainfall to ensure capacity is available to capture runoff from the next event.

5.2 Proposed strategy

The functionality of the proposed water management strategy is diagrammatically described in Figure 5.1 and the system layout is shown in Figure 5.2. Additional information on key aspects of the strategy is provided after the figures.

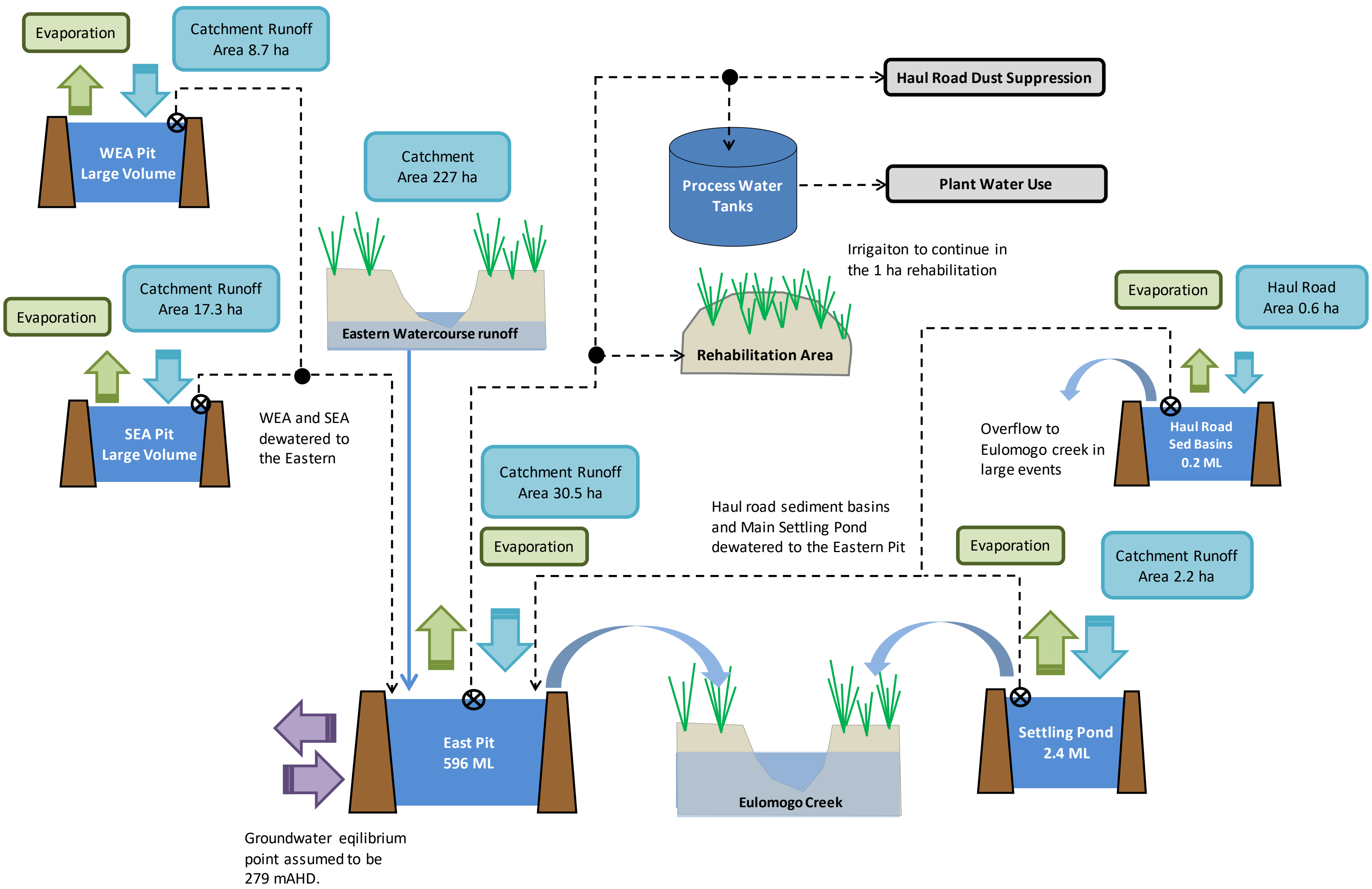
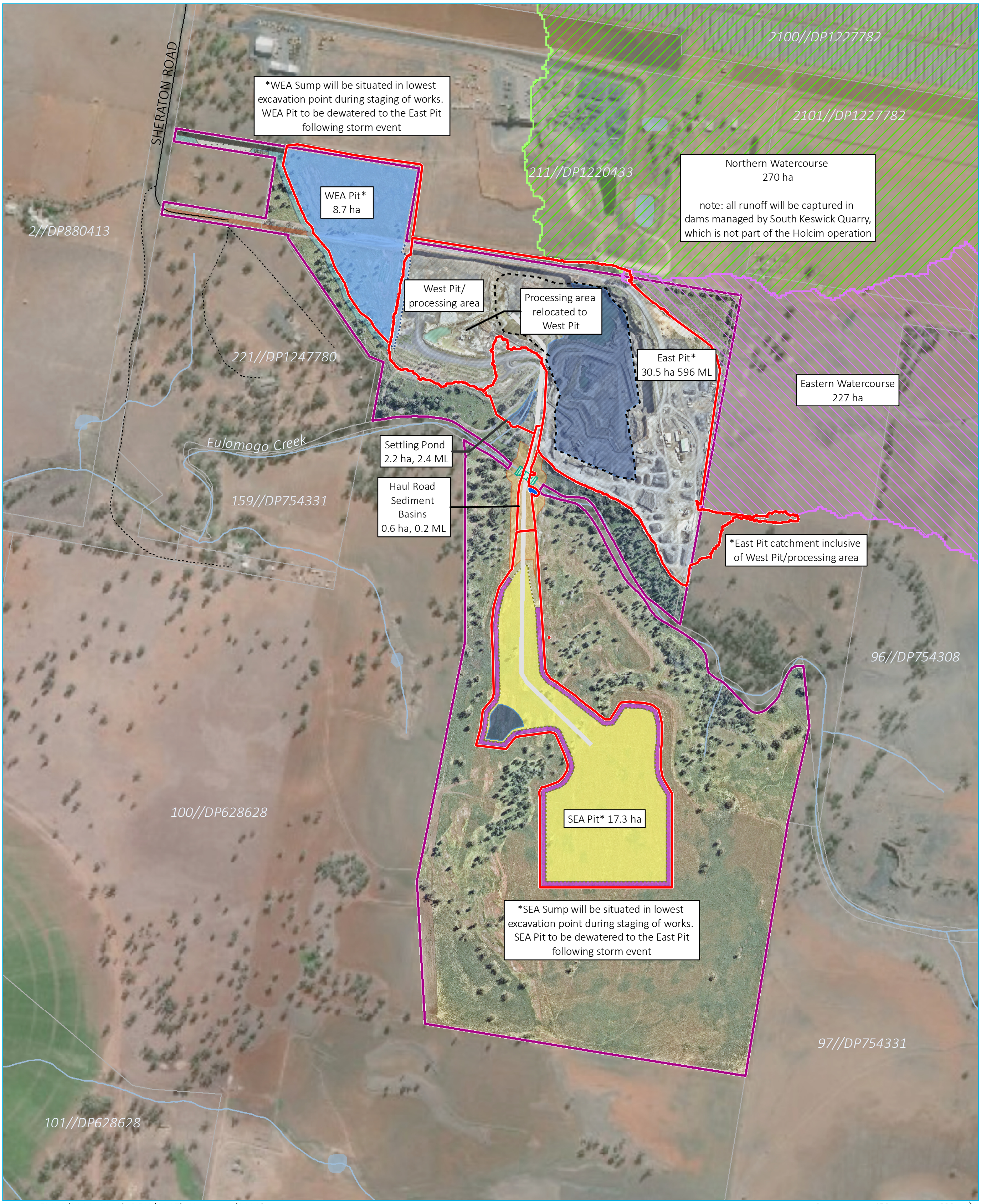


Figure 5.1 Water management system functionality: proposed operations



Source: EMM (2020, 2022); DFSI (2017); Nearmap (2020)

0 150 300
m
GDA 1994 MGA Zone 55
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KEY

- Project area
- Proposed sub catchment
- The Eastern Watercourse - 227 ML
- The Northern Watercourse - 270 ML
- Proposed water management dams
- Proposed sedimentation pond
- Indicative existing disturbance area
- Indicative proposed water crossing
- Bund wall
- Alternative access road
- Alternative truck tarping area
- Existing access road
- Proposed haul road
- Western extension area
- Western disturbance area
- East pit (extraction boundary)
- Haul road disturbance area
- Southern extension area
- Southern disturbance area
- Minor road
- Vehicular track
- Watercourse/drainage line
- Waterbody
- Cadastral boundary (data does not align with surveyed site boundary)

Proposed water management system layout

Dubbo Quarry Continuation Project
Surface water assessment
Figure 5.2

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5.2.1 Proposed modifications and new controls

Table 5.2 provides a summary of proposed modifications to the existing water management system and new controls.

Table 5.2 Proposed modifications and new controls

Proposed modification/new controls	Outcome
Modifications to the existing system	
1. The water level in the In Pit Dam/East Pit will generally be maintained at or above a level that restricts groundwater inflows. However, during dry periods, water in the pit may be drawn down to a level that enables groundwater inflows to occur up to Holcim's existing WAL entitlement of 90 ML/year. It is noted that further monitoring and investigation is required to confirm pit water levels that relate to no groundwater inflows and 90 ML/year of groundwater inflow. It is also noted that the peak safe storage level in the East Pit will be developed based on a review of geotechnical risks.	• Maintaining a higher water level in the pit will minimise groundwater inflows into the pit, reducing the associated water take and need to discharge surplus water.
2. Any overflows or pumped dewatering from the East Pit will be discharged directly downstream of the Settling Pond, just upstream of Eulomogo Creek.	• The current practice of dewatering the East Pit into the Settling Pond can keep the pond full for extended periods of time. This reduces the pond's effectiveness to manage runoff from its contributing catchment area.
New controls	
3. The WEA and SEA pits will not be developed below the interpreted groundwater table.	• To avoid any material groundwater inflows into the pits.
4. During the initial stages of pit development when a pit sump has not been established, surface water runoff from the WEA and SEA will be managed in accordance with the methods recommended in *Managing Urban Stormwater: Volume 1* (Landcom 2004) and *Volume 2E* (DECC 2008).	• To achieve an industry best practice standard for erosion and sediment control.
5. Where practical, runoff from all new haul roads will be managed in accordance with the methods recommended in *Managing Urban Stormwater: Volume 1* (Landcom 2004) and *Volume 2E* (DECC 2008).	• To achieve an industry best practice standard for erosion and sediment control.
6. Water from the WEA and SEA pit sumps will be pumped to the East Pit or managed in a way that does not require discharge of surplus water. For example, water that accumulates in the SEA sump could be used within the SEA for haul road dust suppression and irrigation of bund walls and rehabilitation areas.	• To avoid direct discharge from the WEA and SEA pits and maximise the utilisation of the In Pit Dam/East Pit.

5.2.2 Summary of storages for proposed operations

The water management system for the proposed operations includes five key storages (refer to Figure 5.2). A summary of the key characteristics of each storage is presented in Table 4.1.

Table 5.3 Water management storages: proposed operations

Storage	Description/function	Contributing catchment area	Groundwater inflows	Volume	Overflows to
Existing storages					
In Pit Dam (East Pit)	As described in Table 5.2, the East Pit will be partially filled to minimise groundwater inflows and will be utilised as a water storage for the quarry. As shown in Figure 5.1, the pit will receive water pumped from other sumps and sedimentation dams and will supply operational water. The pit will continue to receive runoff from adjoining quarry areas and the Eastern watercourse and will be dewatered (via pumping or a gravity drain) to Eulomogo Creek when it is close to full.	*Existing catchment* 25.8 ha – quarry area (East Pit and West Pit/processing area) 227 ha – Eastern watercourse 252.8 ha – total *Proposed catchment* 30.5 ha – quarry area (East Pit and West Pit/processing area) 227 ha – Eastern watercourse 257.5 ha – total	Groundwater inflows are assumed to occur when the pit water levels are below 279 m AHD, 11 m above the pit floor. As described in Table 5.2, the pit water level will generally be maintained at or above a level that restricts groundwater inflows. However, during dry periods, water in the pit may be drawn down to a level that enables groundwater inflows to occur up to Holcim's existing WAL entitlement of 90 ML/year.	596 ML	Eulomogo Creek
Settling Pond	The existing Settling Pond receives runoff from the site office and stockpiling area and immediate surrounds. The following modifications are proposed in the catchment: • Diversion of the eastern portion of the catchment to the East Pit will occur via construction of the Haul Road to SEA. • Water captured in the pond will be dewatered to the East Pit within 5 days following the cessation of rainfall. Overflows from the pond to Eulomogo Creek will occur when the runoff volume from its contributing catchment exceeds the storage volume.	*Existing catchment* 6.5 ha – processing and quarry area *Proposed catchment* 2.2 ha – quarry area and haul road.	No groundwater inflows are known to occur.	2.4 ML	Eulomogo Creek

Table 5.3 Water management storages: proposed operations

Storage	Description/function	Contributing catchment area	Groundwater inflows	Volume	Overflows to
Proposed storages					
WEA sump	Runoff from the WEA will drain to a pit sump. Accumulated water will be either reticulated back to the East Pit or used within the WEA for haul road dust suppression.	8.7 ha	The pit will not be developed below the groundwater table, so no groundwater inflows are expected.	Large	No overflows expected due to large storage and operating principles.
SEA sump	Runoff from the SEA will drain to a pit sump. Accumulated water will be either reticulated back to the East Pit or used within the SEA for haul road dust suppression.	17.3 ha	The pit will not be developed below the groundwater table, so no groundwater inflows are expected.	Large	No overflows expected due to large storage and operating principles.
Haul road sedimentation basins	As indicated in Figure 5.2, two sedimentation ponds will be established near the proposed haul road crossing of Eulomogo Creek. The basins will be designed, constructed and operated in accordance with the methods recommended in *Managing Urban Stormwater: Volume 1* (Landcom 2004) and *Volume 2E* (DECC 2008), which includes dewatering captured water within 5 days following the cessation of rainfall. Overflows from the ponds to Eulomogo Creek will occur when the runoff volume from its contributing catchment exceeds the storage volume. This is likely to occur when the 5-day rainfall exceeds 37 mm.	0.6 ha	The basins will not require deep excavation (around 2m) and are, therefore, not expected to intercept the groundwater.	0.2 ML	Eulomogo Creek

5.2.3 Changes to operational water use

The expanded operation will use process water for dust suppression on haul roads and within the processing plant. Table 5.4 provides estimates of annual water use.

