7. WATER RESOURCES

7.1 ASSESSMENT CRITERIA

7.1.1 EPA objective

The EPA objectives for the quantity and quality of surface and groundwater are:

- *To maintain the quantity of water (surface and ground) so that existing and potential environmental values, including ecosystem maintenance, are protected*
- *To ensure that the quality of water emissions (surface, ground, and marine) does not adversely affect environmental values or the health, welfare and amenity of people and landuses, and meets statutory requirements and acceptable standards.*

7.1.2 EPA Position statements and guidance

Bulletin 1078: Implementation of ANZECC 2000 Water Quality guidelines

The ANZECC (2000) Australian and New Zealand Water Quality Guidelines, whilst not regulation, provide trigger levels for assessing water quality and developing appropriate strategies for water release. Bulletin 1078 (EPA 2002e) discusses the application of the guidelines to the management by the State of significant water resources and is of limited application to the Proposal, which will not interfere with any State-significant water resources[51].

7.1.3 Other relevant legislation, policies and guidelines

Rights in Water and Irrigation Act

The *Rights in Water and Irrigation Act 1914* prohibits the interference with beds and banks in proclaimed catchments without a permit or license from the Department of Water (DoW). The Proposal is located within the proclaimed Capel River catchment area, close to its boundary with the Preston River catchment.

South West Regional Water Plan (DoW 2008d, draft)

The DoW has published seven long-term water management objectives for the water resources of the south west, including:

- minimise extraction of natural water through efficient water use
- sustainably manage water resources in consultative and transparent processes
- use appropriate knowledge and data for sound adaptive management and make such publicly-available.

[51] The ANZECC guidelines do not apply to groundwater resources.

Whicher area surface water management plan (DoW 2008c, draft)

The Proposal area lies within the upper slopes of the Gynudup Brook and Tren Creek Surface Water Management Areas. The taking water for commercial uses from watercourses in these areas requires a licence under the *Rights in Water and Irrigation Act 1914*. The management plan does not specifically advise whether or not the mining Proposal and its necessary requirements to prevent contaminated stormwater from being discharged into watercourses constitutes 'taking water' and specific advice will be sought from DoW in this regard.

The *River Action Plan for the Gynudup Brook and Tren Creek* (GeoCatch 2004), prepared for the Geographe Catchment Council and the Capel Land Conservation District Committee, provides both general and specific information and advice in relating to the subarea and its watercourses.

State Water Quality Management Strategy

The *State Water Quality Management Strategy Implementation Framework for Western Australia* for the Australia and New Zealand Guidelines for Fresh and Marine Water Quality and Water Quality Monitoring and Reporting (SWQ6, Govt of WA 2004) requires that water management in regions and local areas should occur within the framework of an environmental management system (EMS). This model states that for each environmental value identified, a set of environmental objectives be developed and for each objective environmental criteria or benchmarks be set.

Water quality protection guidelines

There are several relevant Water Quality Protection Guidelines published by the West Australian Government, through the former Water and Rivers Commission (WRC), including

- *Water quality management in mining and mineral processing: an overview*
- *Mining and Mineral Processing – Minesite water quality monitoring*
- *Mining and Mineral Processing – Minesite stormwater*
- *Mining and Mineral Processing – Mine dewatering*.

These guidelines are associated with surface water management and address key issues associated with mining and mineral processing and provide a consistent framework for dealing with them.

In addition, Best Practice for the management of stormwater is provided in the *Stormwater Management Manual for Western Australia* (DoE 2004-2007). The manual describes objectives and strategies for the management of stormwater in order to improve local flood protection, water quality management, protect ecosystems and increase re-use.

7.1.4 Environmental Scoping Document

The Environmental Scoping Document (ESD, Strategen 2007) sets out the scope of studies and information required to assess the Happy Valley Proposal. In regards to water resources, the following studies and information were required:

- using a baseline data set of local and regional groundwater data, describe levels, contours and chemistry of each aquifer and of any surface water features to assess relationships between each

- undertake a local groundwater user assessment, describing: abstraction mechanism, use, requirements, reliance, potential impacts, management, consultation, monitoring and contingency measures
- identify groundwater-dependent ecosystems (GDE) that may be dependent on groundwater affected by the Proposal
- develop cross-sections of the mining area showing: key geological and groundwater features, vegetation cover, depth of monitoring bores, water tables, test pits, soil samples, photographs, soil-water relationships, flow paths
- conduct pump tests of mine intersects water table, to determine aquifer parameters
- estimate water use and justify estimates
- identify existing and future dewatering and abstraction schemes that may impact on the groundwater table, relevant to the mine
- review performance of the Yarragadee production bore in regards to impacts on other aquifers and GDE
- review climate change predictions and their implications on the Proposal
- estimate flow regimes for streams and catchment areas potentially affected by the Proposal (include rehabilitated flows)
- review the hydrodynamic effects of mining
- describe the current and proposed groundwater monitoring network and provide construction details.

7.1.5 Definitions and concepts

Aquifer

An aquifer is an underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, silt, or clay) from which groundwater can be usefully extracted using a well/bore. The surface of saturated material in an aquifer is known as the watertable. An aquifer may consist of one or more geological formations or strata.

Dewatering

Dewatering is used to describe the process whereby water that enters a mine void from groundwater seepage or from excessive rainfall is collected and removed from the void.

Flocculants

The flocculants used by Bemax are long chain hydrocarbon polymers that bind together small particles that are suspended in the untreated water to create larger particles that will rapidly settle out. The flocculants are commercially available for water treatment and have been subject to environmental toxicity testing. Free residual polymers in water solution are considered of moderate toxicity to aquatic organisms, however they are not considered to be of significant threat to environment because the polymers are strongly adsorbed onto clay particles and not available in the subsequent aqueous phase; and polymers breakdown into harmless materials such as water, CO_2 and ammonia over a period of days.

Groundwater Dependent Ecosystem

A groundwater dependent ecosystem (GDE) is typically an assemblage of vegetation that includes key taxa (in terms of dominance and/or function) that are phreatophytic, that is, rely more on the presence of shallow groundwater or surface inundation than on (unsaturated) soil moisture for survival. GDEs can be made up of either terrestrial (upland) plants or wetland plants.

