10.0 Surface Water

This Chapter describes the existing water environment on the Project Site in the context of surrounding catchments and sub catchments. The Chapter looks at the effectiveness of the existing water management system on the Project Site for managing water flows and water quality both on and off site and assesses the potential impacts of the continuation of quarrying and brick making operations in terms of water quality and surface water management. Mitigation measures are identified to minimise the impact of the Project on the surrounding water quality where appropriate.

10.1 Existing Environment

10.1.1 Catchments

The Project Site is situated within the Hawkesbury Nepean Catchment, with a total area of approximately 22 000 km^2 (2.2 million hectares) and which covers the majority of the western half of the Liverpool LGA extending west to the Hawkesbury Nepean River (the Liverpool LGA boundary). It includes two sub catchments, the South Creek catchment and Upper Nepean catchment.

The Project Site is located within the South Creek sub catchment which is part of the greater Hawkesbury Nepean catchment area. The South Creek sub catchment covers an area of 620 km^2 and is mostly made up of small rural farms and residential houses. The portion of South Creek sub catchment in the Liverpool LGA includes three major creeks -Kemps Creek, South Creek and Badgerys Creek. The main issues affecting the South Creek sub catchment include loss of vegetation, poor water quality and high soil salinity.

The main channel of South Creek is in a predominantly unmodified state as are its main tributaries, including Ropes Creek, Kemps Creek and Eastern Creek (RTA, 2002).

The Project Site rises within the central (65 m AHD) and southern (80 m AHD) site portions, and falls towards South Creek to the east (45 m AHD) and towards Badgerys Creek (50 m AHD) to the west.

10.1.2 South Creek

South Creek flows into the Hawkesbury River east of Windsor. It enters Liverpool LGA from the south and flows north for some 11 km before entering Fairfield LGA. South Creek forms the eastern property boundary of the Project Site and has a small tributary in the eastern portion of the Project Site.

South Creek is an intermittent creek of average health whose topsoil consists of brown, silty sand and clay. The creek has a very gentle slope and contains stagnant water with floating vegetation. There is frequent erosion along the river edge and banks contain weeds. The creek is used to water cattle which graze on the eastern portion of the Project Site.

The tributary of South Creek in the eastern portion of the Project Site is also of average health and has isolated connectivity. The topsoil of the area comprises mottled brown clayey silts with no erosion evident. Weeds are dominant and the tributary is used to water stock.

10.1.3 Badgerys Creek

Badgerys Creek is also located within the South Creek sub catchment and 7 km of Badgerys Creek is within the Liverpool LGA. The western property boundary of the Project Site adjoins Badgerys Creek and a small tributary of Badgerys Creek is located in the south-western portion of the Project Site, between the western stockpile and Pit 2 (see **Figure 4**) (Liverpool City Council, 2009).

Badgerys Creek is a permanent creek of average health whose topsoil consists of fine grained, orange-brown sandy silt. There is scattered erosion in this area, frequent weeds and a few dead trees.

The Badgerys Creek tributary is a seasonal or intermittent creek of poor health with eroded banks and large areas of weeds. Topsoil comprises grey, silty, sandy clay soils.

10.1.4 Flood Prone Areas

Current quarrying operations on the Project Site are located outside of the flood prone areas identified on LCC flood maps and the SWGC Flood Zone Map. However, a portion of the Project Site that is east of Martin Road is located within the South Creek floodplain and the western site boundary along Badgerys Creek is located within the Badgerys Creek floodplain (see **Figure 8**). The Western stockpile located in the south west corner of the Project Site is within the Badgerys Creek floodplain has been in its current location since 2002 and has been rehabilitated to provide a stabilised final landform. The dimensions of the Western stockpile would not change as a result of the proposal.

10.1.5 On Site Drainage

Existing surface water flow on the Project Site is shown on **Figure 8**. Within the disturbed area, there are seven sub catchments including:

- **Sediment Basins 1 and 2**

  The catchment of Sediment Basin 1 includes the area around the brick making facility, gate house, pallet storage area and a small overland flow component. Sediment Basin 1 has a total catchment area of 17.3 ha.

  Capacity exists for runoff from Pit1 to be pumped into Sediment Basin 1 on an as required basis in order to maintain the volume of Pit 1.

  Sediment Basin 1 overflows into Sediment Basin 2. Sediment Basins 1, 2 and 3 are used for stock watering and irrigation of pasture as part of the dairy operation.

  There are also additional minor sediment basins at the bases of several of the stockpiles on the Project Site. These sediment basins aid sediment removal from site runoff and reduce the volume of run-off entering the Project Site water management system. In larger rainfall events, these additional sediment basins are submerged and run-off flows via roads and open grassed channels to Pit 1.

- **Pit 1**

  Pit 1 has the largest catchment on site, comprising 37.2 ha. Pit 1 contains a basin and a floating off-take pump. Runoff from the unusable material and overburden stockpiles to the south of Pit 1 drain to the Pit 1 Basin. During minor rainfall events runoff ponds in localised areas or smaller sediment basins, however during larger rainfall events the minor sediment basins are submerged and run off flows to Pit 1 via roads and open grassed drains. Surface water detained in Pit 1 is either transferred to Sediment Basin 1 via the off-take pump, remains stored within the pit or is used for dust suppression across the Project Site.

- **Pit 2**

  Pit 2 is currently being rehabilitated. It contains a sediment basin and pump out facilities. Runoff flowing to Pit 2 is pumped into Pit 1.