Table 5.4 Process water use (proposed operations)

Process water use	Description	Annual water use
Haul road dust suppression	The haul road area available for dust suppression will be increased as part of the proposed operations due to the increased haul area.	Between 166 and 181 ML/year for wet and dry years, respectively.
Dust suppression within the processing plant	No changes to the quarry's production rates are anticipated as part of the proposed operations.	Constant at 18 ML/year.

5.2.4 Monitoring plans

Holcim will prepare the following monitoring plans post approval.

- Quarry pit groundwater inflow management plan. This plan will:
  - provide methods to monitor pit water levels and calculate groundwater inflows into all quarry pits; and
  - establish management protocols to achieve the objectives described in Table 5.1.
- Surface water monitoring plan. This plan will:
  - establish surface water quantity and quality monitoring requirements; and
  - establish trigger action response plans to enable progressive improvement.
- Water management plan. This plan will:
  - describe how water will be managed to achieve compliance with consent and EPL licence conditions; and
  - establish responsibilities and reporting requirements.

All plans will be progressively reviewed and updated.

A water monitoring program for the existing operation is provided in Water Addendum (Water RtS Appendix A).

5.2.5 Contingency measures

Table 5.5 describes a range of contingency measures that could be implemented if required.

Table 5.5 Contingency options

Trigger	Contingency measure
Groundwater inflows exceed existing WAL allocations.	• If practical, maintain higher water levels in pit sumps to reduce groundwater inflows. • Acquire additional WAL entitlements.
The water management system is in surplus and discharges from the East Pit are required frequently, outside of significant wet weather events.	• Irrigation activities can be expanded to include the proposed bund walls around the WEA and SEA, new rehabilitation areas established progressively during the project life and unused haul roads. This would substantially increase water use. • There is potential for Holcim to supply water to nearby irrigators for beneficial use.

6 Eulomogo Creek crossing

A haul road crossing of Eulomogo Creek is proposed to connect the SEA to the existing operation. A concept design for the crossing was prepared by Pitt and Sherry and is provided in Appendix C. A flood impact assessment for the crossing was also prepared by GRC Hydro and is provided as Appendix A.

This chapter describes the creek crossing proposal and is structured as follows.

- Section 6.1 describes the characteristics of Eulomogo Creek at the crossing site.
- Section 6.2 provides an overview of the crossing concept proposed in the EIS (the EIS concept).
- Section 6.3 provides a summary of flood impacts for the EIS concept.
- Section 6.4 describes minor revisions to the EIS concept that has been made due to the revised project layout (see Section 1.4.2), which includes changes to the haul road route.
- Section 6.5 discusses consistency of the crossing design with controlled activity approval guidelines.

6.1 Eulomogo Creek characteristics

As described in Section 3.5, Eulomogo Creek is a third order watercourse that flows in a westerly direction and joins the Macquarie River, approximately 2.7 km west of the site. The creek is ungauged but is known to have an intermittent flow regime meaning that, during an average rainfall year, streamflow will occur for most of the year but may cease for weeks or months, typically in late summer or early autumn. Streamflow would also cease for extended periods of time during dry periods. The creek has a catchment area of 52 km^2 (upstream of the quarry).

At the crossing site, Eulomogo Creek has a confined channel that is bedrock controlled. The longitudinal grade of the channel is approximately 0.9% and the channel width (when the creek is in flood) ranges from 20 to 35 metres. The channel banks and immediate riparian zone are sparsely vegetated with native and exotic species. Photograph 6.1 shows the creek near the crossing site, looking to the south towards the SEA. Note this photograph is reproduced from Chapter 3.

The GRC flood study (provided as Appendix A) included hydrologic and hydraulic modelling to characterise flooding at the proposed crossing site. The assessment concluded the following:

- peak flows at the crossing site are estimated to be 83, 111 and 201 m^3/s for the 20, 10 and 1% Annual Exceedance Probability (AEP) events respectively; and
- hydraulic modelling results characterise flooding within Eulomogo Creek as being confined to the channel and immediate overbank areas. No flood waters are predicted to enter existing quarry pits or impact existing infrastructure. Typical velocities range from 2.5 to 3.5 m/s for the 20 and 1% AEP events, respectively.

Refer to Appendix A for more detailed information on flood characteristics and flood maps.

Photograph 6.1 Eulomogo Creek near the crossing site

6.2 EIS proposed concept

A culvert-based crossing of Eulomogo Creek was proposed in the EIS. Preliminary engineering designs of two options were prepared by Pitt and Sherry. Option 1 includes five 2.1 m diameter precast pipes and Option 2 includes five 3.0 x 2.1 m Rectangular Box Culverts (RBCs). Both options are similar in terms of the overall design concept and include the following common aspects:

- the haul road will be a single land road to minimise the disturbance footprint and will be slightly skewed relative to the culvert alignment (which will be parallel to the creek). The road surface will be a 400 mm concrete pavement;
- the culverts will be approximately 27 m long and will be located within the creek channel zone with invert levels that are similar to the creek bed levels;
- headwalls and scour protection will be provided at the inlet and outlets;
- 1.4 m high vehicle safety berms will be constructed on either side of the haul road; and
- the height from the culvert invert to the top of the safety berm is approximately 3.9 m.

Concept design drawings for both options are provided in Appendix C. It is noted that the flood levels indicated on the drawings were initial estimates and are superseded by the flood levels given in the flood assessment (refer to Appendix A).

6.3 Flood impacts

The GRC flood study assessed flood impacts associated with the Option 2 (RBC) design. The assessment concluded that:

- the culverts will have a capacity that is similar to the 20% AEP peak flow. This accounts for some culvert blockage (refer to Appendix A for details);
- the haul road and safety berm will be overtopped when flows exceed the culvert capacity. The haul road will be unsafe during these conditions;
- the crossing will result in a flood level impact of up to 3 m in 1% AEP event. The magnitude of the impact is mostly due to the safety berm, which combined with the concrete pavement forms a 1.8 m high blockage above the culverts. Model results indicate that the flood level impact will:
    - extend approximately 300 m upstream of the culvert;
    - be confined to the creek channel zone and immediate surrounds; and
    - occur only within the quarry site.
- localised increases in velocities are expected immediately downstream of the culvert due to the concentration of flows through the culverts.

Flooding is not anticipated to impact on quarry operations for the following reasons:

- The duration of flooding of Eulomogo Creek is less than 24 hours. Operations can continue during this time on the northern side of Eulomogo Creek.
- Access to the southern side of Eulomogo Creek can be achieved via an alternate light vehicle access road, facilitating storm event preparation (such as moving plant items) and personnel evacuation.

6.4 Revised crossing design

The haul road route has been modified as part of the revised project layout (see Section 1.4.2) to approach the crossing via a more direct route from the East Pit. This will allow the crossing to be less skewed and potentially narrower than the EIS Concept. No material changes to the location, size and proposed elevations of EIS concept are required due to this change. Hence, the design drawings and flood impact assessment have not been updated.

The use of a conveyor to transport resource from the SEA to the West Pit Processing Area is also being considered by Holcim. If proposed, the conveyor will be installed on the crossing structure adjacent to the haul road at a level of 283 mAHD (above the 1% AEP flood event).

6.5 Consistency with CAA guidelines

As described in Section 2.2.1 guidelines for controlled activities are provided by DPIE-Water. These guidelines provide information on design and construction principles for controlled activities, and other ways to protect waterfront land. Controlled activity approvals are not required for the project as it is a SSD. Notwithstanding, the principles described in the following guidelines have been considered when preparing the concept design:

- *Guidelines for riparian corridors on waterfront land* (NSW Office of Water 2012); and
- *Guidelines for watercourse crossings on waterfront land* (NSW Office of Water 2012).

Table 6.1 describes key design principles from the above guidelines and notes how they have been addressed in the concept design.

Table 6.1 Consistency with guidelines for CAA

Design principle	Concept design response
Guidelines for riparian corridors on waterfront land	
Table 2 from the guideline notes that culvert road crossings are suitable for 3rd and 4th order watercourses.	Eulomogo Creek is a 3rd order watercourse. Hence, the concept design is consistent with this principle.
Guidelines for watercourse crossings on waterfront land	
Minimise the design and construction footprint	A single lane haul road is proposed to minimise the width and footprint of the culvert structure.
Maintain the existing or natural hydraulic, hydrologic, geomorphic and ecological functions of the watercourse Where a raised structure is proposed, demonstrate there will be no detrimental impact to natural hydraulic, hydrologic, geomorphic and ecological functions of the watercourse	**Impacts to hydrology** • No changes to the hydrology of Eulomogo Creek is expected as streamflow will simply pass through the culvert structure. **Impacts to hydraulics** • No material changes to local hydraulics are expected during non-flood conditions as the culvert capacity is large relative to streamflow during non-flood conditions. • Some localised changes to hydraulics are expected during flood conditions. These changes are described in Section 6.3. **Impacts to geomorphology** • The culverts are not expected to block or alter sediment transport along Eulomogo Creek as the culverts are large and located within the creek channel. **Impacts to ecology** • Impacts to ecology from the creek crossing are addressed in the Dubbo Quarry Continuation Project Biodiversity Development Assessment Report (EMM 2020b)
Protect against scour	Culvert headwalls and scour aprons are proposed at the inlets and outlets. However, given that Eulomogo Creek is bed rock controlled at the culvert location, the need for scour aprons will be assessed further at detailed design.
Stabilise and rehabilitate all disturbed areas.	Rehabilitation of areas disturbed by the construction of the culvert will be addressed at detailed design using standard methods.

7 Residual impacts

This chapter describes residual impacts associated with discharges from the proposed operations and addresses the NSW water quality and river flow objectives that were established in Chapter 2. It is noted that impacts associated with the proposed Eulomogo Creek Crossing are described in Chapter 6.

7.1 Water discharge impacts

As described in Chapter 4 discharges from the existing quarry into Eulomogo Creek occur due to sedimentation basin overflows and dewatering of the East Pit. The water management strategy for the proposed operations (described in Chapter 5) seeks to minimise these discharges by modifying existing infrastructure and operating principles and establishing new infrastructure for the expansion areas. This section describes the changes to discharge regimes, the expected water quality of discharges and associated changes to receiving water quality.

7.1.1 Changes to discharge regimes

The water management strategy for the proposed operations applies the following measures to reduce discharges:

- Groundwater inflows into new and existing pits will be minimised by:
  - allowing the East Pit to partially fill and by maintaining a pit water level that generally restricts groundwater inflows; and
  - not developing excavations in the WEA and SEA below the interpreted groundwater table, avoiding any material groundwater inflows.
- The East Pit will be used to store water pumped from pit sumps and sedimentation dams. This reduces the need for discharges during, and shortly following, rainfall events.
- Sedimentation basin overflows will be reduced by:
  - dewatering the basins to the East Pit within 5 days following each rainfall event; and
  - diverting water that is dewatered from the East Pit to downstream of the Settling Pond.

Water balance modelling (documented in the Water Addendum (Water RtS Appendix A)) was used to estimate discharge regimes from both the existing and proposed operations. Key results are presented as follows.

- Table 7.1 compares the annualised discharge volumes for dry, median and wet years.
- Figure 7.1 is a probability of exceedance chart that compares the annualised discharge volumes. It is noted that the y-axis (annual discharge) is presented at a log scale.

Both Table 7.1 and Figure 7.1 provide a break-down of discharges due to sedimentation basin overflows and East Pit dewatering.

Table 7.1 Changes to discharge regimes: existing and proposed operations

		Existing operation			Proposed operations		
	Units	Dry year	Median year	Wet Year	Dry year	Median year	Wet Year
Sediment basin overflows	ML/year	1	8	20	0.0	0.1	0.5
East Pit dewatering	ML/year	161	270	449	0.0	0.0	99
East pit seepage to palaeochannel	ML/year	0.0	0.0	0.0	0.0	4.3	17
Total discharges	ML/year	162	279	468	0.1	4.4	116

Notes: 1. Dry year referes to a typical 10th percentile rainfall year
2. Wet year refers to a typical 90th percentile rainfall year