Mine water circuit

The mineral sands wet separation process uses water to slurry the mineralised ore through a gravity concentrator. The water is collected for re-use but must first be treated to remove the clays (fines) that are washed from the ore, using a process involving dosing with flocculants and treatment through a deep cone thickener tank. In the tank, the clays settle to the bottom and are pumped to solar drying dams to dry to a manageable state before they are reincorporated into the mine fill, while the treated water is decanted from the top of the tank and into the water storage dam for re-use. Water for the circuit is sourced from the production bore and from stormwater harvested from the mine area. Water is lost from the circuit through evaporation, for dust suppression and in the sand and clay tails.

7.2 DESCRIPTION OF FACTOR

7.2.1 Surface water resources and uses

Catchments

Mapping of the local catchment boundaries (watersheds) was conducted using a digital elevation model (5 m horizontal resolution) and the Spatial Analyst extension for ArcGIS (® ESRI software). The mapping identified six local and sub-catchments potentially affected by the proposed mining operation, which are shown in Figure 7-1 and characterised in Table 7-1.

The usefulness of the catchment boundary mapping exercise as a means of assessing the impact of the Proposal on catchment runoff is greatly constrained by the gentle slopes of the common landforms, including wide crests and valleys, the distribution of vegetation and the predominance of sandy soils with high infiltration capacities. This is particularly relevant in the lower slopes of the Forrestfield System, where all of the watercourses discharge directly to the groundwater through the sandy soils of the CSs phase (see Section 4.2.2). Consequently, attempts to model catchment discharges were unable to reliably replicate observed flows over the past 3 years (only three episodic flow events occurred over that period), and are therefore not presented for consideration. The relative aerial impact on each catchment in Table 7-1 is therefore a subjective analogue to catchment runoff modelling.

Table 7-1 Happy Valley Project Area catchment assessment

Catchment	Hydrology	Downstream Users	Catchment area and land-use
C1A	Ephemeral stream, no recorded flows at boundary of Loc 214 and Lot 109, upper catchment dammed	Discharges to aquifer; riparian rights to Loc 214	110 ha, mostly cleared
C1B	Predominantly Kingia (plateau) and Whicher Valley	Farm dam, Loc 214	161 ha mostly State Forest
C2A	Ephemeral stream, influenced by dam on upper catchment	Farm dam, Loc 217	30 ha cleared

Catchment	Hydrology	Downstream Users	Catchment area and land-use
C2B	Kingia and Whicher Slopes (low gradients, high infiltration)	Farm dam, Loc 215	152 ha mostly State Forest
C3	Mostly Rosa soil-landform unit (sandy with subsoil sandy clays) discharging into Cartis sands; significant proportion of inflows to dams is through upper walls	Discharges to aquifer; some small fire dams on Loc 4965 (controlled by proponent)	730 ha mostly cleared
C4	Rosa (head waters) Whicher and Cartis soil-landform units; discharges into latter	Discharges to aquifer; riparian rights to Loc 4485 (owned by Proponent)	568 ha, State Forest in upper reach, cleared in lower

The Happy Valley Proposal will affect two catchments containing surface water features accessed by other users:

- GWSW2 (local catchment C2) has been previously identified as an important supply to a farm dam on Loc 217, where it terminates. Monitoring records show, however, that the stream has only flowed on three occasions for the period 2000 – 2008 and that water levels in the dam on Loc 215 upstream along the same watercourse are often quite low and require supplementation from a windmill (Leederville Formation) on the property
- the Proposal will affect a very small proportion (less than 3%) of the edge of the catchment of a farm dam on Loc 214 (local catchment C1B). Soils are sandy and the slope is minor and it expected that the influence of mining will be indeterminably small.

Surface water features

The *Gynudup Brook and Tren Creek River Action Plan* (GeoCatch 2004) identifies four watercourses crossing the Proposal tenements and these (from north to south) are described as follows:

1. A small tributary of Gynudup Brook that begins in State Forest 27, passes under Gavins Rd, through a gully dam on Location 215 (Bemax monitoring location GWSW2) and into another gully dam on Lot 217, where it terminates (local catchment C2). Flows are very minimal (map 19 of GeoCatch 2004).
2. Two small tributaries of Gynudup Brook that begin in depressions between rows of bluegums on Location 4965, flow through small gully dams (Bemax monitoring locations HVSW2 and HVSW3) and disappear into the sand shortly after (local catchmentC3). Flows are minimal (maps 14, 19 and 20 of GeoCatch 2004).
3. A small tributary of Gynudup Brook that flows out of State Forest 27, onto private land (Bemax monitoring location GWSW4) and skirts the Gwindinup South mine, where it discharges into a roadside drain (local catchment C4). The tributary contained no flows and was not assessed by GeoCatch (maps 15 and 20 of GeoCatch 2004).

These watercourses, as well as a smaller additional one on Location 4965, are shown in Figure 7-1, which also indicates the results of the foreshore assessment conducted by GeoCatch (2004), using the method of Penn and Scott (1995), which is summarised in Table 7-2. The watercourses of the Proposal area are rated from ‘B1’ (State Forest) to ‘C3’ (farmland).

Table 7-2 Foreshore assessment grades used by GeoCatch 2004, after Penn and Scott 1995

Grade	Criteria/Description
A1: Pristine	The river embankments and/or channel are entirely vegetated with native species and there is no evidence of human presence or livestock damage. This category, if it exists at all, would be found only in the middle of large conservation reserves where the impact of human activities has been negligible.
A2: Near pristine	Native vegetation dominates but introduced weeds are occasionally present in the understorey, though not to the extent that they displace native species. Otherwise there is no human impact. A river valley in this condition is about as good as can be found today.
A3: Slightly disturbed	Here there are areas of localised human disturbance where the soil may be exposed and weed density is relatively heavy, such as along walking or vehicle tracks. Otherwise, native plants dominate and would quickly regenerate in disturbed areas should human activity decline.
B1: Degraded - weed infested	In this stage, weeds have become a significant component of the understorey vegetation. Although native species remain dominant, a few have probably been replaced or are being replaced by weeds.
B2: Degraded - heavily weed infested	In the understorey, weeds are about as abundant as native species. The regeneration of some tree and large shrub species may have declined.
B3: Degraded - weed dominated	Weeds dominate the understorey, but many native species remain. Some tree and large shrub species may have declined or have disappeared.
C1: Erosion prone	While trees remain, possibly with some large shrubs or Grass Trees, the understorey consists entirely of weeds, mainly annual grasses. Most of the trees will be of only a few resilient or long-lived species and their regeneration will be almost negligible. In this state, where short-lived weeds support the soil, a small increase in physical disturbance will expose the soil and render the river valley vulnerable to serious erosion.
C2: Soil exposed	Here, the annual grasses and weeds have been removed through heavy livestock damage and grazing, or other impacts such as a result of recreational activities. Low level soil erosion has begun, by the action of either wind or water.
C3: Eroded	Soil is being washed away from between tree roots, trees are being undermined and unsupported embankments are subsiding into the river valley.
D1: Ditch - eroding	Fringing vegetation no longer acts to control erosion. Some trees and shrubs remain and act to retard erosion in certain spots, but all are doomed to be undermined eventually.
D2: Ditch - freely eroding	No significant fringing vegetation remains, and erosion is completely out of control. Undermined and subsided embankments are common, as are large sediment plumes along the river channel.
D3: Drain - weed dominated	The highly eroded river valley may have been fenced off enabling colonisation by perennial weeds. The river has become a simple drain, similar if not identical to the typical major urban drain.