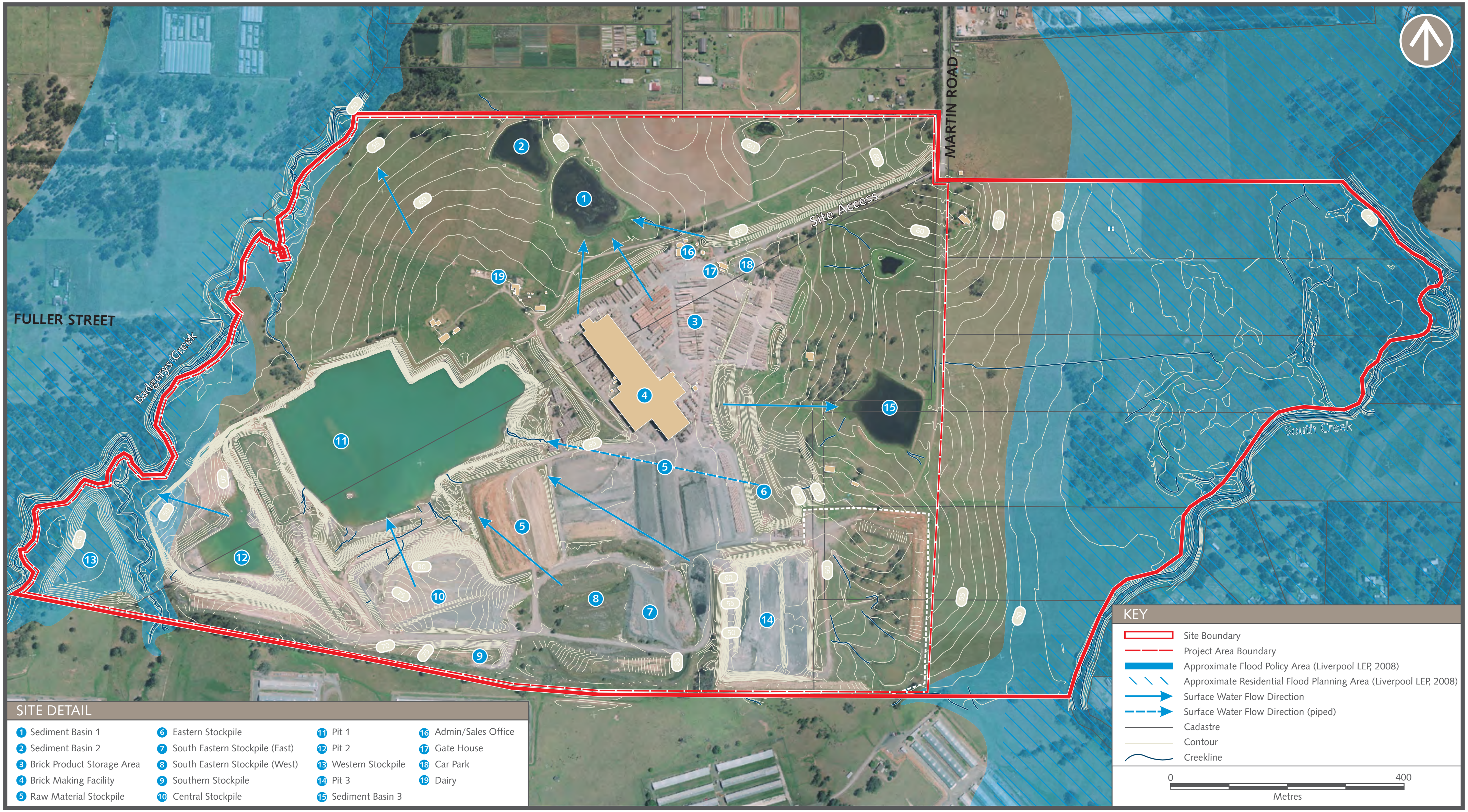
- **Pit 3**

  Pit 3 is the active pit where quarrying is currently occurring. Water collected in this pit is pumped to Pit 1.

- **Brick making facility**

  Roof drainage from the brick making facility flows via the gutter, downpipe, external perimeter open drain, pipe, then grass swale to Sediment Basin 3. Sediment Basin 3 is used as a stock watering point by the on-site dairy farming operation. Sediment Basin 3 also has an overland flow catchment.

  Areas surrounding the brick making facility drain separately, with the northern side draining to Sediment Basin 1 via a slotted agricultural pipe, and the southern part draining via an access road and a culvert into Pit 1.



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EXISTING SURFACE WATER MANAGEMENT

Environmental Assessment

Boral Quarry and Brick Making Facility, Badgerys Creek

Figure 8

- **Western Stockpile**

  The Western stockpile drains to both Badgerys Creek and a Badgerys Creek tributary and is at a lower elevation than the surrounding site.

  Rehabilitation of this stockpile was undertaken in March 2006 to prevent runoff and sediment from entering Badgerys Creek and the Badgerys Creek Tributary. This rehabilitation involved sediment fencing, earthworks (including slope reshaping, crest bunding and contour deep ripping), waste amelioration (including the use of gypsum, the use of chicken manure as a topsoil alternative, final ripping/scarification) and revegetation (including pasture establishment and native woodland establishment).

- **South East Drain**

  A section of the southern end of the raw material stockpiling area, a section of road and an unusable material stockpile drain to the south via a grassed open drain and culvert. During minor rainfall events localised ponding may occur and during larger events discharge is controlled through bunding.

- **East Drain**

  Runoff from the eastern stockpile and the raw material stockpiles runs through dish drains and is piped into Pit 1. The Eastern stockpile is vegetated to control erosion. The raw material stockpiles are generally used within a 12 month period and show no signs of significant erosion.

The majority of run-off from the Project Site flows to Pit 1 or Sediment Basin 1. Runoff collected within Pit 1 is reused for dust suppression during quarry campaigns on Project Site and Sediment Basins 1, 2 and 3 are used for stock watering and irrigation of pasture as part of the dairy operation. There is no stormwater discharge offsite.

10.1.6 Sewage Disposal

Sewage is discharged from the plant, gate house office and Project Site office to three septic tanks. The site office and plant septic tanks are connected to absorption trenches located west of the brick making facility. Retained solid effluent from the gate house and site office septic tanks is pumped out on a monthly basis by a licensed contractor and biannually from the Plant as required.

10.1.7 Truck Washing Facility

The truck wash facility located in the central north portion of the Project Site, north east of Pit 1, captures dirty water in an oil and water separator. Clean water from this area is piped back to the brick making facility.

10.2 Potential Impacts

Operation of the quarry and brick making facility would involve activities largely the same as those currently carried out on the Project Site, however the proposed works would result in the loss of some existing water storage and the creation of additional voids (expanded Pit 3, Pit 4 and Pit 5).

The establishment of Pits 4 and 5 would result in the loss of Sediment Basins 1, 2 and 3 and the continued rehabilitation of Pit 2 would ultimately result in a change to the landform in the western portion of the Project Site, such that the existing void would be filled to just above ground level. This would also result in potential impacts to stormwater runoff.

10.2.1 Stormwater Runoff

In order to manage stormwater runoff and achieve nil discharge from the Project Site as under existing operations, runoff currently draining to Sediment Basins 1, 2 and 3 would be diverted to Pit 1 for storage and use for dust suppression.

The proposed project would ultimately result in the following changes to site drainage although these would occur in stages over the life of the project:

- Diversion of drainage of brick making facility and surrounding sealed area;
- Total site operating area to increase from 64 hectares to approximately 114 hectares;
- Pit 3, Pit 4 and Pit 5 to have surface areas of approximately 8.9, 14.2 and 19.5 hectares respectively;
- Pit 3 and Pit 4 to be used as water storage pits post quarrying;

- Pit 5 to be pumped to Pit 4 for storage during active quarrying;
- Either infrastructure to be installed to enable Pit 1 to spill to Pit 4 and Pit 4 to spill to Pit 3, or catchment plan to be reconfigured to reduce Pit 1 catchment area and increase Pit 3 and Pit 4 catchment area; and
- Water captured in Pit 1 to be used for increased dust suppression as per AQMP. Boral to actively investigate and pursue opportunities for the reuse of this water for other beneficial purposes.

Figure 9 illustrates proposed surface water management on the Project Site.