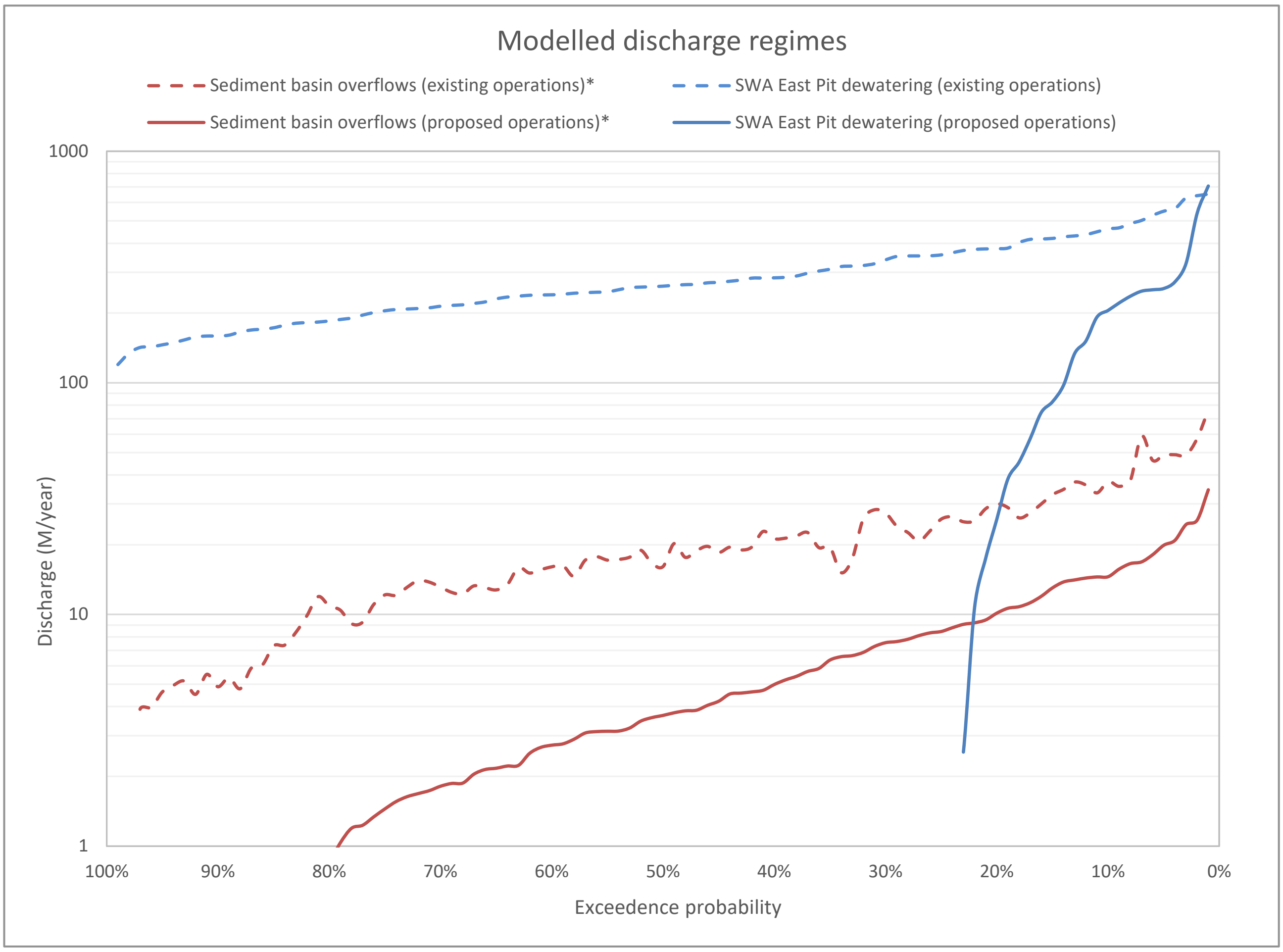

Figure 7.1 Comparison of discharge regimes: existing and proposed operations

The water balance results presented in Table 7.1 and Figure 7.1 demonstrate that the water management strategy for the proposed operations will be effective in substantially reducing both the frequency and magnitude of discharges due to sedimentation basin overflows and East Pit dewatering, with discharges via both mechanisms occurring during wet conditions only and at reduced magnitudes.

7.1.2 Water quality of discharges

The water quality characteristics of water storages was detailed in 3.6.2ii. As described in Chapter 4, groundwater inflows into the East Pit are a primary source of water to the existing water management system and are, therefore, expected to influence the quality of water that discharges from the East Pit and Settling Pond. The water management strategy for the proposed operations (described in Chapter 5) seeks to minimise groundwater inflows. As a result, surface water runoff from quarry areas and the Eastern watercourse will be the primary sources of inflows and some changes to water quality are expected.

The water quality of groundwater inflows is poorly understood. However, there is potential that groundwater inflows have higher salinity and nitrate concentrations then surface water runoff and that the salinity levels and nitrate concentrations in the East Pit may decline overtime as the water management strategy for the proposed operations is implemented.

Surface water monitoring is proposed (see Section 5.2.4) which will enable changes to water quality to be identified and the water management approach to be adjusted if required.

7.1.3 Potential changes to receiving water quality

The water management strategy for the proposed operations will substantially reduce the frequency and magnitude of discharges to Eulomogo Creek from both sedimentation basin overflows and East Pit dewatering, with discharges via both mechanisms occurring during wet conditions only, and at reduced magnitudes. These reductions will occur despite the quarry footprint increasing from approximately 34 to 60 ha due to the proposed WEA and SEA extensions.

Table 7.2 provides a summary of expected changes to nutrient loads, sediment laden and turbid water, salt loads and metals and toxicants in discharges. Overall, the reduced frequency and magnitude of discharges will beneficially change receiving water quality.

Table 7.2 Changes to the water quality profile of discharge

Aspect	Description of changes
Nutrient loads	Water quality monitoring data has identified that nutrients (particularly nitrate and reactive phosphorus) in the existing water management system storages are elevated relative to DGVs. The water management strategy for the proposed operations will reduce nutrient loads in discharges, primarily due to the lower discharge volumes. However, if existing groundwater inflows into the East Pit are the primary source of the nutrients, there is potential for additional reductions to occur given that groundwater inflows will be substantially reduced. The magnitude of the overall reduction cannot be reliably quantified but is expected to be substantial.
Sediment laden or turbid water	As described in Section 7.1.1, the frequency and magnitude of sedimentation basin overflows is expected to be substantially reduced relative to existing conditions. This is primarily due to the proposed changes to the Settling Pond, which is currently operating below the standard recommended in *Managing Urban Stormwater: Volume 1* (Landcom 2004) and *Volume 2E* (DECC 2008). Water quality monitoring data presented in Section 3.6.2 indicates that the turbidity in the East Pit is generally below the DGV. Hence, discharges from the East Pit are not expected to be either turbid or sediment laden.
Salt loads	Salt loads in discharges are expected to be significantly reduced due to the lower frequency and magnitude of discharges and decreases to (likely moderately saline) groundwater inflows into the East Pit.

Table 7.2 Changes to the water quality profile of discharge

Aspect	Description of changes
Metals and toxicants	The occurrence of metals and other toxicants in quarry water is poorly understood. A single sample collected as part of the EIS sampling (see Section 3.6.2) identified potential for zinc and copper concentrations above DGVs in select samples from existing water management storages. Discharges from the water management system for the proposed operations are only expected to occur during or shortly after material wet weather events, when streamflow in receiving waters will be naturally high. Hence, the risk of discharges increasing the toxicity of receiving waters is substantially reduced relative to the existing discharge regime where discharges outside of wet weather events occur.

7.2 NSW water quality and river flow objectives

Section 2.3 established the water quality and river flow objectives for receiving waters relevant to the project. Table 7.3 describes potential impacts to the objectives due to the project (ie the proposed operations).

Table 7.3 Assessment of water quality and river flow objectives

<table>
<tr><th>Environmental value</th><th>Objective</th><th>Application to proposed development</th></tr>
<tr><td colspan="3">Water quality objectives</td></tr>
<tr><td>Aquatic ecosystems</td><td>Maintaining or improving the ecological condition of water bodies and their riparian zones over the long term.</td><td>As described in Section 7.1.3, the reduced frequency and magnitude of discharges is expected to beneficially change receiving water quality. This may result in improved ecological conditions.</td></tr>
<tr><td>Visual amenity</td><td>Aesthetic qualities of waters.</td><td>As described in Section 7.1.3, the water management strategy for the proposed operations will reduce nutrient loads in discharges. This may reduce the risk of blue-green-algae blooms in downstream watercourses. It is also noted that discharges are not expected to have elevated concentrations of oils, petrol chemicals or floating debris which can impact the visual amenity of water (ANZECC 2000).</td></tr>
<tr><td>Secondary contact recreation</td><td>Maintaining or improving water quality for activities such as boating or wading, where there is a low probability of water being swallowed.</td><td rowspan="2">As described in Section 7.1.3, the water management strategy for the proposed operations will reduce nutrient loads in discharges. This may reduce the risk of blue-green-algae blooms in downstream watercourses. It is also noted that discharges are not expected to have elevated concentrations of coliforms, enterococci or protozoans as there is no source of these pollutants in the surface water management system.</td></tr>
<tr><td>Primary contact recreation</td><td>Maintaining or improving water quality for activities such as swimming in which there is a high probability of water being swallowed.</td></tr>
<tr><td>Livestock water supply</td><td>Protecting water quality to maximise the production of healthy livestock.</td><td rowspan="2">The water quality of discharges is expected to be suitable for both livestock consumption and irrigation. As described in Section 7.1.3, the water management strategy for the proposed operations is expected to reduce salt loads in discharge which will make a small contribution to achieving the catchment wide salinity targets noted in Table 2.2.</td></tr>
<tr><td>Irrigation water supply</td><td>Protecting the quality of waters applied to crops or pasture.</td></tr>
</table>

Table 7.3 Assessment of water quality and river flow objectives

Environmental value	Objective	Application to proposed development
Drinking water at point of supply – disinfection only Drinking water at point of supply – clarification and disinfection Drinking water at point of supply – groundwater	These objectives apply to all current and future licensed offtake points for town water supply and to specific sections of rivers that contribute to drinking water storages or immediately upstream of town water supply offtake points. The objectives also apply to sub-catchments or groundwater used for town water supplies.	Town water supply in the region is provided by Dubbo Regional Council. Water is extracted from Macquarie River downstream of the site for town water supply and treated at the John Gilbert Water Treatment Plan in Macquarie Street south. As described in Section 7.1.3, the reduced frequency and magnitude of discharges is expected to beneficially change receiving water quality. It is also noted that discharges are not expected to have elevated concentrations of coliforms, enterococci or protozoans as there is no source of these pollutants in the surface water management system.
River flow objectives		
Protect pools in dry times	Protect natural water levels in pools of creeks and rivers and wetlands during periods of no flows.	The water management strategy for the proposed operations will reduce the frequency and magnitude of discharges to Eulomogo Creek and groundwater take from the local hard rock aquifer. Resulting changes to the streamflow regime of Eulomogo Creek are expected to be beneficial (ie closer to a naturalised flow regime).
Protect natural low flows	Share low flows between the environment and water users and fully protect very low flows.	
Protect important rises in water levels	Protect or restore a proportion of moderate flows and high flows.	
Maintain wetland and floodplain inundation	Maintain or restore the natural inundation patterns and distribution of floodwater supporting natural wetland and floodplain ecosystems.	
Maintain natural flow variability	Maintain or mimic natural flow variability in all streams.	
Manage groundwater for ecosystems	Maintain groundwater within natural levels and variability, critical to surface flows and ecosystems.	
Minimise effects of weirs and other structures	Minimise the impact of instream structures.	As described in Section 6.4, the concept design for the proposed haul road crossing of Eulomogo Creek has considered relevant guidelines for controlled activities and no detrimental impact to natural hydraulic, hydrologic, geomorphic and ecological functions of the watercourse are expected.

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Abbreviations

AHD	Australian Height Datum
ARI	average recurrence interval
BOM	Bureau of Meteorology
DCP	development control plan
DGV	default guideline value
DPIE-Water	Department of Planning Industry and Environment: Water Division
DRC	Dubbo Regional Council
EIS	environmental impact statement
EPA	Environment Protection Authority
EPL	environment protection licence
LDP	licensed discharge point
LGA	Local Government Area
MDB	Murray Darling Basin
MHRDC	Maximum harvestable rights dam capacity
Mt	Million tonnes
NATA	National Association of Testing Authorities
PMF	probable maximum flood
POEO Act	*Protection of the Environment Operations Act 1997*
RCBC	Rectangular concrete box culvert
RMS	Roads and Maritime Services
SEA	Southern Extension Area
SILO	Scientific Information for Land Owners
SSD	State significant development
tpa	tonnes per annum
WAL	water access licence
WEA	Western Extension Area
WMA	*Water Management Act 2000*
WSP	water sharing plan

Appendix A

Flood assessment

DUBBO QUARRY CONTINUATION PROJECT

FLOOD STUDY AND IMPACT ASSESSMENT

Final Report

October 2020

Dubbo Quarry Continuation Project

Flood Study and Impact Assessment

Project:	Dubbo Quarry Continuation Project – Flood Study and Impact Assessment
Project Number:	190036
Client:	Holcim / EMM Consulting Pty Ltd
Report Author:	Nicola De Paolis, Zac Richards
Verified by:	Zac Richards

Date	Version	Description
15-July-2019	1	Preliminary Report
23-July-2019	2	Draft Report
20-October-2020	3	Final Report

Filepath: J:\190036\Admin\Report\Dubbo Quarry - Flood Study and Impact Assessment -Draft Final Report.docx

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Cover image: Satellite picture of Dubbo Quarry

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EXECUTIVE SUMMARY

Introduction

Holcim's Dubbo Quarry is located approximately 6 km south-east of the Dubbo town centre and to the north of Eulomogo Creek. Holcim are proposing to expand the quarry's existing operations to the southern side of Eulomogo Creek. To facilitate the expansion, a haul road crossing is proposed to connect the southern and northern sides of the Creek.

GRC Hydro has been appointed to undertake a flood study for the Site and to assess flood impact associated with the proposed Eulomogo Creek crossing concept design.

Hydrology

Hydrologic modelling has been undertaken using XP-RAFTS, with design flows derived for the site for the 1%, 10% and 20% AEP events. Validation of the derived design flow estimates has been undertaken via comparison to ARR2016 Regional Flood Frequency Estimates (RFFE) and results from a coarse direct rainfall TUFLOW model developed for the catchment upstream of the site.

The validation results were found to improve the robustness of the XP-RAFTS design flow estimates.

Hydraulics

A TUFLOW hydraulic model was constructed for the site on a 2 m grid resolution. Upstream and internal boundary conditions were applied based on outputs from the XP-RAFTS model, and the Macquarie River 1% AEP flood level was applied as a static tailwater level at the downstream boundary. Applied Manning values were consistent with nearby studies and ARR2016 guidelines.

Results

Flood maps for the 1%, 10% and 20% AEP events were produced. The maps present peak flood depths and levels in the existing and proposed scenarios and flood impact maps to assess the change in water levels caused by the proposed road embankment and culverts.