A site investigation was conducted in September 2007 after steady rains, with the objective of observing and recording surface water features, including flows, ponds, soaks and dams. A particular emphasis was placed on streams and tributaries in the Proposal area, which were followed from their head to the point where surface flow ceased. Results are presented in Appendix W1 and summarised below.

- the headwaters of GWSW2 are in the State Forest on M70/901 and from there it continues downstream under Gavins Road, across Location 215 into a gully dam before continuing and terminating in a gully dam on Location 217. Flows observed were relatively low, with water depth approximately 2 cm in a narrow stream flow. Riparian vegetation was restricted to the herb layer, if at all. The culvert under Gavins Road is largely blocked by sediment that has washed in from the Gavins Road roadside drain
- a targeted search for springs or soaks as an indicator of the potential presence for groundwater-dependent ecosystems (GDE) was conducted along the upper reaches of GWSW2, as the topographical and geological model for the Proposal indicated that groundwater from the underlying Leederville formation to the east or local perched aquifers to the southwest could discharge into the creek. No evidence of soil saturation or discharge was found, at least within the extents of M70/901

- HVSW1, considered only a minor watercourse, is a barely discernable surface feature on Loc. 4965 (Bemax) that crosses into Loc 3829 (Bemax), where it disappears. No flow was noted, though some stagnant puddles were evident at a downstream location. Flow appeared to be sourced from run off collection and drainage, most likely triggered by rainfall events
- HVSW2 had a visible flow line near the eastern boundary of Location 4965 (Bemax), however flow was only noted approximately 200 m downstream of this point. Remnant vegetation (herb and shrub layer) is present along much of the watercourse, although most of the overstorey has been cleared along the upper reaches. Flow appeared to fluctuate between surface and subsurface, with the channel becoming almost non-existent at times. A small farm dam is located at the termination of the watercourse on Loc 4965. It appears from aerial photography that overflows and subsurface flows from the dam may join HVSW3 down-slope
- HVSW3 had the most significant flow of any of the streams and tributaries in the Proposal area. The head of the tributary is located in blue gums on Loc 4965 (Bemax). Flow increased downstream where a buffer of remnant vegetation has been maintained before flowing into a dam on Loc 4965. Moderate flow continued downstream of the dam before disappearing on Loc 3818 (Iluka Resources)
- GWSW4 and its catchment is located south of the proposed disturbance area and is unlikely to be impacted by mining operations. Upstream flow was relatively low but present, however this flow decreased downstream to the extent that no flow was recorded as the stream terminated on the boundary of Location 4485 (Bemax).

Riparian ecosystems

Bennett (2003, 2007) mapped the vegetation of the creek systems of the Proposal area over several seasons and found that typically, the vegetation of the creeks mimicked that of the surrounding vegetation. Bennett (2007) recorded that some of the creeks retained very small remnants of what would have been more widely distributed vegetation units, but which had been cleared as a result of agriculture. The P1 plant species *Boronia humifusa* was also located in two of the creek quadrats, although the taxon is considered to be widespread across the Proposal area, hence the plant is not considered to be riparian.

The dams into which HVSW2 and HVSW3 flow, whilst not natural, may provide a valuable resource to native fauna over the summer period. Flows in all of the noted water resources were relatively minimal, seasonal and flowed only in intermittent seasons. The dams, however, typically retain low levels of (often stagnant) water over summer.

These ecological values and functions have been described in detail in the vegetation and fauna sections of the ERMP.

Wetlands

The closest wetlands to the Proposal area are the paluslope wetlands at the base of the Whicher Scarp at Gwindinup, 1.5 km from the edge of mining. Paluslope-type wetlands are seasonally waterlogged wetlands with a gentle topographic gradient (Semeniuk and Semeniuk 1995). These wetlands have been described by Bennett (2003), Cable Sands (WA) Pty Ltd (2003) and PB (2008b). The wetlands are wet all year round but become increasingly inundated in winter and spring. Geological cross-sections and bore data prepared by Cable Sands (2003) and reviewed by Aquaterra (2005) and IGT (2006) strongly indicated that the wetlands are fed by a combination of subsurface runoff from surrounding duplex soils (foothills), seasonal surface runoff from surface clays of the Pinjarra Formation and upward flows of groundwater from the Leederville Formation.

7.2.2 Groundwater resources and uses

Aquifers

There are three key groundwater resources associated with the Happy Valley Proposal, namely:

- the superficial aquifer (Ridge Hill Formation)
- the Leederville Formation
- the Yarragadee Formation.

As the Proposal does not intersect the Leederville formation and there is little significant variation of the Yarragadee formation on a local scale, research efforts have concentrated on the hydrogeology of the superficial formation.

Groundwater monitoring results

Bemax has previously installed five groundwater monitoring bores within the Happy Valley deposits and these have been monitored monthly since March 2006. Four of these bores are screened to the base of the mineral sands deposits (i.e. the maximum depth of mining) and one (HVMB 4A) is screened above the subsurface low-permeability layer to monitor for a perched water table. The borelogs, geological cross-sections and monitoring results are provided in Appendix W2.