Water Balance Modelling

As part of the EA, water balance modelling was undertaken based upon a single 'worst case scenario' represented by the full development of Pits 4 and 5. The objective of the modelling exercise was to assess the ability of the Project Site to provide on-site water retention with no offsite discharge. The model comprised two components:

- Estimating the storage capacity required to contain runoff from the individual design rainfall event (90th percentile, 5 day) as required by the EPL; and
- Water balance modelling to develop strategies for achieving no offsite discharge over a 10 year rainfall period.

Modelling Approach

The modelling approach is described in detail in the *Addendum to Badgerys Creek Brick Works Soil and Water Management Plan* (AECOM, 2010), included as **Appendix C** to this EA. Modelling was undertaken in accordance with *Managing Urban Stormwater: Soils and Construction – Mines and Quarries* (DECC, 2008) which recommends carrying out water balance modelling with a daily time-step over a ten year period when assessing the performance of internal quarry storages. The major inflows and outflows of the Project Site considered in the water balance are shown in **Table 37**.

Table 37: Summary of inflows and outflows

Inflows	**Outflows**
Initial system storage	Evaporation from pit surfaces
Direct rainfall onto pit surface	Seepage losses (assumed to be negligible)
Rainfall/runoff within catchment	Controlled extraction of water for dust suppression or to manage storage levels

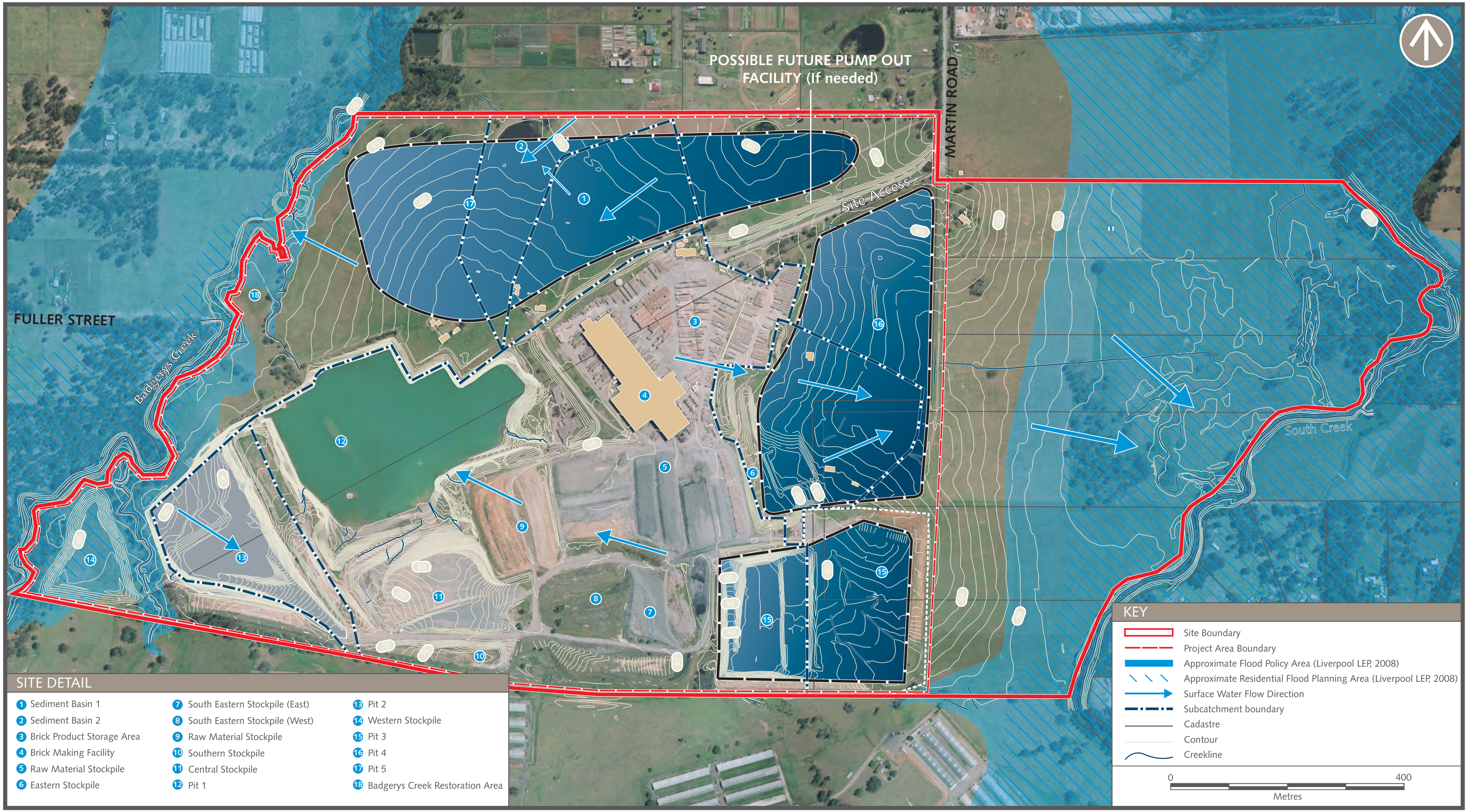
Modelling Results

The results of modelling in relation to the available storage capacity to accommodate an individual rainfall event as required by the EPL for the Project Site are summarised in **Table 38**.

Table 38: Available site storage capacity required to comply with EPL requirement

Catchment	**90th Percentile, 5 day Volume (m^3)**
Pit 1	5368
Pit 3	3030
Pit 4	4377
Pit 5	7408
Impervious	2939
Other Pervious	18405
Total	**41528 (42ML)**

Allowing for sediment loading over 20 years for the 'worst case scenario', all pits have capacity to contain runoff of approximately 42 ML from a 90th percentile, five day rainfall event at the Project Site.



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PROPOSED SURFACE WATER MANAGEMENT

Environmental Assessment

Boral Quarry and Brick Making Facility, Badgerys Creek

Figure 9

Detailed results of ten year water balance modelling for the Project Site are provided in **Appendix C**. The results indicate that the combined capacity of Pit 1, Pit 3 and Pit 4 is sufficient to contain site runoff without offsite discharge post development of Pit 4 and Pit 5, subject to a reconfiguration of the catchment plan or the installation of infrastructure to enable Pit 1 to spill to Pit 4 and Pit 4 to spill to Pit 3.

Based upon this arrangement, the level of on-site storage would be sufficient to contain runoff on the Project Site without discharge for ten years. Beyond ten years the combined storage level of these pits would eventually reach capacity, however, once operations at Pit 5 are complete, significant additional storage would be available in this void. In addition, the extraction regime applied on the Project Site could be adapted to assist with the management of storage levels and spill risk. Extraction regimes can reduce the risk of uncontrolled offsite discharge by stabilising storage levels. A daily extraction regime may include a future reuse project where stored runoff is frequently used in the brick making process or for reuse at other premises offsite. Currently 30 kL/day of water is extracted from Pit 1 for reuse onsite for dust suppression.