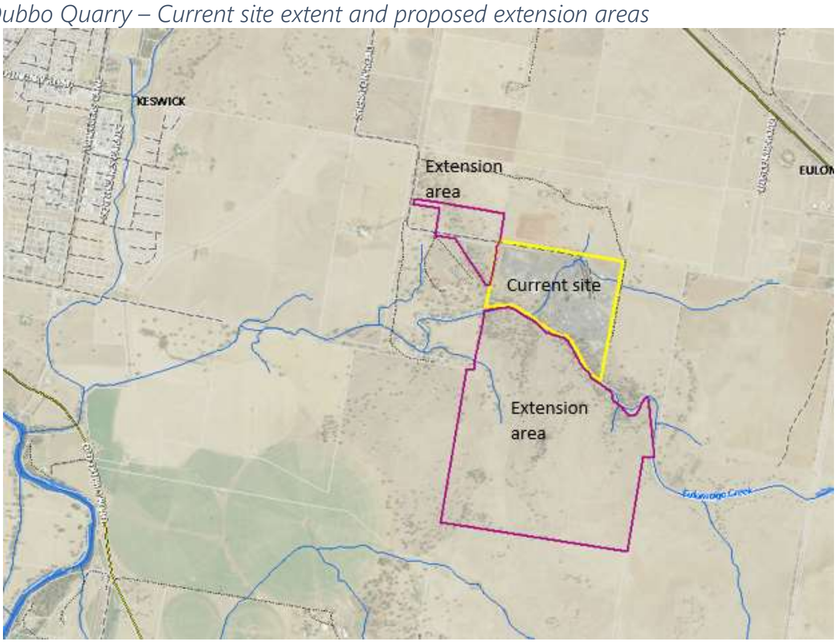
Flood levels are expected to overtop the proposed road crossing during the 20% AEP and greater magnitude events. However, Holcim have advised that alternate road access is available to the site which can be used during periods of flood. Flooding of the creek crossing may pose a risk to vehicles attempting to use the crossing during times of flood and operating protocols should be implemented to manage this risk. It is also noted that there is no public access to the road crossing.

Comparison of peak flood levels between the existing and proposed conditions show a water level increase up to 3 meters in the 1% AEP event, however flood impacts are confined to land owned by Holcim.

1. INTRODUCTION

Holcim's Dubbo Quarry is located approximately 6 km south-east of the Dubbo town centre and to the north of Eulomogo Creek. Holcim are proposing to expand the quarry's existing operations to the north-west as well as to the southern side of Eulomogo Creek, as presented in Image 1.

Image 1: Holcim Dubbo Quarry – Current site extent and proposed extension areas



Eulomogo creek is an intermittent watercourse and a tributary of the Macquarie River. The Eulomogo creek catchment area to the site is ~52 km^2. A key component of the proposed works is the connection of the southern and northern sides of Eulomogo Creek.

GRC Hydro has been appointed to undertake a flood study for the Site and to assess the proposed Eulomogo Creek crossing concept design.

1.1 Objectives

The objectives of this study are to define 1%, 10% and 20% AEP flood behaviour for Eulomogo Creek at the project site under the existing and proposed conditions scenarios and assess the flood impact caused by the proposed Eulomogo Creek crossing. This study is focused on mainstream flooding only and minor overland flow paths within the site have not been assessed.

2.HYDROLOGY

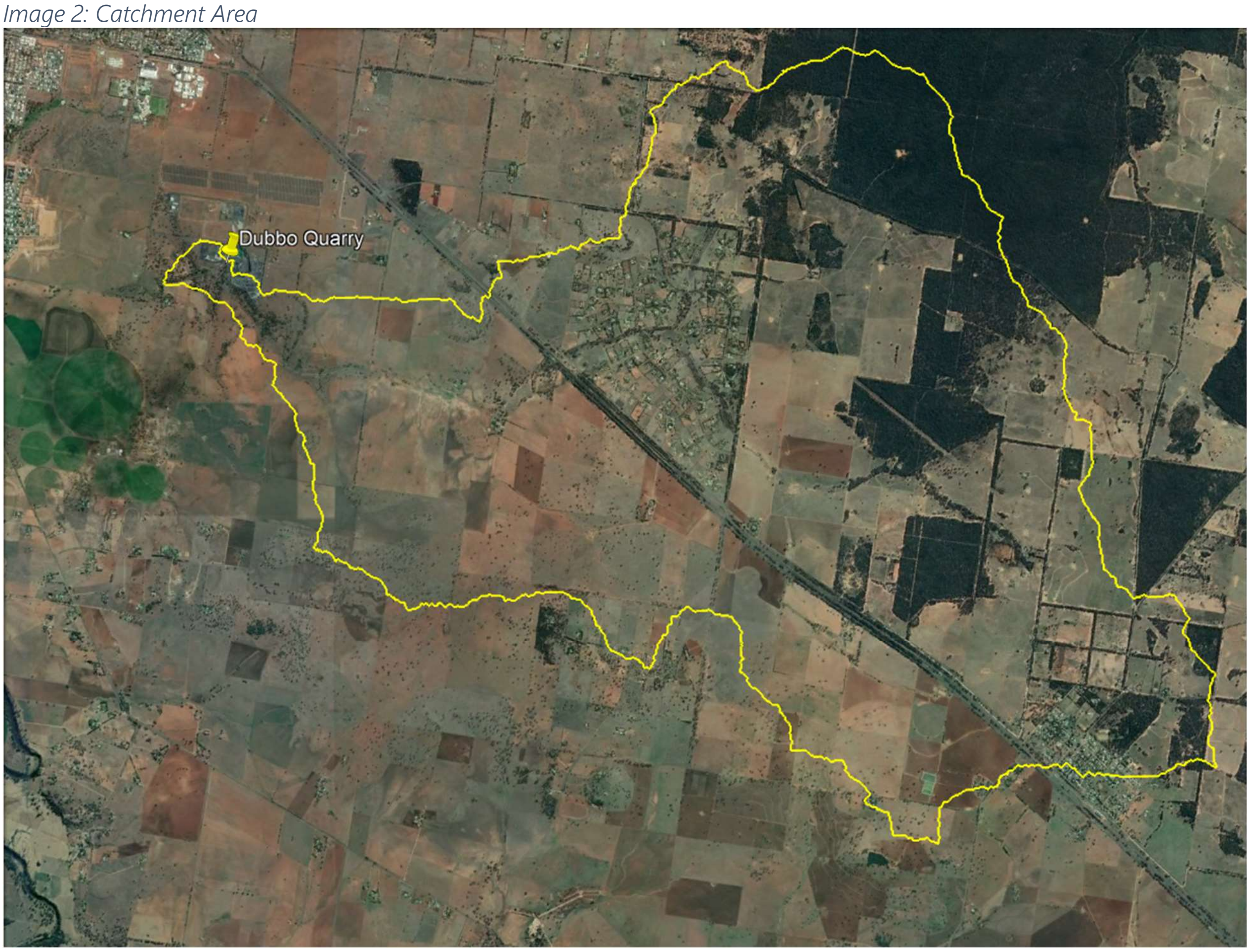
2.1 Catchment Description

Eulomogo Creek is an intermittent watercourse and a tributary of the Macquarie River. The Creek catchment at Dubbo Quarry has an area of 52 km^2, with ground elevations ranging between approximately 277 to 421 mAHD. Typical catchment slopes range between 1.1% to 2.6% with a maximum stream length of 16 km from the upper catchment to the site. The Eulomogo Creek catchment area upstream of the quarry is presented in Image 2.

The region is predominantly rural in nature; however, some rural residential development is present to the north of the A32 Highway, which crosses the catchment from north-east to south-west.

In western areas of the catchment, land use is predominately pastural grasslands with typically sparse vegetation, with more dense vegetation noted along the watercourse. In the upper catchment, to the north-east, woodlands of medium vegetation density are noted.

Image 2: Catchment Area



Local catchments to the north and east of the quarry have not been assessed in the hydrologic analysis, due to the following reasons (as advised by EMM):

- Local catchment directly to the north – a quarry has recently been established to the north of the site which captures all runoff from this catchment; and
- Local catchment to the east of the quarry – runoff from this catchment is contained by the quarry's water management system (i.e. void).

2.2 Hydrologic Modelling

The hydrologic aspects of this study have been undertaken using XP-RAFTS. XP-RAFTS is a software program used to simulate runoff hydrographs at defined points throughout a watershed based on a set of catchment characteristics and specific rainfall events. The software is suitable for use in both rural and urban catchments, making is suitable for use in the current study.

There is no stream gauge present within the Eulomogo Creek catchment and accordingly, event base model calibration was not possible. In lieu of suitable calibration data, validation of the derived design flow estimates has been undertaken via the following methods:

- Comparison to ARR2016 Regional Flood Frequency Estimates (RFFE); and
- Comparison to results from a coarse (10m) direct rainfall TUFLOW model for the upstream catchment.

The following sections discuss the XP-RAFTS model build, model parameters, design flow results and flow validation.

2.2.1 XP-RAFTS Hydrologic Model Build

2.2.1.1 Model Schematisation and Parameters

The XP-RAFTS hydrologic model requires the derivation of sub-catchment areas and associated catchment characteristics. The catchment described in Section 2.1 was divided into 11 sub-catchments with comparable surface area, shape and ground slopes characteristics. Table 1 summarises the features of each sub-catchment, with the sub-catchments layout presented in Figure 1.

Table 1: XP-RAFTS model schematisation

Sub Catchment ID#	AREA (ha)	slope %
1	541.8	1.45
2	696.4	1.82
3	635.5	1.15
4	662.6	1.14
5	220.2	2.20
6	507.9	2.20
7	483.2	1.42
8	719.3	1.72
9	263.0	2.63
10	437.1	1.51
11	178.0	1.78

XP-RAFTS model parameters were determined via inspection of available data, including aerial imagery and a 1m DEM obtained from NSW Spatial Services ('*Dubbo201407-LID1-AHD*' dataset).

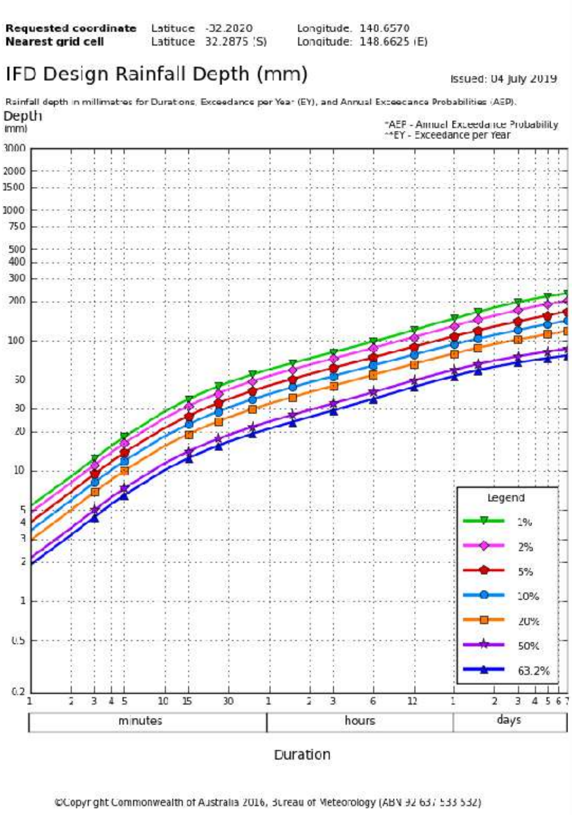
Sub-catchment slopes were determined via methods outlined in the XP-RAFTS user manual, where an 'equal angle slope' was calculated based on a sub-catchment's minimum and maximum elevation and maximum stream length (via interrogation of the 1 m DEM). Lag times for inter-catchment routing were determined using the major flow path length (L) and slope (S) and the formula outlined in the Laurenson's method (lag time = $L / S^{0.5}$).

A global Manning value of 0.04 was implemented which is generally consistent with rural land uses in the catchment (confirmed using relative guidelines including ARR2016, Chow 1959). As discussed in Section 2.1, areas of medium density vegetation are present which have higher Manning values, however application of a lower Manning value leads to conservative flow estimates and is therefore appropriate.

2.2.1.2 Design Rainfall

ARR2016 design rainfall depths for various durations were obtained from the Bureau of Meteorology (BoM). Details are presented in Image 3 and Attachment A.

Image 3: Design rainfall information obtained from the BoM



Duration	63.2%	50%#	20%*	10%	5%	2%	1%
	Annual Exceedance Probability (AEP)						
1 min	1.90	2.14	2.92	3.47	4.02	4.77	5.37
2 min	3.20	3.62	4.98	5.92	6.86	8.07	8.99
3 min	4.42	5.00	6.86	8.15	9.44	11.1	12.4
4 min	5.53	6.24	8.53	10.1	11.7	13.8	15.5
5 min	6.50	7.33	10.0	11.9	13.8	16.3	18.2
10 min	10.1	11.4	15.5	18.4	21.3	25.3	28.5
15 min	12.5	14.1	19.1	22.7	26.3	31.4	35.4
20 min	14.2	16.0	21.8	25.9	30.1	35.8	40.4
25 min	15.6	17.6	23.9	28.5	33.0	39.3	44.4
30 min	16.7	18.8	25.7	30.6	35.5	42.2	47.6
45 min	19.2	21.7	29.7	35.3	41.0	48.7	54.8
1 hour	21.0	23.8	32.6	38.7	45.0	53.3	59.9
1.5 hour	23.7	26.8	36.8	43.8	50.7	60.0	67.2
2 hour	25.8	29.2	40.0	47.5	55.0	65.0	72.7
3 hour	29.0	32.8	44.8	53.2	61.5	72.5	81.1
4.5 hour	32.7	36.9	50.2	59.4	68.6	81.0	90.6
6 hour	35.6	40.1	54.4	64.3	74.1	87.6	98.2
9 hour	40.3	45.2	61.0	71.9	82.8	98.1	110
12 hour	43.9	49.2	66.0	77.8	89.5	106	120
18 hour	49.3	55.1	73.7	86.7	99.7	119	136
24 hour	53.3	59.5	79.4	93.4	108	129	147
30 hour	56.5	62.9	83.9	98.8	114	138	157
36 hour	59.0	65.7	87.7	103	119	144	165
48 hour	62.8	70.0	93.5	110	128	155	179
72 hour	67.7	75.6	102	120	140	171	197
96 hour	70.8	79.3	107	128	149	182	209
120 hour	73.2	82.1	112	133	156	190	218

The recommended ARR2016 ensemble approach to applying temporal patterns has been utilised in the current study. The ensemble approach to flood modelling applies a suite of 10 different temporal patterns for each duration. The temporal patterns were obtained from ARR2016 for the 'Murray-Darling Basin` region and applied using the XP-RAFTS software.

2.2.1.3 Rainfall Losses

An Initial and Continuous Loss (IL / CL) model was implemented with losses obtained from the ARR2016 datahub. The Probability Neutral Burst initial loss was implemented based on recommendations in the OEH Floodplain Risk Management Guide (2019). The losses presented in Table 2 were applied to the model.