Based on monitoring results, none of the bores has intercepted a permanent water table. Results for the deeper bores closer to the Ridge Hill Shelf indicate that, at the end of wet winters (October-December), the sediments at the interface of the Ridge Hill Shelf and Leederville Formation become semi-saturated to saturated, resulting in sludge and/or groundwater to be recorded in some of the bores during this period. For the main, however, all bores are dry.

Independent dewatering assessment

Parsons Brinkerhoff (PB 2008b) was engaged by Bemax to assess the dewatering requirements for the proposed Happy Valley mine. The assessment included a desktop review of the local hydrogeology, the development of a conceptual geological model using sample assays from the Bemax exploration database (over 400 drill holes) and the installation of additional groundwater test bores as part of the hydrogeological interpretation of the site. Much of the information relating to the subsurface geology has been presented in Section 4 of this ERMP.

The desktop review examined records from DoW groundwater monitoring bores, one at Happy Valley South and one at Happy Valley North. The average groundwater level was found to be 24 m below ground level, which approximated the depth of the interface between the superficial formations and the Leederville Formation. This is well below the maximum anticipated depth of mining, which is 18 m below ground level.

PB 2008a supervised the establishment of a further eight monitoring bores (Appendix W2). Five of the bores were drilled to the base of the Ridge Hill Sands, which corresponded to the depth of mining. Three monitoring bores were installed at shallower depths above clayey sand horizons to monitor for perched groundwater. These bores are in addition to the five monitoring bores previously installed by

Bemax at a range of depths and monitored on a monthly basis since March 2006, in which no permanent groundwater has ever been observed.

The PB (2008b) investigation did not intercept groundwater in seven of its eight monitoring bores. The one bore where groundwater was observed was subsequently identified as being screened into the Leederville Formation (26.5 m below ground level, beyond the depth of mining). The PB investigation subsequently concluded that the watertable is below the depth of mining and it is therefore very unlikely that there will be significant inflows of groundwater to the pits.

Potential for localised seasonal perched watertables

The potential for shallow perched water tables to exist seasonally on a localised scale in the Proposal area and surrounds has been previously established (e.g. Oracle 2003, Strategen 2007b). These watertables rely on areas of impeded sub-soil drainage (within approximately 6 m of the ground surface) and negligible slope to intercept and retain rainfall. Depending on the depth and duration of the watertable, it may play an important role in supporting overlying vegetation. Vegetation that is strongly reliant on such water tables is usually identified as a groundwater-dependent ecosystem (GDE) (Eamus et al. 2006).

As described in section 4 and also confirmed by PB (2008b), a 1 – 5 m thick layer of well-cemented sand and gravel ferricrete (laterite) exists across both deposits, at a depth that varies between 0 and 10 m below ground level. The laterite is expected to have very low porosity and permeability and is also typically underlain by low permeability clayey sands. Because of this impeded drainage, the potential for seasonal perching is considered to be high. This potential has been confirmed by a number of shallow test holes returning saturated and semi-saturated samples (Section 4), vegetation typically associated with wet or damp sands (section 5) and the water-retaining capacity of the sub-laterite layer (Figure 4-8).

Groundwater users

One other Yarragadee abstraction bore currently exists within a 5 km radius of the Proposal and that is operated by Iluka Resources Pty Ltd at the Yoganup Extended minesite, about 3 km south west. As shown in Figure 7-4, the local water resource users within a 2 km radius of the Proposal (other than Bemax) are:

- two operational bores in the Yoganup Formation, also for stock watering
- four operational bores in the Leederville Formation, used for stock watering, irrigation and domestic supply.

7.3 ASSESSMENT OF POTENTIAL IMPACTS, MITIGATION AND RESIDUAL IMPACT

7.3.1 Overview of potential impacts to water resources

The purpose of the following section is to identify those actions or processes associated with the Happy Valley Proposal that might affect water resources and values.

Groundwater abstraction

The proposed mining operations will require 1.5 GL of groundwater a year, sourced from one of two abstraction bores, screened in the Yarragadee Formation. This volume is based on receiving negligible pit inflows and only seasonal inputs from stormwater harvesting. Of this volume, approximately 0.9 GL will be used for processing the mineralised ore, with the remainder predominantly for dust suppression. The proposed requirements represent a continuation of the existing groundwater allocation and licence issued by the DoW for the nearby Gwindinup minesite and managed through the environmental management plans for the operations.

The hydrogeology of the Yarragadee Formation production bores, proposed for Happy Valley and currently in use at the Proponent's Gwindinup North mine site, has been previously described for Gwindinup and in applications made to the DoW. Modelling associated with those applications indicates that, based on continuous use of the current production bore (PB2), drawdown would be approximately 8.0 m after one year, 8.1 m after two years and 8.2 m after five years (Aquaterra 2005). The relevant reports are included on the CD-ROM.

It is proposed to continue with the current abstraction of 1.5 GL/annum, as per Groundwater Licence No. 161841(3). Records to date (December 2007 – June 2008) for the Gwindinup North mine site production bore (PB2) indicate that, during periods when the bore is not operating, standing water levels quickly return to levels similar to those recorded at the Gwindinup South production bore (PB1), which is not in use, and drawdown effects in other monitoring bores have been negligible.

Catchment disturbances

The Proposal will divert any surface runoff from mining operations from entering the local waterways to protect their environmental values, as the runoff is expected to contain elevated levels of suspended solids, particularly if flowing from disturbed areas. The diverted stormwater will be pumped from collection points into the process water circuit for treatment and re-use.

The sandy nature of the Proposal area means that rainfall infiltrates rapidly and, typical of the jarrah forest, most lateral water movement is subsurface (Mauger, Day and Croton 1998). Attempts to estimate catchment runoff using stochastic methods have not matched empirical data, particularly as the three waterways that cross the Proposal area do not flow every year.

The impact of catchment disturbances on existing watercourses will be substantially reduced by the retention of vegetated buffers, to a distance of 50 m at Happy Valley North, and 30 m for the lesser watercourses at Happy Valley South.

Creek disturbances

While separation buffers have been established for mining, a number of creek crossings will have to be established for the purposes of vehicle movement and pipelines (Figure 1-3 and Figure 1-4). These crossings will be minor and will require approval under the *Rights in Water and Irrigation Act 1914*, administered by the Department of Water. All crossings will be fully rehabilitated at the completion of mining.