Due to the low level of reuse currently proposed for captured runoff, storage levels in pits are generally likely to rise over time, and a storage solution alone would likely exceed the capacity of Pits 1, 3 and 4 over a 10-15 year outlook for the ‘worst case scenario’. It is important to note however that the conservative ‘worst case’ scenario represents the largest likely total catchment area post development of Pit 4 and Pit 5, and assumes infiltration from storage pits to be negligible. It is also important to note that the existing Pit 1 has contained onsite runoff for many years without spill.

Given the transition from the current catchment configuration to the potential ‘worst case’ scenario is likely to occur over the next 5-10 years and the quarrying of Pit 5 is expected to provide additional storage capacity in the next 10-15 years, the proposed storage is considered sufficient to contain runoff without site discharge for the next 20 years.

It is noted that the WM Act identifies basic landholder rights including harvestable water rights and when access licences are required. The harvestable water right has been defined in terms of an equivalent dam capacity, the Maximum Harvestable Right Dam Capacity (MHRDC). Schedule 1 of the *WM Regulation* exempts certain classes of dam including those dams solely for the capture, containment and recirculation of drainage and/or effluent, consistent with best management practice or required by a public authority to prevent the contamination of a water source. Consequently, as the on-site pits (dams) are used solely for the capture, containment and reticulation of drainage, consistent with best management practice to prevent the contamination of Badgerys Creek, the pits (dams) are exempt from the need to obtain a licence under the WM Act.

10.2.2 Water Quality

To date there have been no recorded discharges from the Project Site with the majority of run-off from the Project Site flowing to Pit 1 or Sediment Basin 1, where it is used for stock watering, irrigation, dust suppression or is simply stored.

The development of future quarry pits would alter surface water flow and sub-catchments across the Project Site and would also increase the area of surface disturbance on the Project Site resulting in greater potential for water quality impacts, including:

- Increased potential for erosion and sedimentation resulting in associated increased potential for sediment laden runoff to enter surrounding waterways, potentially resulting in increased turbidity and degradation of water quality; and
- Increased potential for contamination of soil and water resulting from accidental spillage of fuel from vehicles or machinery entering nearby waterways.

As the Project Site would remain a nil discharge site with surface water runoff fully contained on site, the proposal would not impact on the water quality of either Badgerys or South Creeks.

10.2.3 Flooding

Current quarrying operations on the Project Site and the proposed future quarry Pits 4 and 5 are outside of the flood prone areas identified on Council’s flood maps and the SWGC Flood Zoning Map (refer to **Figure 8**).

As the location of future quarrying is not within the South Creek or Badgerys Creek floodplains, the proposal would not have a significant impact on the natural functioning of the floodplain and the quarry pits themselves would not be at significant risk from flooding.

The Western stockpile located in the south west corner of the Project Site is within the Badgerys Creek floodplain and has been in its current location since 2002. The dimensions of this stockpile would not change as a result of the proposal and therefore would not impact on existing flood storages.

10.3 Mitigation Measures

Soil and water management on the Project Site is well established and the existing operation is managed under a SWMP with nil discharge to the receiving environment. The SWMP investigated the existing stormwater catchment areas and identified management measures which have been implemented on the Project Site. These management measures include bunding, silt fences, an emergency spill kit and stormwater reporting sheets for monitoring purposes. As part of this EA, the SWMP has been updated via an addendum to reflect the proposed future operations over the next twenty years (**Appendix C**) and includes recommendations with regard to the management of stormwater runoff over the life of the project, including:

- Reconfiguration of the catchment to proportion runoff going to storage pits according to their storage capacity. This would maximise the timeframe before spills would occur in the proposed storage pits. For Pit 4, this could be achieved by regrading the area between Pit 4, Pit 5 and Pit 1 to flow to Pit 4, in addition to draining Pit 5 to Pit 4. For Pit 3, this could be achieved by regrading part of the eastern and south eastern stockpiles to drain to Pit 3.
- As an alternative to catchment reconfiguration, infrastructure could be installed to allow Pit 1 to spill to Pit 4 and Pit 4 to spill to Pit 3.
- Investigation of options for the reuse of water stored on-site for beneficial use in order to increase the extraction regime to improve on-site storage capacity. The potential for managing storage levels through adapting the extraction regime onsite is discussed in **Appendix C.**
- Monitoring of storage levels in Pits1, 3 and 4 such that spill risk is managed and the need for additional storage and/or extraction can be readily identified.

Additional mitigation measures to be implemented on the Project Site in relation to proposed operations include:

- The continued use of drains, silt fences and bunding to direct site runoff into appropriate sediment basins and to control erosion;
- Stabilisation of disused stockpiles to minimise the risk of erosion;
- Diversion of stormwater runoff from Sediment Basins 1, 2 and 3 to Pit 1 upon establishment of Pits 4 and 5;
- The use of flocculants in sedimentation basins to increase sediment removal rates if required;
- The removal of oil and grease within the sediment basin by volatilisation if required;
- The maintenance of a riparian corridor of 50 m in width along Badgerys Creek;
- Routine maintenance and inspections of drains, sediment basins and bunds; and
- The continued use of a combination of town water and recycled water for the brick making process.

10.4 Conclusion

The potential water quality and management impacts associated with the proposed project include an increase in the volume of on-site water storage required as a result of the project as the Project Site would continue to operate with nil offsite discharge.

The increased risk of sediment-laden runoff entering nearby waterways due to increased surface disturbance and increased duration of the existing quarrying activities at the Project Site would be significantly reduced by the containment of water onsite. The project is therefore not expected to have significant impacts on surface water on the Project Site or in the surrounding waterways subject to the maintenance and augmentation of water management measures.

11.0 Groundwater

Based on review of existing data, a conceptual model of the hydrogeological regime within the Project Site has been developed. This section discusses the conceptualisation and data used to develop the model as well as potential impacts, mitigation measures and proposed investigation works for continued quarrying activities at the Project Site.

11.1 Existing Environment

11.1.1 Regional Geology and Geomorphology

As indicated by the *1:100 000 Geological Series Sheet 9030 for Penrith*; NSW DMR 1991, the geology in the vicinity of the Project Site comprises the Wianamatta Group of Triassic age, which is made up of shale, carbonaceous claystone, laminate, fine to medium grained lithic sandstone, rare coal and tuff that is predominantly of marine origin. The Wianamatta Group comprises three main geological units, namely the Bringelly Shale, Minchinbury Sandstone and Ashfield Shale. The Bringelly Shale is mined within the Project Site.

The Wianamatta Group extends to a depth of up to 110 m within the southern Sydney Basin and is underlain by the Hawkesbury Sandstone which comprises a medium to coarse grained quartz rich sandstone with claystone, siltstone, minor shale and shale lenses and is known to contain significant amounts of groundwater in some parts of the Sydney Basin.