Table 2: Initial and Continuous Losses

AEP	IL (mm)	CL (mm/hr)
1%	7	2
10%	11.8	2
20%	13.4	2

A review of neighbouring studies that are available online, was undertaken to validate the applied loss values. Only one study close to Dubbo was found, namely the '*Narromine River Bank Levee Feasibility Study*' (Lyall & Associates, 2013). This study implemented an initial loss of 15 mm and a continuing loss of 2.5 mm/h. These losses were noted to be similar, but slightly higher than that recommended by ARR2016 and implemented in the current study. This finding improves confidence in the applied loss values.

2.2.1.4 Areal Reduction Factor

An Areal Reduction Factor (ARF) was applied to rainfall depths to adjust for the catchment's areal average rainfall intensity. The ARF was determined following the methods outlined in ARR2016 using the XP-RAFTS software.

2.2.2 Hydrologic Model Results

Design flows (Critical Storm Flow) for each AEP at the site are presented in Table 3, along with the critical duration, average ensemble flow and critical storm event.

Table 3: Hydrologic model results

AEP (%)	Critical Duration (hours)	Average Ensemble Flow (m^3/s)	Critical Storm	Critical Storm Flow (m^3/s)
20	9	79.0	Storm 6	83.4
10	6	111.2	Storm 7	111.2
1	3	194.6	Storm 4	200.7

The temporal pattern ensemble results extracted from the XP-RAFTS model are presented in Image 4 to Image 6.

Image 4: XP-RAFTS 1%AEP hydrologic model design flows at the site

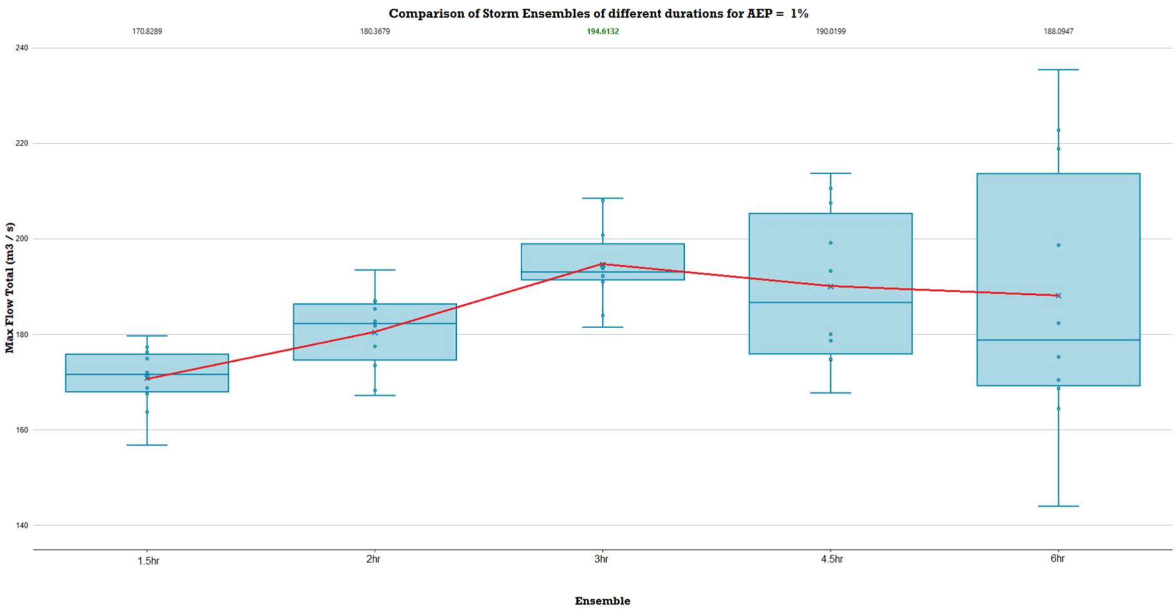


Image 5: XP-RAFTS 10%AEP hydrologic model design flows at the site

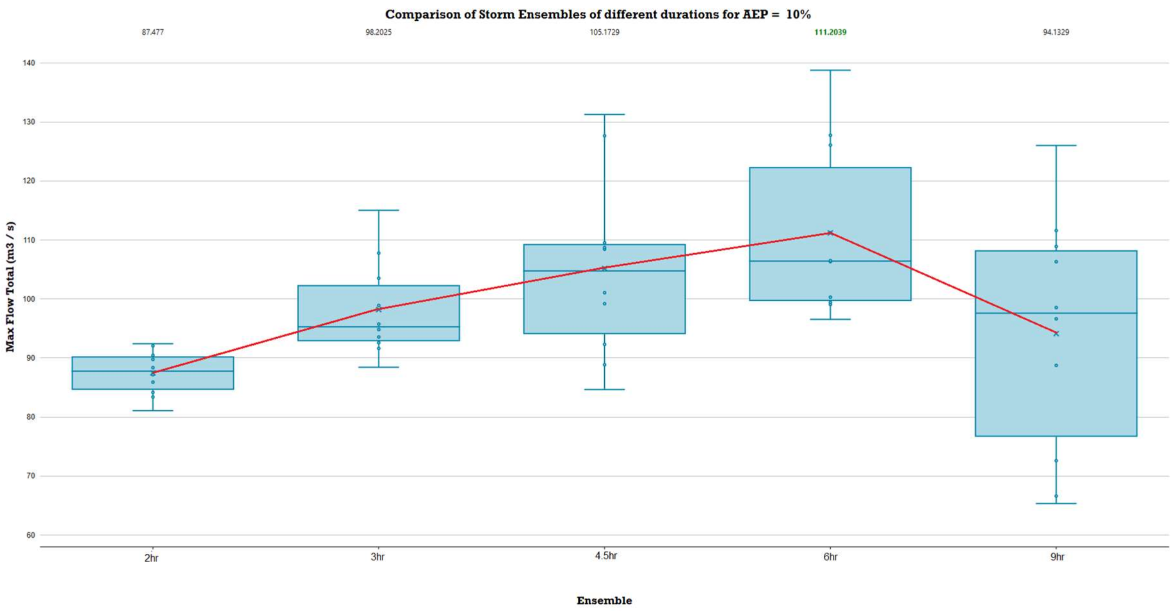
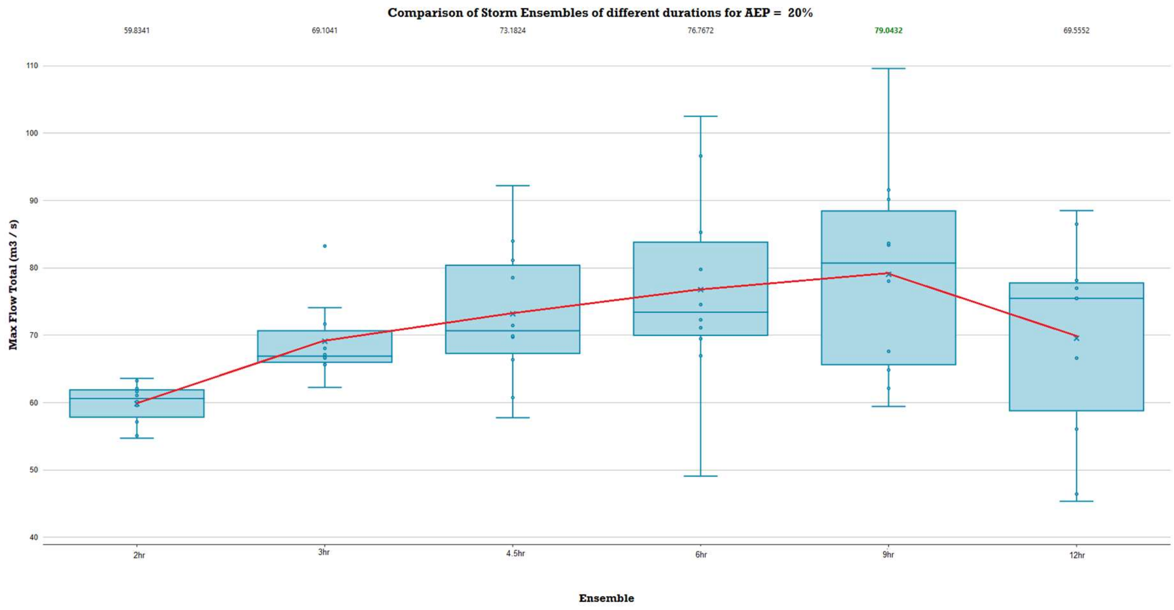


Image 6: XP-RAFTS 20%AEP hydrologic model design flows at the site



2.2.3 Design Flow Validation

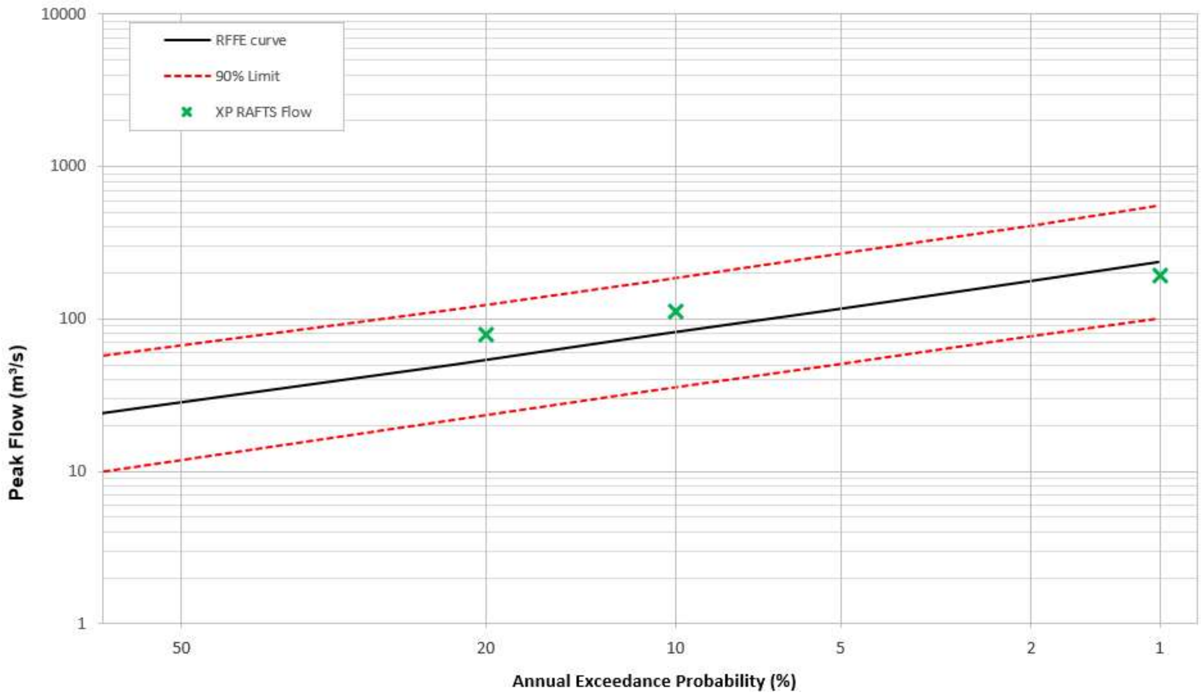
2.2.3.1 Comparison to RFFE

ARR2016 Regional Flood Frequency Estimation (RFFE) design flow estimates were obtained from https://rffe.arr-software.org/. The RFFE model has been developed as part of ARR2016 for the estimation of flows on ungauged small to medium sized rural catchments. The results of the RFFE for the Eulomogo Creek catchment to the site are presented in Attachment C.

It is important to note the ARR2016 states '*that the relative accuracy of regional flood estimates using the RFFE model is likely to be within ± 50% of the true value*' and as such, RFFE design flows estimates should be carefully considered. Accordingly, the 'output_nearby.csv' file was downloaded from the RFFE website and analysed for outliers that have the potential to adversely affect RFFE results. No obvious outliers were noted, providing some confidence in the RFFE model flow estimates for the site.

A comparison of XP-RAFTS flows to RFFE design flow estimates has been made with the results presented in Image 7 on a discharge frequency plot. The analysis indicates that the XP-RAFTS and RFFE design flow estimates are comparable, with the XP-RAFTS flow being higher than RFFE estimates for the 20% and 10% AEP events, and slightly lower than the 1% AEP estimate.

Image 7: Comparison of XP-RAFTS design flows and RFFE flow distribution



2.2.3.2 Comparison to TUFLOW rainfall on grid

A coarse (10m) Rainfall on Grid (RoG) TUFLOW model of the Eulomogo Creek catchment was used to further validate hydrologic model design flow estimates. The critical storms discussed above were applied to the RoG TUFLOW model using the direct rainfall method. Use of the direct rainfall method allowed TUFLOW to calculate catchment routing characteristics to validate the XP-RAFTS model parameters.

Table 4 presents a comparison of XP-RAFTS and RoG TUFLOW model peak flows at the site. The results indicate that the flows are comparable for all three events examined. The results improve the robustness of the XP-RAFTS design flow estimates.

Table 4: Comparison of XP-RAFTS and TUFLOW

AEP	XP RAFTS Peak Flow (m^3/s)	TUFLOW RoG Peak Flow (m^3/s)	Difference (%)
1%	200	234	+17%
10%	111	120	+8%
20%	83	80	-3%

3.HYDRAULICS

3.1 Hydraulic Model Setup

A TUFLOW hydraulic model was developed for the site. TUFLOW is a 1D/2D fully dynamic fixed grid-based model which is widely used throughout NSW and Australia for the assessment of flood hydraulics. The TUFLOW model was developed using best practices modelling methods, and parameters consistent with Australian Rainfall and Runoff.