Storage and use of hazardous materials

Fuel and other hydrocarbons, such as oil and grease will be stored and used onsite. Other materials stored on site may include flocculants and herbicides/pesticides. The storage of hazardous materials is subject to the controls of the *Dangerous Goods Safety Regulations 2007*, administered by the Department of Mines and Petroleum.

Interception of standing groundwater

The Happy Valley deposits do not intercept any significant standing watertable, however the potential exists for localised, seasonal perching (PB 2008b). Plant taxa that have a strong reliance on such hydrological features and that are growing close enough to the pit to be affected. This distance will be determined by:

- whether up or down-slope from the edge of the pit
- the hydrological gradient
- the lateral hydraulic transmissivity of the soils
- the presence of other barriers
- the sensitivity of each taxa to drawdown
- the availability of other plant water sources, including rainfall.

While the distribution of native plant species that have been noted as associated with wet and/or damp sands is widespread through the area, only two areas of sub-surface (i.e. 0 to 1 m) saturation have been identified (Section 4). Both of these areas have been previously drilled to 25 m+ depth on a 50 m by 25 m grid as part of the exploration program in 1998 – the continued presence of saturation reasonably indicates a low lateral transmissivity.

Changes in streamflow

The clearing of native vegetation prior to mining and subsequent rehabilitation has the potential to alter flow regimes due to:

- the disruption of aquatards, resulting in increased infiltration and reduced streamflows
- the decrease in infiltration in the upper soil profile as a result of compaction or other changes to its nature, resulting in increased streamflows
- the removal of understorey vegetation, resulting in more rapid discharge of subsurface flows to streams.

The Proposal is likely to affect streamflows due to the removal of deep rooted vegetation and the disturbance of aquatards, as the contribution by subsurface flows to streamflows in the jarrah forest has been documented previously (e.g. Strategen 2005). The effect of these changes on downstream users is expected to be negligible as there are only two downstream users with catchments that will be affected by the mine, and the largest extent of catchment clearing will be 6% for the stream flowing into Lot 217 Gavins Rd. Recharge of the Leederville aquifer is not expected to change overall but there is potential for a temporary increase in re-charge due to increased rainfall infiltration.

The removal of understorey and deep rooted vegetation in disturbance areas will not result in an increase to streamflow or discharge rates, as the disturbance area will have a segregated drainage system (see below).

Hydrodynamic effects of mining

The potential for soil profiles, both native and reconstructed, to become compacted following mining, typically through the use of heavy machinery, but also as a result of processing or poor soil management and reconstruction is widely recognised (Tongway and Hindley 2003, Grant and Koch

2007, URS 2008, EPA 2005b, 2006b). This compaction may substantially alter the drainage characteristics of a catchment or sub-catchment, resulting in reduced infiltration and subsequently increased runoff. These impacts may be exacerbated by any reduction in vegetation associated with the mining activity.

Changes to the subsoil characteristics will alter the rate at which groundwater percolates through the profile, either laterally or vertically or both. In mineral sands mining, this is often associated with the differential placement of sand tails and clay fines, sometimes in massive layers of the latter, and this can also decrease infiltration and groundwater recharge over the full extent of mining.

Bemax has commissioned a number of studies over the years to better understand and improve the nature of reconstructed soil profiles (e.g. Braimbridge and Jasper 2001, Oracle 2002a, Oracle 2002b, Outback Ecology 2002). These studies show that, on average, mined soils retain similar hydrological properties to unmined soils and that proper management of the two tailings main streams is integral to ensuring the scale of any differences is kept as localised as possible.

7.4 WATER RESOURCE MANAGEMENT MEASURES IN DETAIL

7.4.1 Creek buffers

The original Proposal as referred has been amended to exclude mining from within 30 m of the centreline of the creeks designated HVSW2 and HVSW3 and from 50 m within the centreline of the creek designated GSW2 (Figure 7-1). Minor crossings for vehicle access, haulage and pipelines will be required but the impacts of these will be minimal and will be completely rehabilitated at the completion of mining.

7.4.2 Proposed Water Resources Management Plan

The Proponent has prepared a Water Resources Management Plan (WRMP) for the Happy Valley Proposal to address issues associated with surface and ground water management. The plan is presented in Volume 2 of the ERMP and summarised below.

WRMP Objectives

The objectives of managing water resources for the Proposal are:

- to maintain the quantity of water so that existing and potential environmental values, including ecosystem maintenance, are protected
- to maintain the integrity, ecological functions and environmental values of wetlands and rivers.

WRMP Scope

The WRMP specifically addresses:

- management of impacts to surface water that may be directly or indirectly related to mining
- management of drainage on the mining lease to minimise impacts on surrounding users and ecosystems
- operating strategy for production bore abstraction from the Yarragadee formation

- monitoring of discharges from the site.

Monitoring focuses on neighbouring water users, the receiving environment and impacts to the groundwater table. The WRMP will incorporate experiences obtained during operation of the adjacent Gwindinup mine site and results of ongoing monitoring.

7.4.3 Groundwater operating strategy

The groundwater production bore for the Gwindinup operations is managed in accordance with the Groundwater Management and Monitoring Plan (GMMP, Strategen 2006). The purpose of the GMMP is to describe the management actions that will be implemented as necessary to avoid, minimise and/or mitigate the effects of mining and related activities on local groundwater supplies to neighbouring users. The GMMP includes a description of the groundwater sources used by surrounding users, the Bemax groundwater monitoring network and agreements in place with surrounding neighbours should influences from the production bore become unsatisfactory.

7.5 OTHER MATTERS RELEVANT TO THE ASSESSMENT

7.5.1 Potential impacts of climate change

Changes in global climate arising from increasing levels of greenhouse gases in the atmosphere pose major challenges to managers of both natural resources and the built environment. In particular, climate change or extremes in climate variability that result in a significant decrease in rainfall will diminish the availability of water resources and will require adaptation of dependent systems.

Catchment yield impacts

Berti et al. 2004 reported on a study into the impact of a projected change in climate on water yield of the Stirling Dam catchment. Their study found that a 10% increase in potential evaporation, coupled with the 11% decrease in rainfall predicted to occur by the middle of this century, could result in water yield reductions of greater than 40%.