The creek systems adjacent to the Project Site (Badgerys Creek and South Creek) are flanked by surficial Quaternary fluvial deposits comprising medium grained sands, clays and silts.

The regional geology is dominated by the north-south trending Lapstone Monocline and Nepean Fault west of the Site, the Luddenham Dyke System, and a series of anticlinal and synclinal structures. Block faulting has disrupted the strata in the vicinity of the Project Site and faults have been observed within existing excavations and interpreted from core data within the Project Site.

A summary of the local stratigraphic sequence is provided in **Table 39**. The maximum depth of quarrying activities associated with the development is approximately 35 metres, within the Bringelly Shale.

Table 39: Upper Stratigraphy of the Southern Sydney Basin

Period	Group	Stratigraphic Unit	Indicative Depth to Base of Formation	Lithology	Hydrogeology[1]
Triassic	Wianamatta Group	Bringelly Shale	60 m	Shale, carbonaceous claystone, claystone, laminate, fine to medium grained sandstone, rare coal and tuff.	Aquitard Total Dissolved Solids (TDS) > 3000 mg/L
		Minchinbury Sandstone	70 m	Fine to medium grained quartz lithic sandstone.	
		Ashfield Shale	110 m	Dark grey to black claystone, siltstone and fine, sandstone-siltstone laminate.	Aquitard TDS >3000 mg/L
	Mittagong Formation		120 m	Interbedded shale, laminate and medium grained quartz sandstone.	
	Hawkesbury Sandstone		300 m	Medium to coarse grained sandstone, minor laminated mudstone and siltstone lenses.	Aquifer TDS <500mg/L Yields: 0.2 to 2 L/sec Transmissivity = 3 m²/day

11.1.2 Hydrogeological Setting

The hydrogeological regime of the Project Site is dictated by the structural and textural characteristics of the Bringelly Shale. Bringelly Shale is typically characterised by low permeability and groundwater velocities due to the fine grained and consolidated nature of the interbedded claystones and siltstones. Although technically the Bringelly Shale and Ashfield Shale units are considered aquitards not aquifers, they contain limited (and localised) quantities of saline groundwater, with groundwater flow restricted to occasional horizontal bedding planes or discontinuous carbonaceous lenses within the shales. Groundwater movement within the shale aquitard is minor and occurs within these horizontal zones of slightly higher permeability. Fracturing and faulting may impart a secondary permeability on the rock mass, however these fractured bedrock systems tend to be laterally and vertically discontinuous, resulting in poor hydraulic connection and low groundwater yields. Shallow or 'perched' groundwater is expected as a result of infiltrating rainwater accumulating at the interface between weathered and fresh shale.

Groundwater associated with the Wianamatta Group formations is characteristically saline due to its formation within a marine environment, and is generally unsuitable for extraction and use. Naturally elevated concentrations of metals are also commonly reported for groundwater within these units.

Alluvial deposits of unconsolidated clays and silts with minor sand are present associated with Badgerys Creek to the east and South Creek to the west of the Project Site. Due to the shallow nature of the alluvial deposits, groundwater is highly responsive to rainfall and stream flow. Groundwater flow within the alluvial sediments is expected to follow topography and flow towards the creeks and it is likely that the alluvial aquifer is hydraulically connected to the creeks.

The Hawkesbury Sandstone, underlying the Wianamatta and Mittagong formations is known to contain groundwater suitable for extraction and augmentation of Sydney's potable water supply within the Sydney Basin. However, as the maximum depth of excavation in the development is approximately 35 m, the Hawkesbury

[1] McKibbin and Smith (2000). Sandstone Hydrogeology of the Sydney Region.

Sandstone aquifer, which lies more than 100 m below the surface at the Project Site would not be intercepted or impacted by the development.

11.1.3 Project Site

The Project Site is underlain by the lower 51 metres of the Bringelly Shale. Shale exposed at the surface has weathered to form a clay horizon across the Site, averaging approximately six metres in depth. Groundwater is expected to collect (perch) at the interface between weathered and fresh shale, and/or in iron stone bands within the weathered zone, and reflects seepage from the surface which accumulates locally in joints within the weathered zone.

The quantity of perched groundwater on top of the fresh shale is invariably limited and when exposed during extraction, quickly evaporates on the side walls of the excavation. The presence of limited groundwater within this weathered zone is supported by Project Site exploration drilling, which did not identify groundwater within this zone.

Exploration drilling within the floodplain adjacent South Creek has identified alluvial sediments between three and ten metres in thickness. Groundwater within these alluvial sediments has been identified up to 200 metres from the current alignment of South Creek (Borehole RP18). Groundwater levels encountered within the alluvial sediments suggests connectivity between the alluvial aquifer and South Creek.

Alluvial deposits or groundwater associated with Badgerys Creek have not been encountered within the Project Site. The overbank deposits associated with Badgerys Creek predominantly lie to the west of the creek, with limited alluvial material deposited on the Project Site (east) side of the creek. Alluvial deposits were not reported in the closest boreholes to Badgerys Creek (RP10, RP25, located approximately 60 m from Badgerys Creek), and the topography of the Project Site indicates that alluvial sediments associated with Badgerys Creek would be limited on the Site. Slightly increased groundwater inflows into Pit 2 were reported when the excavation advanced to within 20 metres of Badgerys Creek. Excavation ceased and the area has since been rehabilitated.

Extraction within the Project Site to date has resulted in negligible groundwater inflow into the pits.

11.2 Groundwater Usage

A database search of registered groundwater bores in the vicinity of the Project Site identified 14 bores within a five kilometre radius of the development. The locations of the registered bores are provided on **Figure 10**.

The registered uses of the bores were described as being for:

- Monitoring;
- Domestic stock; and
- Industrial.