3.1.1 Existing Conditions

A TUFLOW hydraulic model was constructed to represent existing conditions for the site. Various data and parameters implemented in the existing conditions TUFLOW model are outlined below:

- Model Domain and Grid Size – The hydraulic model domain covers an area of 785ha, extending from Sub-Catchment 11 (see Figure 1, ~600m to the East of the site) to the floodplain of the Macquarie river to west. A model grid size of 2 m x 2 m was implemented, which allowed for a minimum of 15 active cells perpendicular to flow direction. This grid resolution is considered adequate to model Eulomogo Creek channel characteristics.
- Digital Elevation Model (DEM) – The 1 m DEM ('*Dubbo201407-LID1-AHD*' dataset) has been used to inform the topography of the 2D hydraulic model.
- Manning Roughness – Manning values were selected based on inspection of aerial imagery. A Manning value of 0.055 has been applied to the creek and riparian areas, and a Manning of 0.05 to the floodplains and rural areas. This reflects the presence of vegetation along the intermittent water course discussed in Section 2.1. Areas of exposed basalt were assigned a Manning value of 0.03 and a value of 0.02 was assigned to the proposed road surface. The selected Manning values are consistent with previous studies conducted by others ("New Dubbo Bridge – Hydrology and hydraulics working paper – Roads and Maritime Services – February 2019") and ARR2016 guidelines.
- Boundary Conditions – XP-RAFTS flow hydrograph downstream of Sub-Catchment 10 was input as an upstream boundary condition and Sub-Catchment 11 hydrograph was included in the model as internal boundary condition. The downstream model boundary was applied as a static tailwater level. The applied level was the 1% AEP Macquarie River flood level obtained from the '*Dubbo City Council, Flood Prone Land Policy*' (May, 2013). The applied downstream boundary was noted not to influence flood levels at the site due to it being situated 1.5 km downstream, with over 10 m difference in elevation.

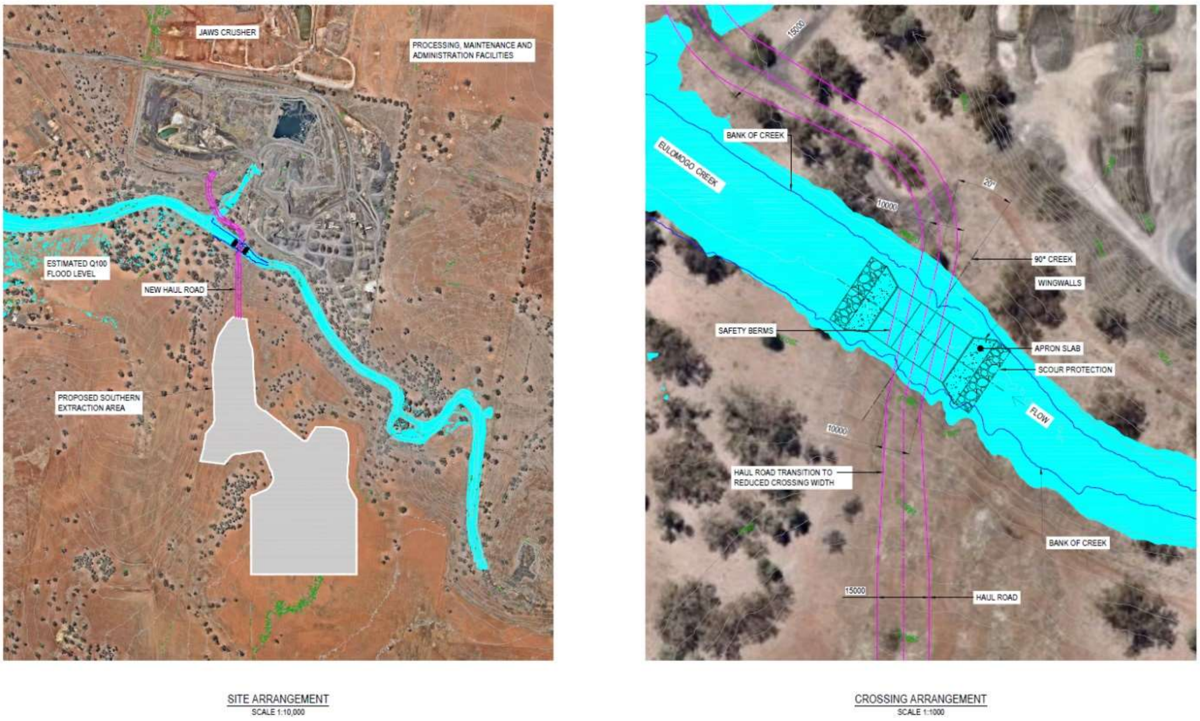
The existing conditions TUFLOW model schematisation is presented in Figure 2.

3.1.2 Proposed Conditions

The proposed Eulomogo Creek crossing concept design was implemented into the existing conditions TUFLOW model to develop a proposed conditions model. Proposed sediment basins were also assessed. The concept design was provided by EMM and was based on concept designs proposed in the *'Dubbo Quarry Continuation Project, Eulomogo Creek – Concept Options Report (Pitt & Sherry, May 2020)'*. A summary of the model changes are outlined below:

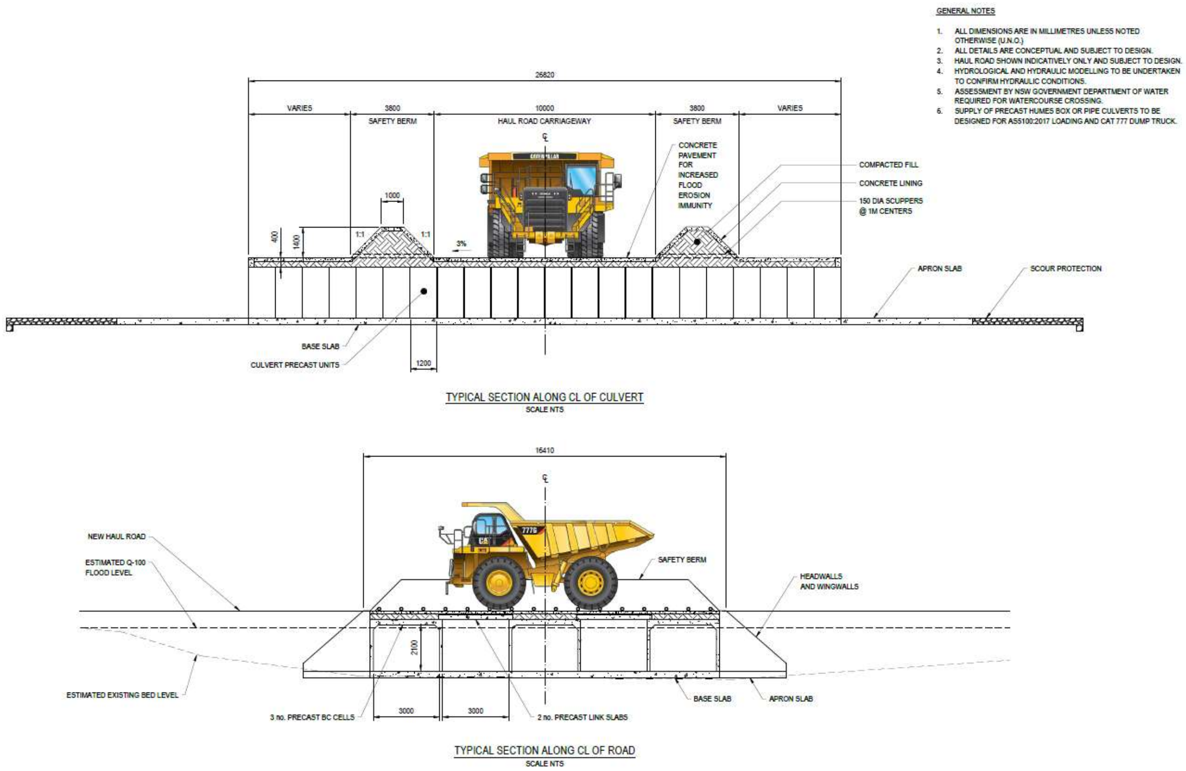
- Road Embankment – The Eulomogo Creek crossing road embankment was implemented into the model as per the alignment presented in the Pitt & Sherry (2020) report. The road alignment is presented in Image 8 and was set at a level of 280.40mAHD. The road feature includes two 1.4m height safety berms in accordance with Pitt & Sherry (2020) design drawings. The berms are not meant for flood protection (i.e. are not constructed with flood resistant materials) but do represent an obstruction to the flow and as such were included into the model.

Image 8: Eulomogo Creek Crossing Road Alignment (extract from Pitt & Sherry, 2020 report)



- Culverts – 5 x 3m x 2.1m concrete box culverts were included in the model to convey flow through the proposed road embankment as per the concept design presented in the Pitt & Sherry (2020) report (reproduced below in Image 9). Blockage was applied as per ARR2019 guidelines, with details presented in Attachment D. Culverts invert levels were set at the thalweg of the creek, upstream and downstream the road. Grading of the creek bed will be required to accommodate the structure.

Image 9: Eulomogo Creek Crossing Road Sections (extract from Pitt & Sherry, 2020 report)



The proposed conditions TUFLOW model schematisation for the concept crossing is presented in Figures 6.

3.2 Hydraulic Model Results

3.2.1 Existing Conditions

Existing conditions design flood depths and levels for the 1%, 10% and 20% AEP event are presented in Figure 3, 4 and 5 respectively.

Typical stream velocities are 3.5 m/s for the 1% AEP event, 3.0m/s for the 10% AEP event and 2.5m/s for the 20%AEP. Localised areas of higher velocities are noted.

Channel and floodplain cross sections have been extracted at three locations as presented in Image 10. These cross sections, presented in Image 11 to Image 13, aim to assist in visualising channel characteristics near the proposed creek crossing.

Image 10: Channel Cross Section and Flood Level – Location Map

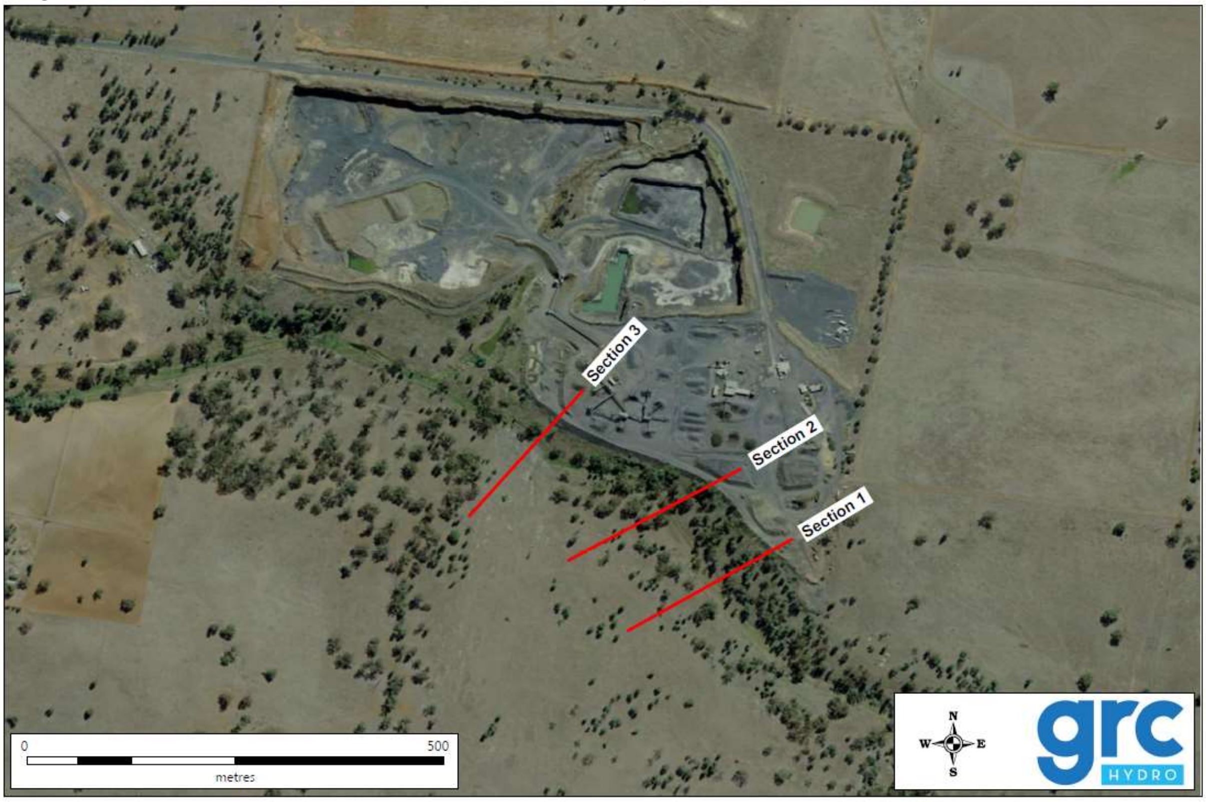


Image 11: Channel Cross Section #1 – Ground Elevation and Flood Levels (mAHD)

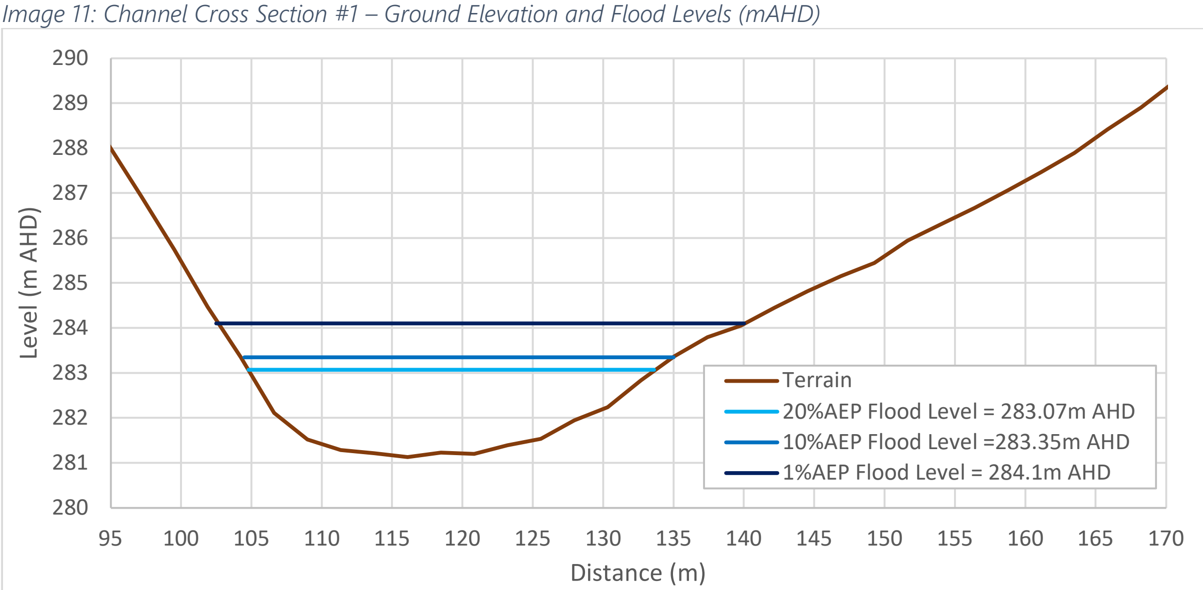


Image 12: Channel Cross Section #2 – Ground Elevation and Flood Levels (mAHD)