Soil moisture impacts

Smith (2003) reviewed the effect of recent declines in rainfall on Wandoo (*Eucalyptus wandoo* Blakely). The lower mean rainfall and few above-average rainfall years have led to lower groundwater recharge. On fully timbered slopes the long-term decline in rainfall appears to have resulted in groundwater (and soil moisture) decline. Soil moisture, although not always correlated with soil water or groundwater level, is expected to have generally declined in response to decreased rainfall. Howden et al. (2002) links such changes to corresponding shifts in species distribution and ecosystem composition, as more drought-tolerant taxa are advantaged.

Relevance to Happy Valley

The short time-frame of disturbance to the landscape associated with the Happy Valley Proposal is relatively short. The Proposal involves about five years of mining with another 10 – 15 years for vegetation to become fully re-established. This limits the potential for climate change to influence the predicted environmental impacts of the mine. In any case, the species that colonise rehabilitation areas will be adapted to any change that may take place. Other factors that will further reduce the influence of climate change include:

- absence of permanent and even annual flows in watercourses that cross the site, coupled with the low numbers of downstream users (i.e. one only)
- the absence of any permanent or significant seasonal groundwater within the proposed disturbance zone
- there is no interaction between the mine and groundwater-dependent ecosystems at the base of the Whicher Scarp, over 1 km from the mine
- biological diversity of the Proposal area lies within the herb and shrub layer, with the more conservation significant taxa present in deep sands where seasonal drought conditions already exist, i.e. those habitats already appear to favour drought-tolerant taxa.

7.5.2 Prior performance of the proponent

For the period 1996 – 2007, Bemax operations recorded thirteen complaints relating to the turbidity of water being discharged from the mining operations, or to such discharge causing increased moisture in nearby pasture.

In addition to these complaints a further twenty surface water related incidents have been recorded. Incidents reported by Bemax staff relate to discharge outside set water quality targets, or uncontrolled release of water from site. In all these incidences quality and water flow were quickly identified as an issue and action taken to rectify the situation.

Overall the review of performance identified approximately 1.2 complaints per year, and 1.8 incidents per year on average over the past eleven years, none of which significantly affected the environment or required off-site remediation.

7.6 PREDICTED ENVIRONMENTAL OUTCOME

In predicting the likely environmental outcome of the Proposal, the following key points have been considered:

- the retention of buffers from mining and dams
- the low yield and relatively small scale of impact on surface water catchments
- the absence of downstream users for all but two of the catchments
- the absence of a watertable of volumetric significance within the mine pits
- the absence of impacts to date from the existing borefield.

The environmental review of the potential adverse impacts to water resources after the application of management measures within and surrounding the Happy Valley proposed disturbance area confidently supports the following conclusions:

1. The quantity of surface and groundwater will not affect identified environmental values, including ecosystem maintenance.

2. The quality of groundwater and surface water emissions will not adversely affect environmental values or the health, welfare and amenity of people and landuses, and will meet statutory requirements and acceptable standards with appropriate management.

The conclusions are based on site and project reviews conducted by qualified and experienced specialists and has considered the full range of aspects identified during the environmental scoping process.

A Water Resources Management Plan (draft) is proposed and describes the measures that will be implemented by Bemax, including the monitoring and reporting of water use and key indicators of the receiving environments to ensure the above outcomes are achieved.

7.6.1 Potential residual impacts

The following effects on environmental values may occur as a result of the implementation of the Proposal after the application of management measures are:

- a permanent increase in vertical hydraulic transmissivity for pit areas
- a local reduction in stream yields during mining and active rehabilitation, which will be partially restored when landforms are sufficiently stable to be ‘reconnected’ to the native drainage system.

Table 7-3 EIA Summary table – Water Resources

Management Objective	Potential Impact	Proposed Management
To maintain the quantity of water (surface and ground) so that existing and potential environmental values, including ecosystem maintenance, are protected	Reduce catchment yield during mining by diverting stormwater runoff.	Develop alternative supplies for affected users, prior to impact if possible. Continue monitoring of surface water flows over the course of the project, including rehabilitation phase. Minimise delays to rehabilitation.
	Increase surface flow rates (erosion risk) after mining be decreasing infiltration and/or vegetation cover.	Restore pre-mine contours and vegetation cover. Implement deep-ripping to increase infiltration. Continue monitoring of surface water flows over the course of the project, including rehabilitation phase.
	Affect groundwater availability to surrounding vegetation by intersecting local aquifer (seasonal superficial aquifers only).	Monitor pit walls for inflows. Maintain a clearing perimeter surrounding edge of mine pit, as per mine plan. Reinstate soils as per Rehabilitation Plan.
	Reduce groundwater availability to surrounding users as a result of production bore (Yarragadee).	Limit abstraction from the production bore to 1.5 GL/annum. Continue monitoring of groundwater piezometer network for all aquifers. Liaise with DoW and/or affected parties.
	Increase erosion risk/flooding by inadequate management of emergency overflows/discharges.	Establish emergency water discharge points in consultation with DOW and landowners. Immediately respond to spills or other threats to water resources, such as erosion.
To ensure that the quality of water emissions (surface, ground, and marine) does not adversely affect environmental values or the health, welfare and amenity of people and landuses, and meets statutory requirements and acceptable standards	Affect surface water quality during mining by disturbing catchment/interrupting processes.	Develop, implement and maintain a drainage design that directs all potentially contaminated water for re-use in processing. Establish and demarcate buffers around GWSW2 (50 m) and HVSW2/HVSW3 (30 m).
	Affect surface water quality by disturbing beds and banks for crossings.	Prepare construction and removal plan to accommodate application to DoW.
	Affect surface and/or groundwater quality by poor handling/storage of potentially hazardous materials.	Store hazardous materials in accordance with permits and/or Australian Standards. Immediately respond to spills or other threats to water resources, such as erosion. Include spill response in site induction.
	Affect surface and/or groundwater quality by disturbance of potentially acid sulfate soils.	Continue monitoring of groundwater piezometer network for all aquifers.. Continue monitoring of surface water flows over the course of the project, including rehabilitation phase.
	Affect surface and/or groundwater quality by seepage or overflows from storage dams.	Construct all dams in accordance with engineering guidelines to minimise the risk of release of potentially contaminated water. Manage levels in all dams so that a minimum of 1.0 m freeboard is maintained.