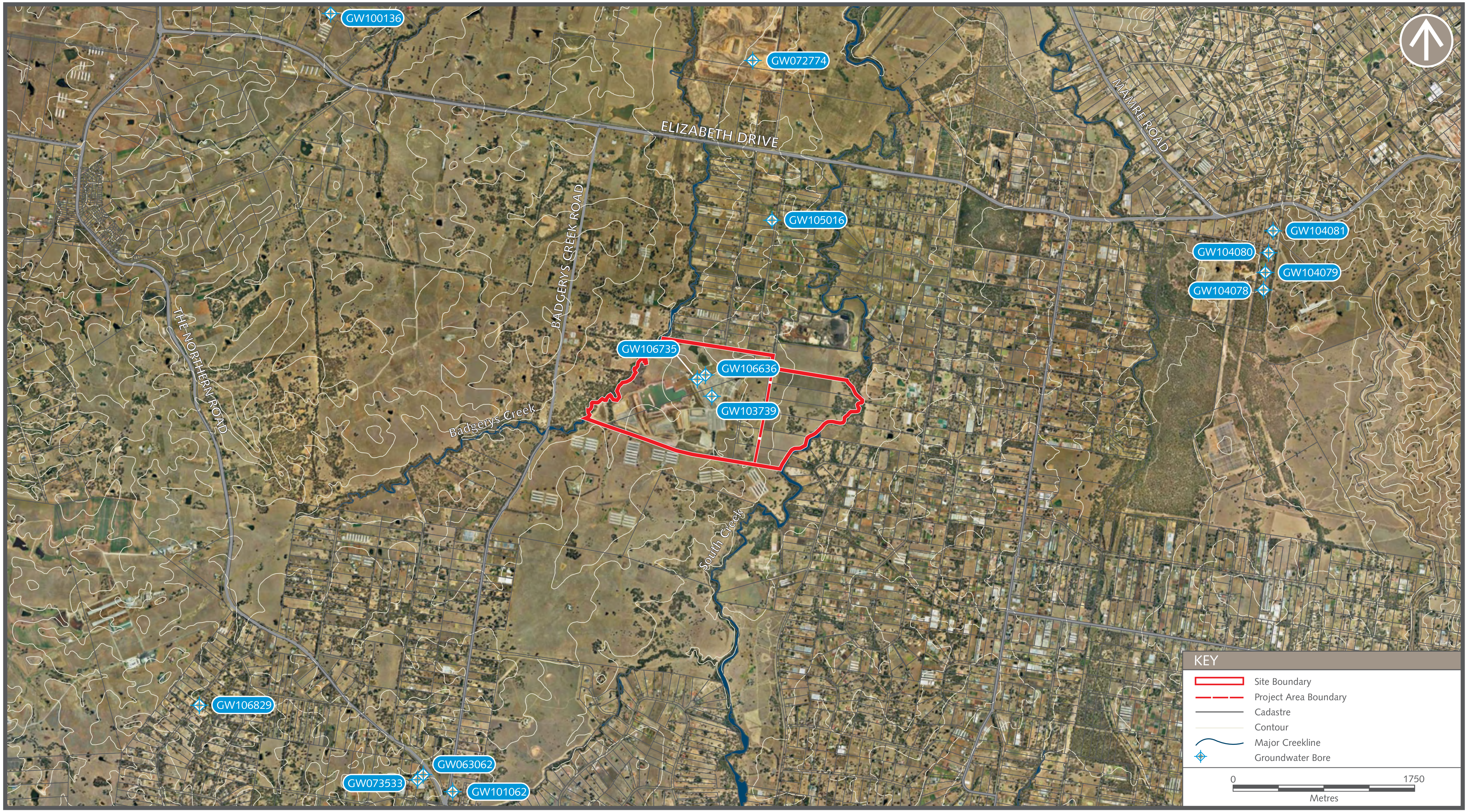
While it is recognised that not all existing bores are likely to be registered, the database gives an indication of groundwater usage in the area. The search reported that bores registered for groundwater abstraction purposes (e.g. domestic stock watering or industrial purposes), extract groundwater from the Hawkesbury Sandstone formation at depths greater than 220 m. Groundwater within the alluvial sediments or Wianamatta Group is not extracted for use in the vicinity of the Project Site.

Overall, it is concluded that the importance of, and reliance on, groundwater by local landowners and residents is limited in the vicinity of the Project Site. The contribution and importance of the groundwater system to stream flows and groundwater dependant ecosystems is discussed further in the following sections.

11.3 Methodology

Based on the review of existing data, a conceptual model of the hydrogeological regime for the Project Site has been developed. A numerical groundwater model was not developed for this assessment for the following reasons:

- The maximum depth of excavation is 35 m into very low permeability rock. No significant groundwater would be encountered, as has been confirmed by previous experience at the site. The storage of water in pits and lack of seepage during mining confirms the low permeability of the rock. Groundwater within the top 35 metres is considered a fractured bedrock aquifer (associated with fractures rather that within the rock itself) and very difficult to model (with any accuracy);
- There is no threat to the Hawkesbury Sandstone aquifer (which lies more than 100 metres below);



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EXISTING GROUNDWATER BORE LOCATIONS

Environmental Assessment

Boral Quarry and Brick Making Facility, Badgerys Creek

Figure 10

- Groundwater is not extracted for use in the vicinity of the Project Area; and
- The groundwater and surface water regimes in the subject area have already been disturbed by mining activities. The natural state of the groundwater regime prior to mining is unknown.

It is considered that intrusive investigation of the alluvial sediments associated with South Creek and Badgerys Creek and the implementation of a groundwater monitoring program would provide beneficial (and real) data than a model would be able to achieve as there is currently very little data available to prepare a numerical model and as such, it the accuracy of the model would be questionable. A conceptual model was therefore developed and would be refined following the alluvial investigation and implementation of a groundwater monitoring schedule.

11.4 Existing Impacts on Groundwater Regime

The presence of the existing open pits within the Project Site would have influenced the local groundwater regime, although the influence would be limited as a result of the relatively impermeable geology. Groundwater present within the weathered zone and upper Bringelly Shale would have slowly drained (dewatered) into the open pits, although as discussed previously, negligible groundwater has been observed.

Pit 1 has been flooded and collects rainfall and surface water runoff from across the Project Site. This water may be providing a source of recharge to surrounding and underlying strata, although the impermeable nature of the shale units suggests that recharge would be minimal.

The presence of the flooded pit (Pit 1) immediately adjacent to open, empty pits within the Project Site, with no observable or measurable impact to groundwater inflows, further confirms the impermeable nature of the geology within the Project Site.

11.5 Potential Impacts

Potential impacts to the groundwater regime as a result of the proposed development may include:

- Aquifer dewatering;
- Contamination by leaking or spilt hydrocarbons; and
- Impact to base flow and groundwater dependant ecosystems, if present.

These potential impacts are discussed in more detail below.

11.5.1 Aquifer Dewatering

Previous operations within the Project Site are likely to have resulted in localised dewatering of the formations exposed within the pits. Although significant groundwater resources are not associated with the Bringelly Shale unit, the limited quantity of groundwater present is likely to have been depleted in the immediate area surrounding the pits.

The presence of groundwater within the weathered zone, particularly following rainfall events, is likely to persist throughout the life of the project with the voids created by ongoing extraction causing the small quantity of groundwater present to flow/seep towards and into the voids. In reality, and based on observations in the existing extraction areas, little if any groundwater would flow/seep into the void, as it would simply evaporate on the exposed side walls of the excavation void.

Cumulative impacts from the mining of additional pits within the Project Site are not expected to result in measurable changes to groundwater levels within the strata of the Wianamatta Group, and as groundwater within the Wianamatta Group is not utilised in the vicinity of the Project Site, adverse impacts as a result of dewatering are not anticipated.

Dependant on the extent of alluvial deposits associated with Badgerys Creek, there is potential for alluvial sediments and associated aquifers to be encountered by quarrying activities (Pit 5), and subsequent dewatering of the alluvial aquifer to occur, if present. Dewatering of alluvial aquifers has the potential to affect groundwater dependant ecosystems (if present) and base flow to the creek, if there is connection between surface water within the creek and shallow groundwater.