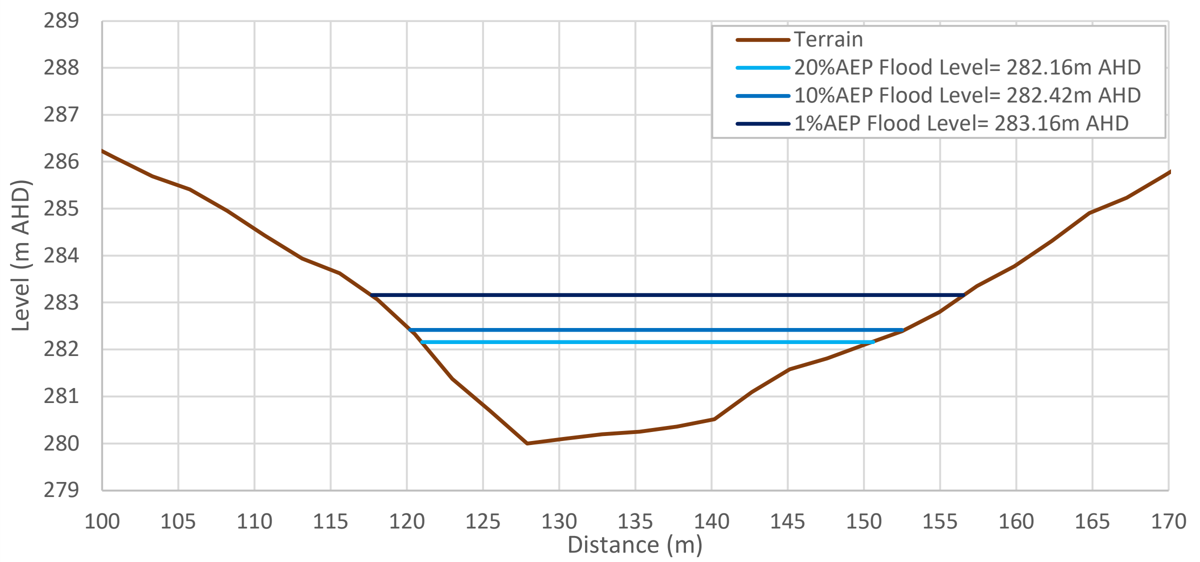
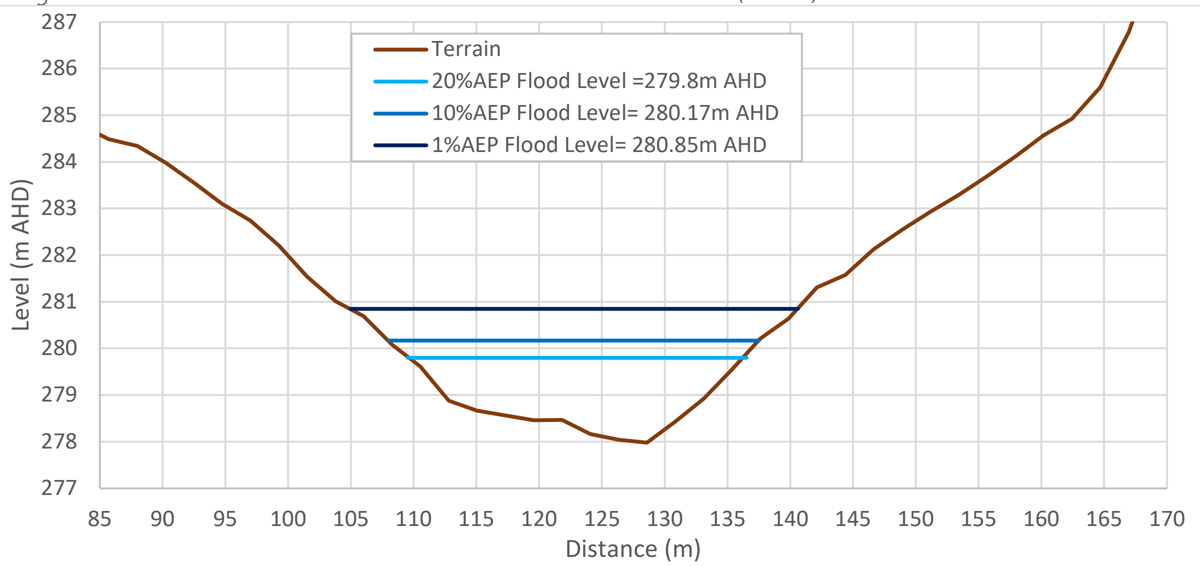


Image 13: Channel Cross Section #3 – Ground Elevation and Flood Levels (mAHD)



3.2.2 Proposed Conditions

Proposed Conditions design flood depths and levels for the 1%, 10% and 20% AEP event are presented in Figures 7, 8 and 9 respectively. A long section of the proposed creek crossing with design flood levels is presented in Image 14.

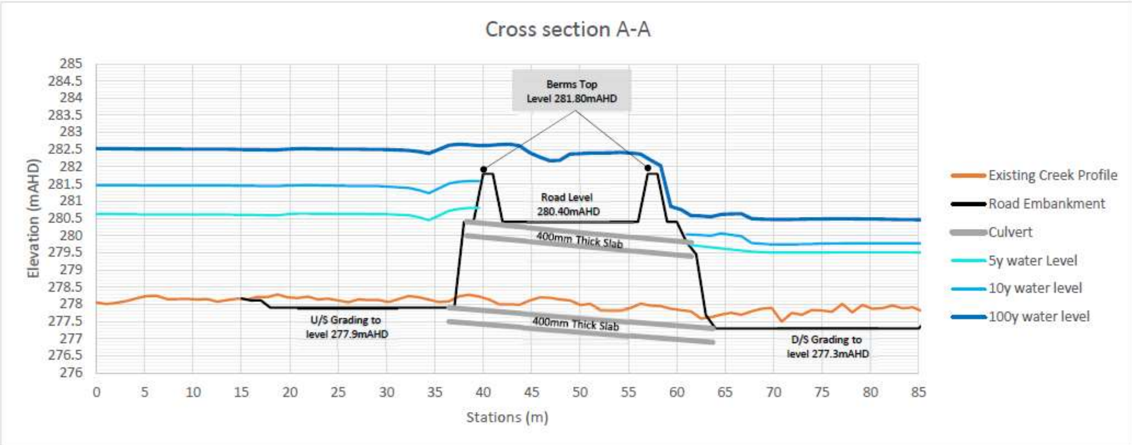
Expected average velocities through the culvert barrels are 4.3 m/s for the 1% AEP event and 3.6 m/s for the 10% AEP event and 20% AEP events.

Flood levels are expected to overtop the proposed road crossing as frequently as the 20% AEP event (assuming that the safety berms do not provide flood protection). However, Holcim have advised that alternate road access is available to the site which can be used during periods of flood if required for emergency access.

Image 14: Eulomogo Creek Crossing Long Section and Flood Levels

CULVERT DATA	
TYPE	CONCRETE BOX CULVERT
NUMBER OF CELLS	5
CELL WIDTH (m)	3
CELL HEIGHT (m)	2.1
Length (m)	~30
U/S I.L (m)	277.9
D/S I.L. (m)	277.3
SLOPE	2.00%

HYDRAULIC DATA	
5-Year Total Flow (m³/s)	83.58
5-Year Flow in the Culverts (m³/s)	83.58
5-Year Average Velocity in Culverts (m/s)	3.62
10-Year Total Flow (m³/s)	111.5
10-Year Flow in the Culverts (m³/s)	111.5
10-Year Average Velocity in Culverts (m/s)	3.63
100-Year Total Flow (m³/s)	201.3
100-Year Flow in the Culverts (m³/s)	115.6
100-Year Average Velocity in Culverts (m³/s)	4.32



Flooding of the creek crossing may pose a risk to vehicles attempting to use the crossing during times of flood. Appropriate warning signage and operating protocols should be implemented to manage this risk.

3.2.3 Flood Impact Assessment

A flood impact assessment has been undertaken by comparing existing and proposed conditions peak flood levels. Figures 10, 11 and 12 show the expected change in flood level associated with implementation of the proposed creek crossing.

Increases in flood level of up to 3 m are expected in the 1% AEP event, with impact reducing for more frequent events (maximum of 2.2m in the 10% AEP event and 1.7m in the 20%AEP event). However, the increases in water level are contained within the Quarry site (i.e. do not affect neighbouring properties) and do not extend more than ~300m upstream of the crossing.

4. CONCLUSIONS

Holcim's Dubbo Quarry is located approximately 6 km south-east of the Dubbo town centre and to the north of Eulomogo Creek. Holcim are proposing to expand the quarry's existing operations to the southern side of Eulomogo Creek. To facilitate the expansion, a haul road crossing is proposed to connect the southern and northern sides of Eulomogo Creek.

GRC Hydro has been appointed to undertake a flood study for the Site and to assess flood impacts associated with the proposed Eulomogo Creek crossing concept design.

Hydrologic modelling has been undertaken using XP-RAFTS, with design flows derived for the site for the 1%, 10% and 20% AEP events. Validation of the derived design flow estimates has been undertaken via comparison to ARR2016 Regional Flood Frequency Estimates (RFFE) and results from a coarse direct rainfall TUFLOW model developed for the upstream catchment. The validation results were found to improve the robustness of the XP-RAFTS design flow estimates.

A TUFLOW hydraulic model was constructed for the site on a 2 m grid resolution. Upstream and internal boundary conditions were applied based on outputs from the XP-RAFTS model, and the Macquarie River 1% AEP flood level was applied as a static tailwater level at the downstream boundary. Applied Manning values were consistent with nearby studies and ARR2016 guidelines.

Following feedback and discussion with Holcim, the Eulomogo Creek crossing concept design was developed by Pitt & Sherry (2020) and incorporated into the flood model as proposed conditions scenario.

Flood maps for the 1%, 10% and 20% AEP events were produced which present peak flood depths and levels for both existing and proposed conditions.

Flood levels are expected to overtop the proposed road crossing during the 20% AEP and greater magnitude events. However, Holcim have advised that alternate road access is available to the site which can be used during periods of flood if required for emergency access. Flooding of the creek crossing may pose a risk to vehicles attempting to use the crossing during times of flood and appropriate warning signage and operating protocols should be implemented to manage this risk.

Comparison of peak flood levels between the existing and proposed conditions show a water level increase up to 3 meters in the 1% AEP event, however flood impacts are confined to land owned by Holcim.

FIGURES

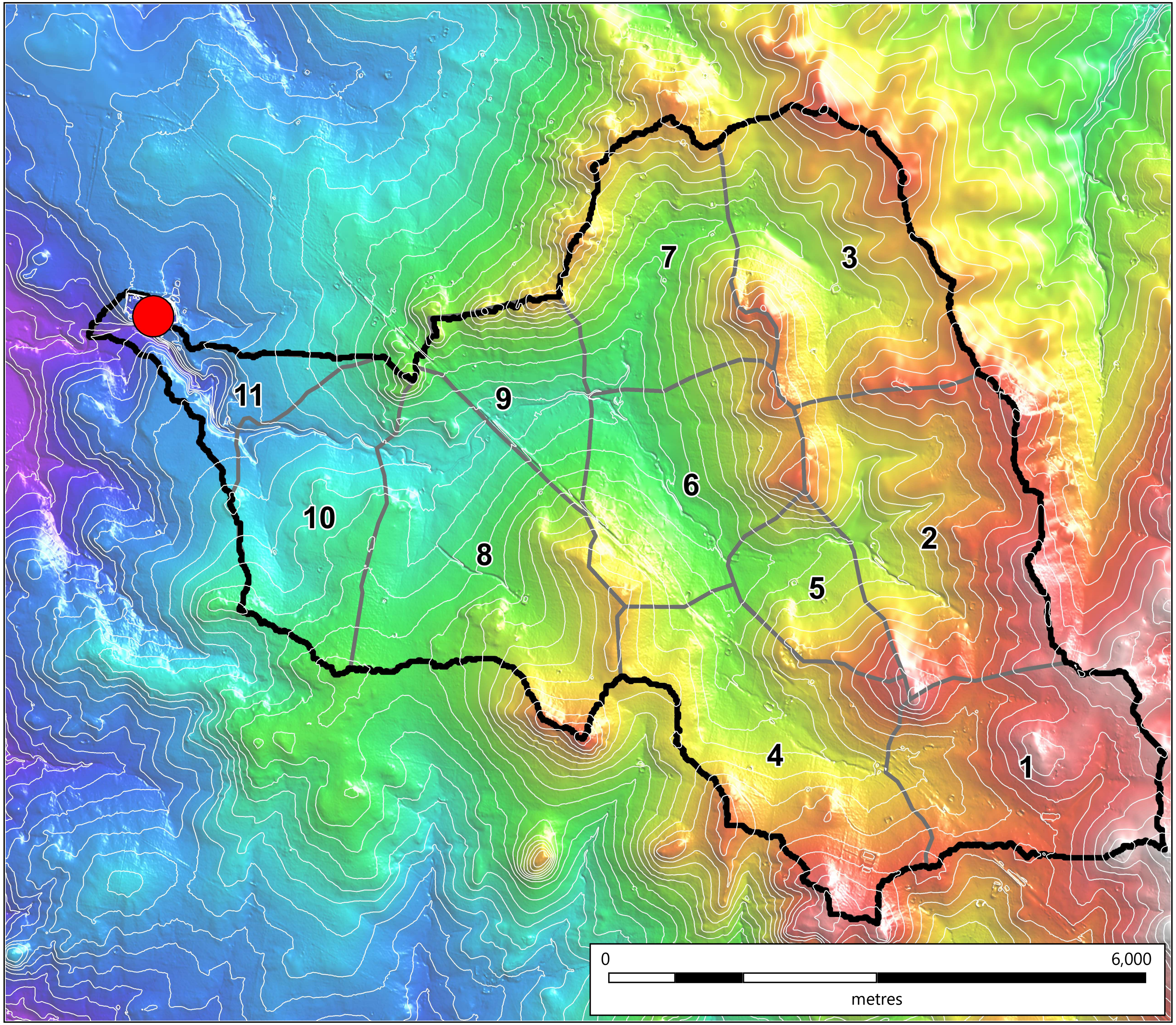


FIGURE NUMBER:	1
PROJECT: **DUBBO QUARRY - FLOOD STUDY**	
PROJECT NUMBER:	**190036**
SCENARIO:	
EVENT:	
TITLE: **GROUND LEVELS AND CATCHMENT AREA**	