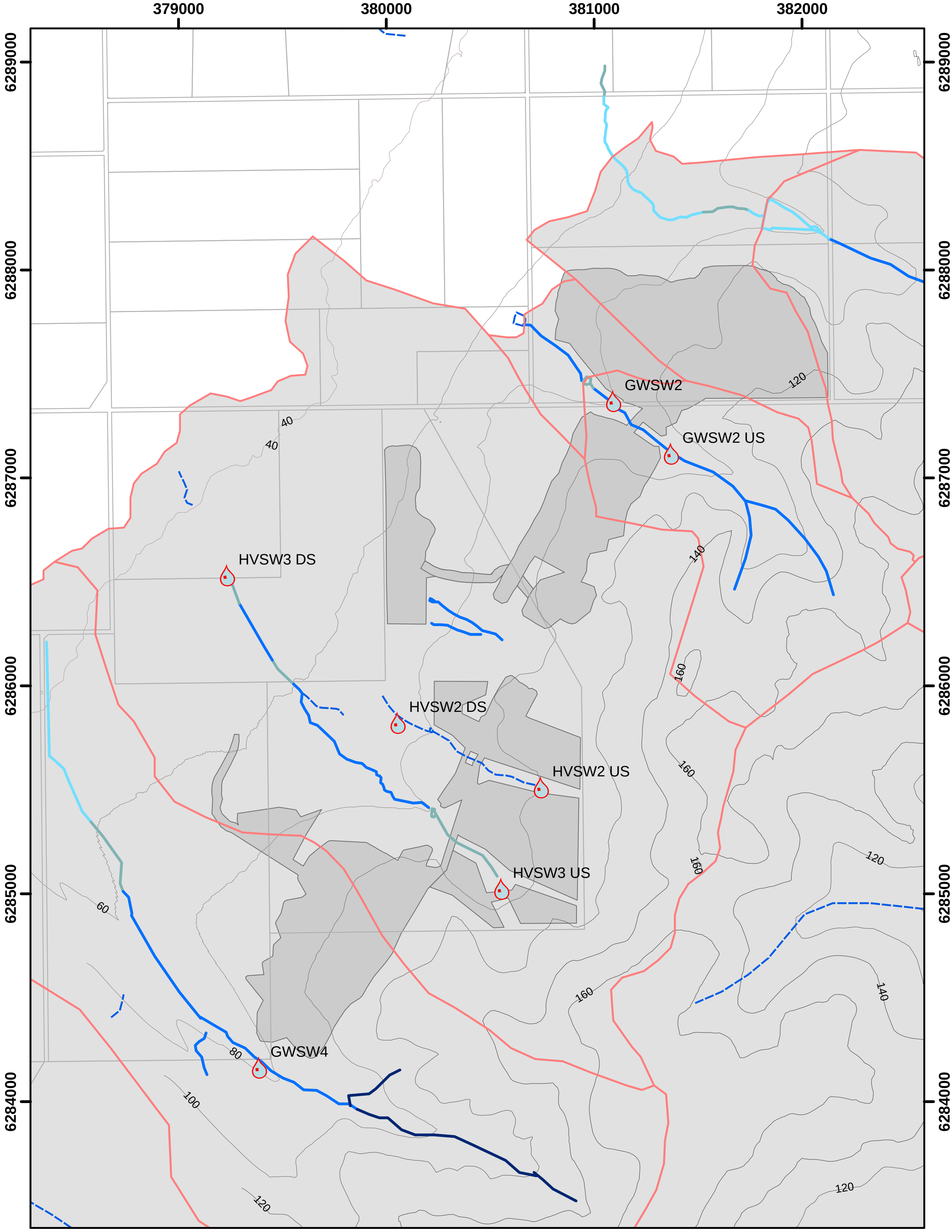

Figure 7-1
Local watercourses and sub-catchment boundaries for the proposal area.

Creek Foreshore Condition *(Geocatch, 2004)*

- Not Assesssed
- A (Pristine - Slighly Degraded)
- B (Degraded)
- C (Erosion Prone - Eroded)
- D (Ditch)

- Catchment Boundaries
- Surface Water Monitoring
- Cadastral Boundaries
- Disturbance