Drilling logs indicate that the alluvial sediments associated with South Creek, which extend some 200 metres west of the Creek, would not be intercepted by the development, with the closest proposed pit (Pit 4) located more than 400 metres west the Creek.

The extent of alluvial sediments associated with Badgerys Creek is expected to be limited within the Project Area and would be further investigated as part of the drilling and mapping program, described in **Section 11.6**. The purpose of the alluvial investigation is to gain a better understanding of the alluvial sediments so that an adequate buffer distance can be established between the alluvial sediments and the proposed pits to ensure the alluvial sediments are not impacted by the development. The extent of the buffer zone would be determined based on the findings of the alluvial investigation and would take into account the geological properties, subsurface conditions encountered and extent of connectivity between the aquifers present.

In addition, groundwater wells would be installed within the alluvial material adjacent to both Badgerys Creek and South Creek and a monitoring schedule implemented to enable unanticipated impacts to the alluvial aquifers, if present, to be readily identified and managed accordingly. The proposed assessment and monitoring program is described in **Section 11.6** and would commence within 12 months of the project approval.

The low permeability of the shales targeted for extraction within the Project Site, combined with the limited and localised occurrence of groundwater within the shale units, would minimise dewatering impacts across the Project Site. Further investigation of the extent of alluvial sediments would be undertaken and an appropriate buffer between the excavated pits and the alluvial sediments established to ensure that the localised dewatering of the formations within the exposed pits would not impact adjacent alluvial sediments and associated groundwater ecosystems, if present.

11.5.2 Impacts to Water Quality

The accidental release of fuels, solvents or chemicals used during the operation of the facility has the potential to contaminate underlying groundwater resources. Impacts to groundwater that occur from spills and leaks are usually limited in extent and are not likely to impact off-site users. The relatively impermeable nature of the geology in the vicinity of the Project Site would further limit the migration of any accidental release and protect underlying aquifers.

The potential for spills and leaks to impact water quality would be minimised through the appropriate storage of fuels and hazardous chemicals, the implementation of appropriate work procedures and regular inspections and maintenance of equipment and plant in accordance with the EMP for the project. The implementation of a groundwater monitoring program (refer to **Section 11.6**) would enable impacts to groundwater quality to be identified and managed accordingly.

11.5.3 Impact to Base Flows and Groundwater Dependant Ecosystems

Dewatering of the alluvial sediments has the potential to result in impacts to base flows and groundwater dependant ecosystems (if present).

The extent of the alluvial aquifers in the vicinity of the Project Site, contribution to base flow within the creeks and presence of groundwater dependant ecosystems is not known, and would be investigated as part of the alluvial investigation and groundwater monitoring program (refer to **Section 11.6**). Based on the findings of the alluvial investigation, an appropriate buffer zone would be implemented between the proposed pits and the alluvial sediments so that the alluvial aquifers are not disturbed by the development and thus impacts to the alluvial aquifer are avoided. In addition, groundwater monitoring wells would be installed and a monitoring program initiated within 12 months of project approval, so that any unanticipated impacts to the alluvial aquifers, if present, are able to be identified and managed accordingly.

11.6 Mitigation Measures

The following mitigation measures would be implemented as part of the proposal.

- Appropriate storage of fuels and hazardous chemicals, implementation of appropriate work procedures as well as regular inspections and maintenance of equipment and plant to minimise potential for contamination due to spills;
- Undertaking of an alluvial investigation and groundwater monitoring program to negate the likelihood of impacts to the alluvial aquifer, base flow to the creeks and groundwater dependant ecosystems (if present). The proposed program is discussed below; and
- Based on the findings of the alluvial investigation, establishment of a buffer zone between the alluvial sediments and proposed pits to ensure the alluvial sediments are not disturbed by the development.

11.6.1 Alluvial Assessment and Groundwater Monitoring Program

Investigation of the alluvial sediments associated with Badgerys Creek and South Creek would be undertaken so that an appropriate buffer distance between the creeks and the proposed workings can be established to ensure the alluvial sediments and any groundwater they contain are not impacted by the proposal.

The alluvial aquifer assessment would include:

- Assess the lateral and vertical extent of the alluvial sediments associated with South Creek and Badgerys Creek;
- Assess the presence of groundwater within the alluvial sediments;
- Establish whether there is connectivity between surface water within the creeks, the alluvial aquifer and groundwater perched within the weathered zone.
- Assess the contribution of groundwater to the base flow of the creeks.
- Assess the presence of groundwater dependant ecosystems in the vicinity of the Project Site.
- Establish a monitoring well network to enable ongoing groundwater monitoring at the Site.

The investigation would comprise the following works:

Mapping of the Alluvial Sediments

A drilling and mapping program would be undertaken adjacent Badgerys Creek and across the flood plain associated with South Creek. Boreholes would be advanced and logged until bedrock is encountered so the lateral and vertical extent of alluvial sediments and presence and depth of groundwater can be assessed.

The indicative drilling program would comprise:

- Advancement of ten boreholes in the vicinity of South Creek and the associated flood plain; and
- Advancement of four boreholes in the vicinity of Badgerys Creek.

Indicative locations are provided on **Figure 11**. It is noted that the number and location of boreholes may alter dependant on access restrictions and the sub-surface conditions encountered during the drilling works.

The drilling program would enable the extent of the alluvial sediments and occurrence of groundwater in the vicinity of Badgerys Creek and South Creek to be established. Mapping of the alluvial sediments would commence within 12 months of project approval.

Groundwater Monitoring Well Installation

As part of the alluvial drilling and mapping program, groundwater monitoring wells would be installed into the alluvial sediments adjacent South Creek and Badgerys Creek. It is anticipated that six wells would be installed within the alluvial sediments, comprising four wells adjacent to South Creek and two wells adjacent to Badgerys Creek.

Two additional groundwater monitoring wells would be installed into the Bringelly Shale to a maximum depth of 35 metres, so that connectivity between aquifers can be assessed and the deeper groundwater can be monitored.