Ground Levels (m AHD)

250 to 270
270 to 280
280 to 290
290 to 310
310 to 320
320 to 330
330 to 340
340 to 350
350 to 360
360 to 370
370 to 380
380 to 390
390 to 400
400 to 410
410 to 420

Project Location

Ground Level Contour Lines (5m Spacing)

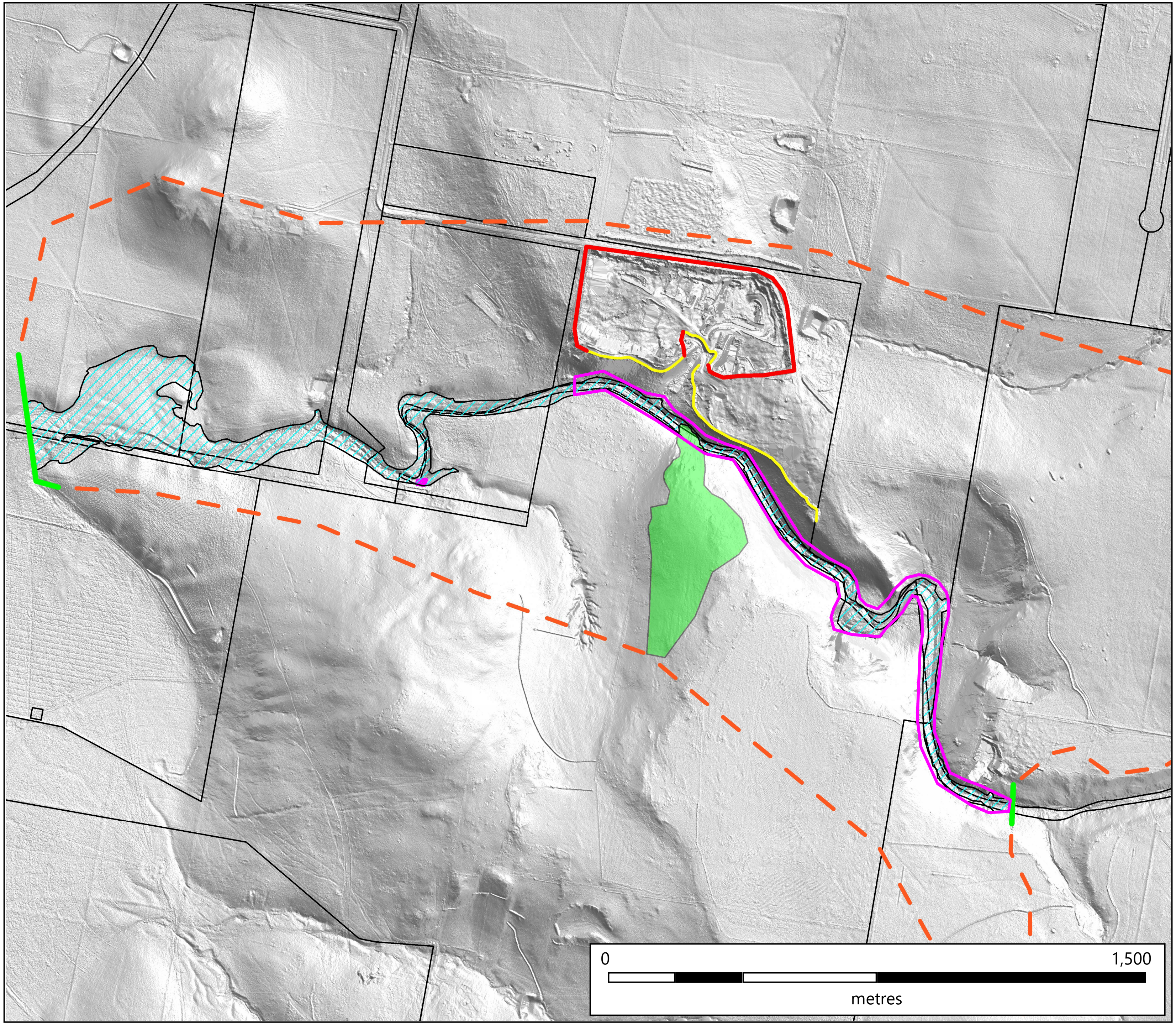
2 Sub-Catchment Areas

N W E S

grc HYDRO

FIGURE NUMBER:	**2**
PROJECT: **DUBBO QUARRY - FLOOD STUDY**	
PROJECT NUMBER:	**190036**
SCENARIO:	**EXISTING CONDITIONS**
EVENT:	

TITLE: **2D HYDRAULIC MODEL SETUP**



- Dubbo Quarry - Existing Area
- 2D Model Extent
- Upstream and Downstream Boundary Conditions
- Internal Boundary Conditions (Storage Areas)
- Creek Area (Manning = 0.055)
- Exposed Layer of Basalt (Manning = 0.03)
- Breaklines
- Cadastral Boundaries

N
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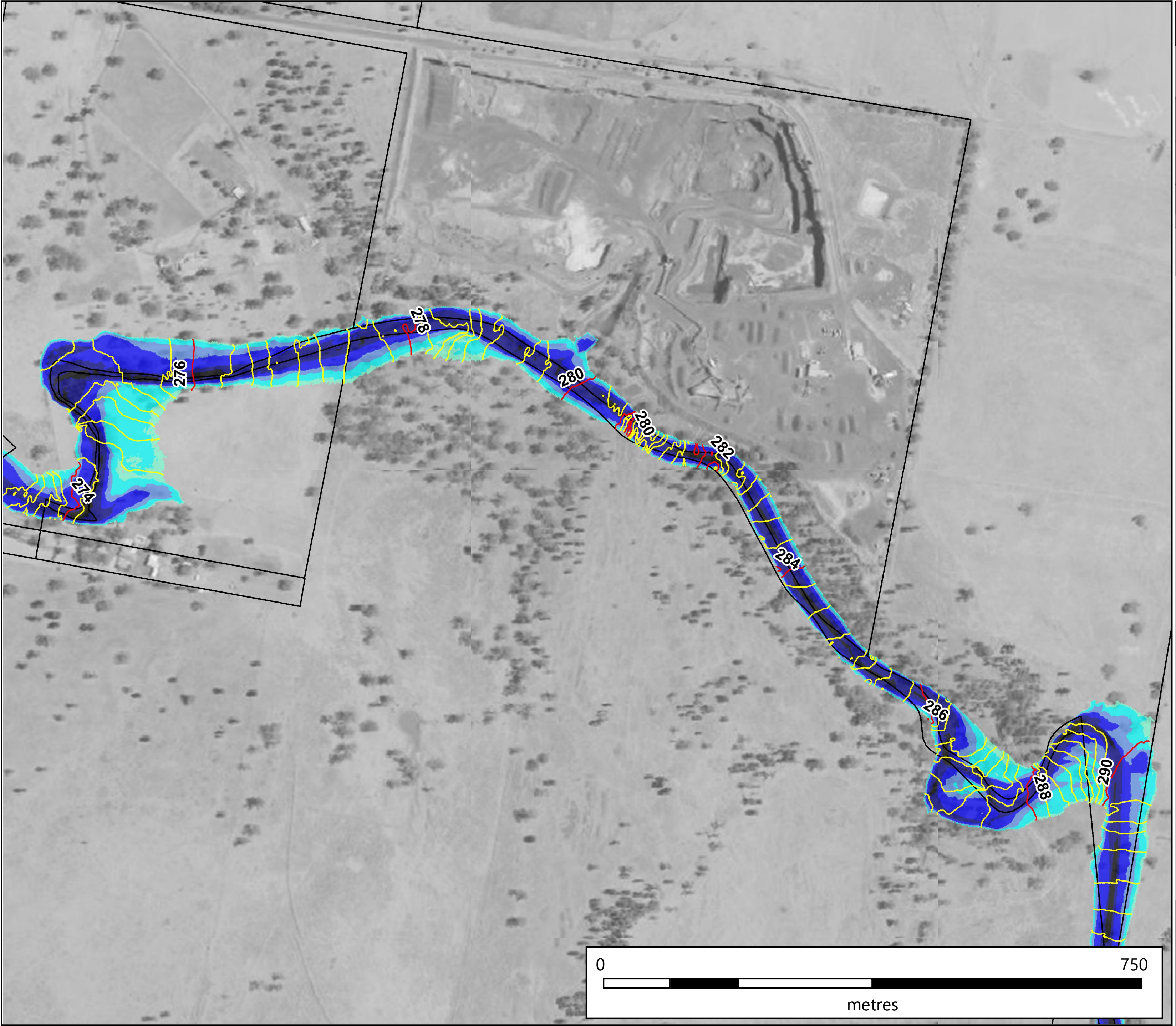

FIGURE NUMBER:	**3**
PROJECT: **DUBBO QUARRY - FLOOD STUDY**	
PROJECT NUMBER:	**190036**
SCENARIO:	**EXISTING CONDITIONS**
EVENT:	**1% AEP**
TITLE: **FLOOD DEPTH AND LEVELS**	

Flood Depth (m)

< 0.1

0.1 to 0.5

0.5 to 1.0

1.0 to 2.0

2.0 to 3.0

> 3.0

Major Flood Level Contours (2.0m Spacing)

Minor Flood Level Contours (0.25m Spacing)

Cadastral Boundaries

N W E S

grc HYDRO

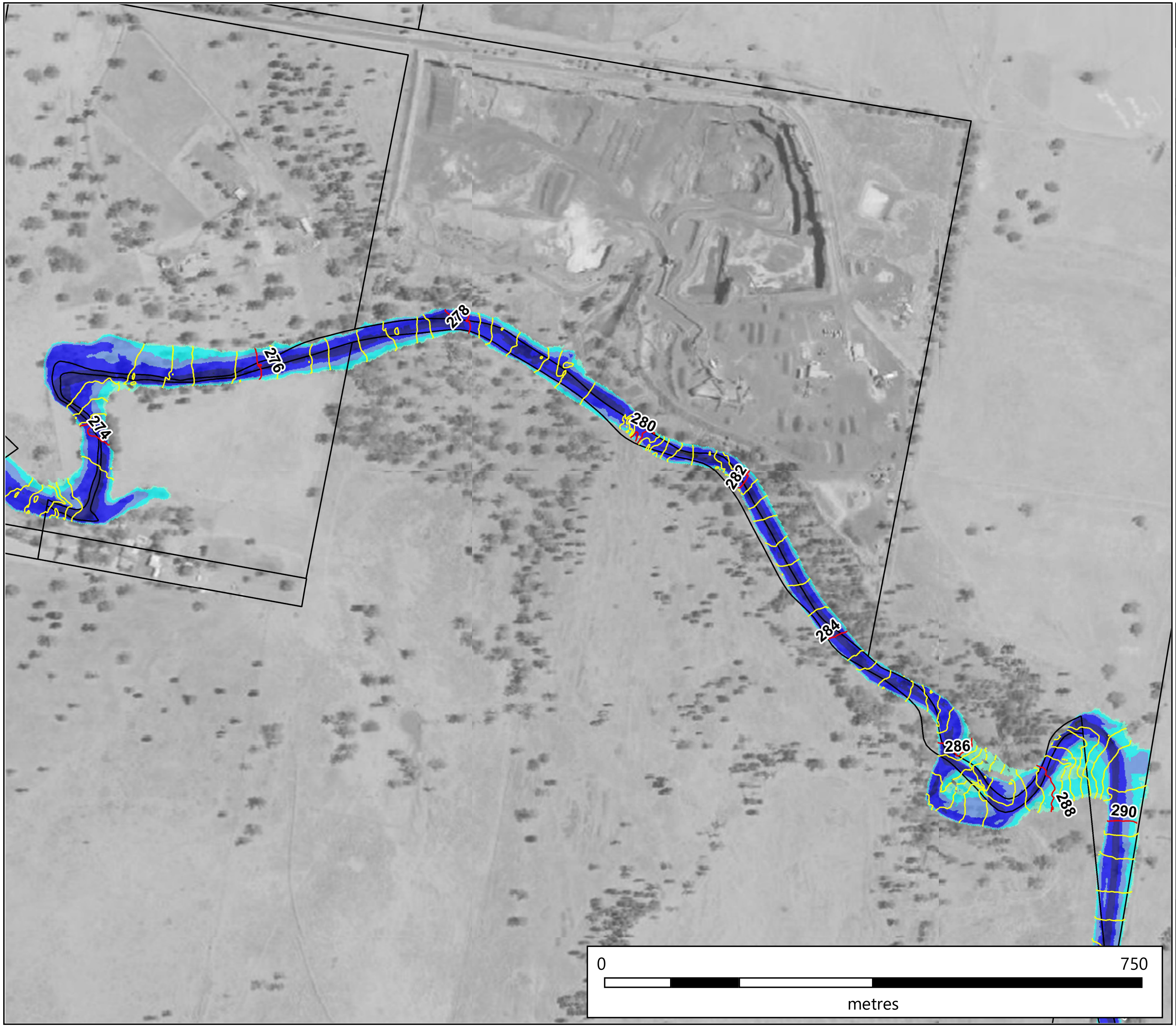

FIGURE NUMBER:	4
PROJECT: **DUBBO QUARRY - FLOOD STUDY**	
PROJECT NUMBER:	**190036**
SCENARIO:	**EXISTING CONDITIONS**
EVENT:	**10% AEP**
TITLE: **FLOOD DEPTH AND LEVELS**	

Flood Depth (m)

- < 0.1
- 0.1 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- > 3.0

Major Flood Level Contours (2.0m Spacing)

Minor Flood Level Contours (0.25m Spacing)

Cadastral Boundaries

N W E S

grc HYDRO