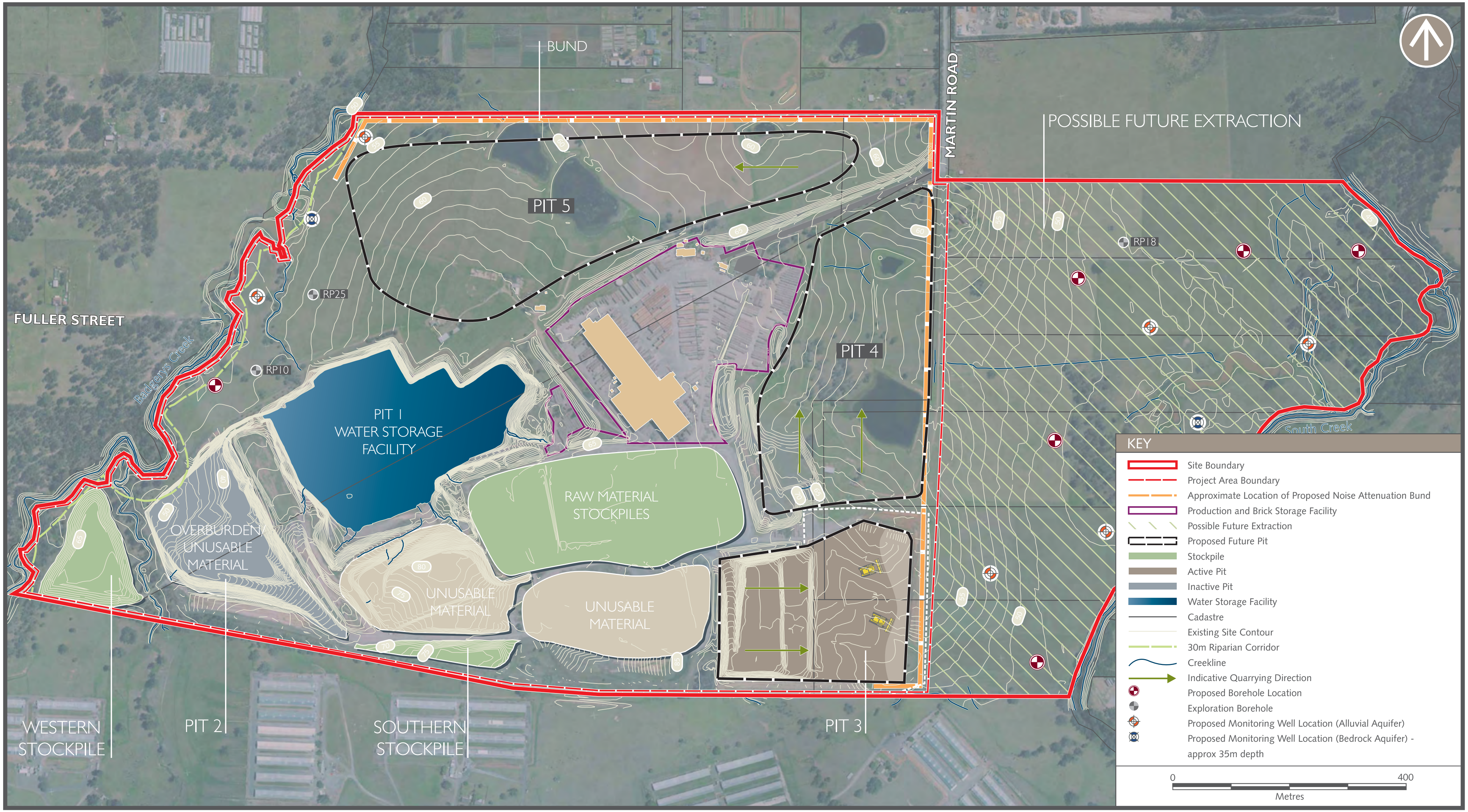
Indicative locations of the groundwater monitoring wells are provided on **Figure 11**, although it is noted that the final location of wells would be dependent on the outcomes of the drilling program.

Licences would be obtained from the NOW enabling the installation of groundwater monitoring wells, prior to the commencement of drilling.

Alluvial Assessment

Once the monitoring wells are installed, the wells and creeks would be surveyed and an assessment of water levels and water chemistry undertaken to determine flow direction, aquifer connectivity and contribution from the alluvial aquifers to the creeks. Permeability testing (slug tests) would be performed to establish the hydraulic conductivity and flow velocities of groundwater across the Site.

Measurement and permeability analysis of the sediments within both South Creek and Badgerys Creek would be undertaken so the base flow of the creeks can be assessed. Information regarding the presence of groundwater dependant ecosystems in the vicinity of the Project Site would be sourced and reviewed (if available).



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Indicative Drilling Locations for Alluvial Assessment

Environmental Assessment

Boral Quarry and Brick Making Facility, Badgerys Creek

Figure 11

Based on the outcomes of the drilling program and alluvial assessment, a buffer zone would be implemented to ensure the alluvial aquifers are not disturbed by the development. The extent of the buffer zone would be established in consultation with the Director-General of the DoP and the NOW.

Groundwater Monitoring Program

Following installation of the groundwater monitoring wells, a groundwater monitoring program would be implemented so that unexpected impacts to the hydrogeological regime as a result of the development can be readily identified and managed accordingly. Groundwater monitoring would commence within 12 months of project approval so that adequate background data would be obtained prior to pits approaching the buffer zone associated with the alluvial sediments. The collection of a robust data set would enable natural variations in groundwater levels to be differentiated from unanticipated impacts associated with the development.

Groundwater monitoring, water level measurement, sample collection, storage and transportation would be undertaken in accordance with t NSW DECCW endorsed guidelines.

The proposed groundwater monitoring program is presented in **Table 40**, although it is noted that the monitoring schedule may change dependant on the outcomes of the alluvial investigation.

Table 40: Proposed Groundwater Monitoring Program

Location	No. of Wells	Parameters	Frequency
Badgerys Creek – Alluvial Sediments	2	Water level, EC, pH	Bi-monthly
South Creek - Alluvial Sediments	4	Comprehensive analysis*	Bi-annually
Bringelly Shale – Bedrock Aquifer	2		

*Comprehensive analysis is to be undertaken on an annual basis. The comprehensive sampling is to include the following: pH, Conductivity, TDS, Na, K, Ca, Mg, Cl, HCO_3, NO_3, SO_4 and hardness.

The groundwater monitoring program would be subject to an annual review and revised or updated as necessary. Results of the groundwater monitoring program would be reported to the Director-General of the DoP and the NOW on an annual basis.

11.7 Conclusion

The hydrogeology of the Project Site is strongly influenced by the geology which comprises low permeability shales and clays across a majority of the as well as Quaternary alluvial deposits flanking the creeks located to the east and west of the Project Site.

Exploratory resource drilling across the Site intercepted little groundwater associated with the shale units, and extraction within the Project Site to date, has reported negligible groundwater inflow from the shale and overlying weathered material into the open pits.

The alluvial deposits which flank South Creek to the east and Badgerys Creek to the west of the Project Site are likely to yield higher quantities of groundwater compared to the shale units. The extent and hydrogeological characteristics of the alluvial deposits would be investigated prior to excavation of additional pits, to provide a more comprehensive understanding of the alluvial aquifers and their importance to base flow within the creeks and groundwater dependant ecosystems.

Based on the outcomes of the alluvial investigation, a buffer zone would be implemented to ensure the alluvial aquifers and groundwater dependant ecosystems, if present, are not disturbed by the proposal. A groundwater monitoring program would also be employed so changes to the hydrogeological regime as a result of the proposal can be identified and managed accordingly.

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