Contour lines at 20m intervals

Datum: GDA 94 Zone 50
Drawn: DH
Date: 8/4/09

BEMAX INCORPORATING CABLE SANDS

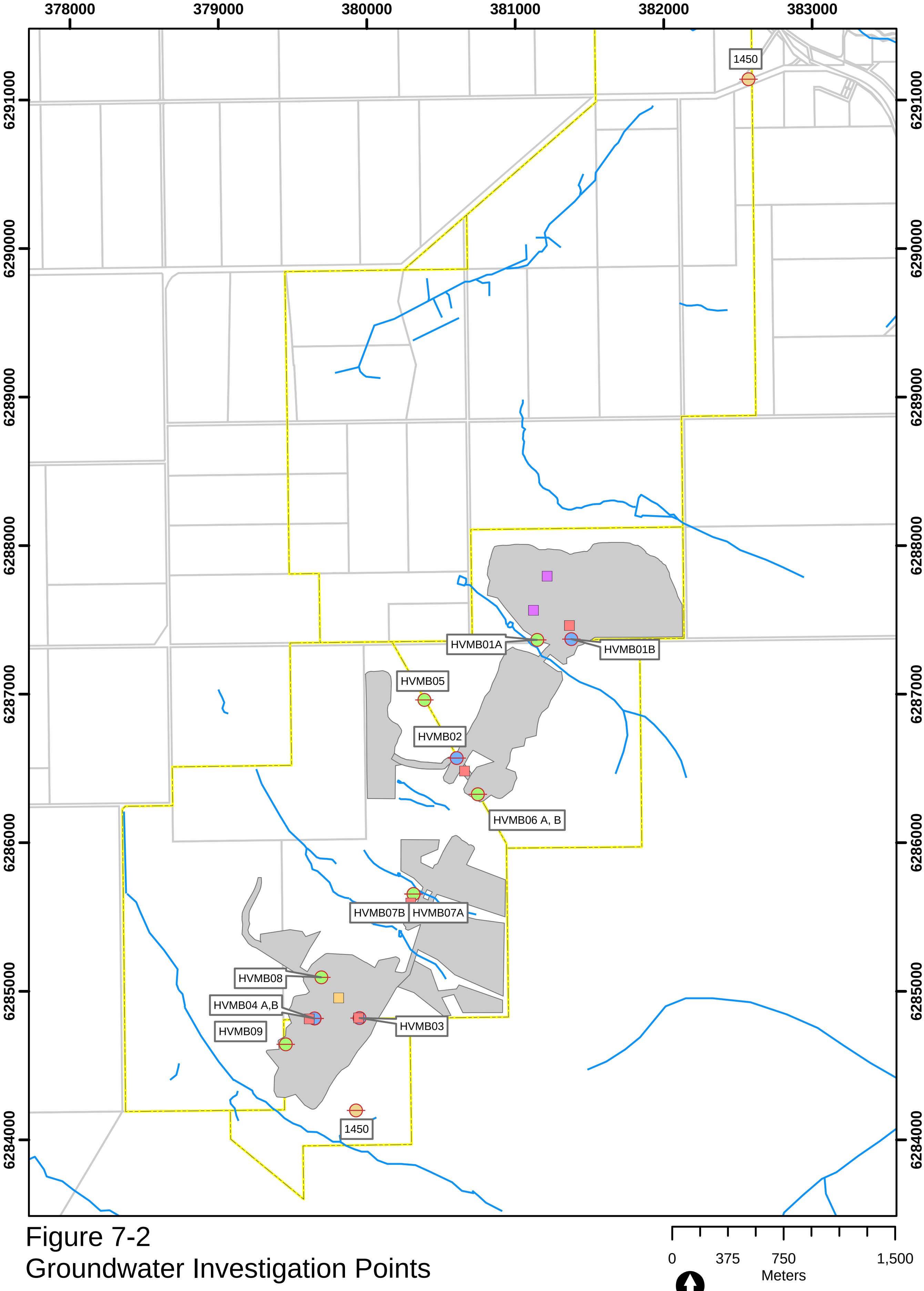

Figure 7-2
Groundwater Investigation Points

Legend

- Disturbance
- Tenement Boundaries
- Cadastral Boundaries
- Creeks
- 2008 Test Pit
- 2001 Test Pit
- 2003 Test Pit
- Bemax Monitoring Bore
- PB Bore
- Regional Bore

Datum: GDA 1994 MGA Zone 50
Drawn: DH
Date: 8/4/09

BEMAX INCORPORATING CABLE SANDS

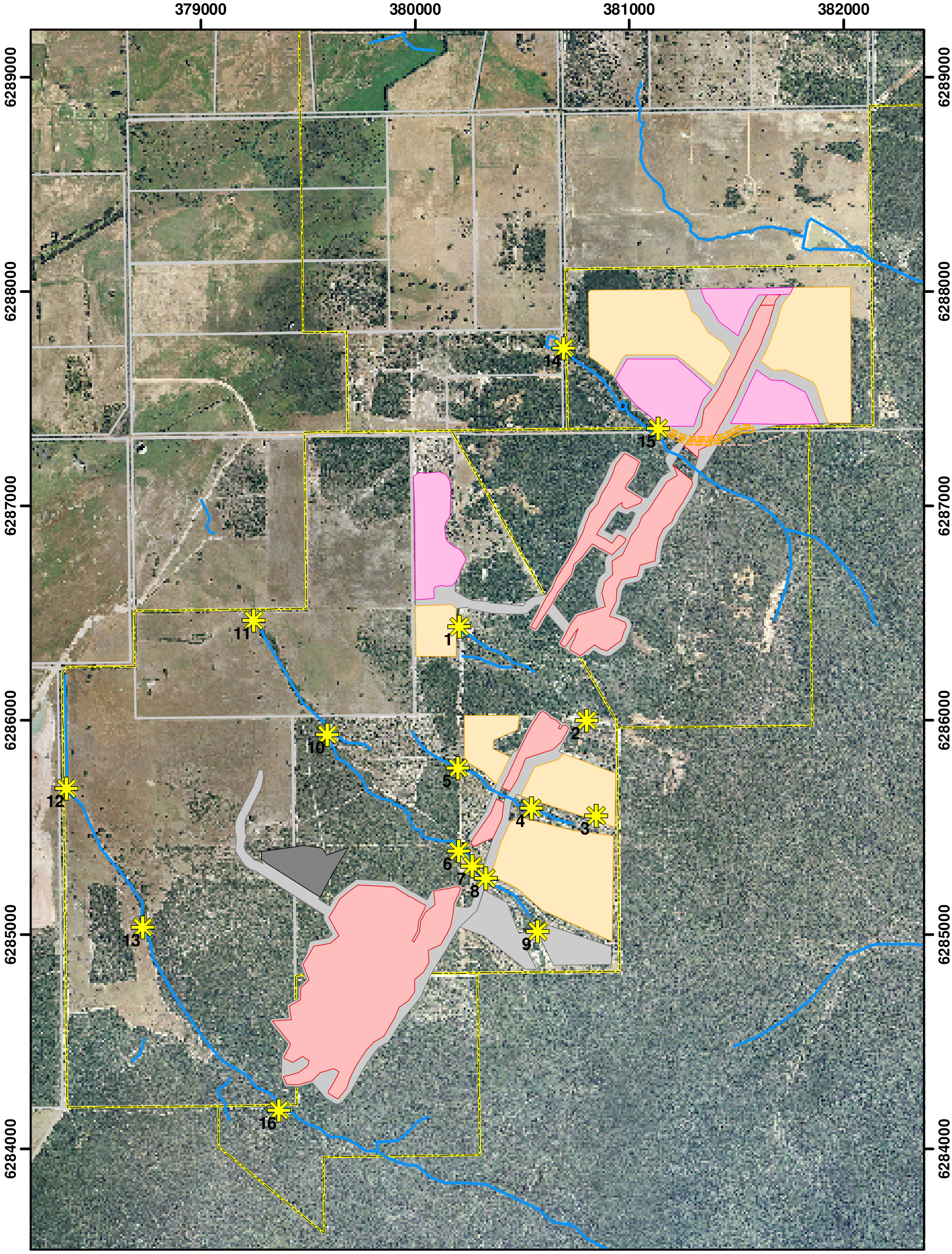

Figure 7-3:
Location of Stream Observation Points

Legend

- Creeks
- Tenement Boundaries
- Cadastral Boundaries
- Disturbance
- Overburden
- Pit
- Infrastructure
- Road Diversion
- Slimes
- Topsoil
- Observation Locations

0 250 500 1,000
Meters

Datum: GDA 1994 MGA Zone 50
Drawn: NG
Date: 08/10/08

BEMAX INCORPORATING CABLE SANDS

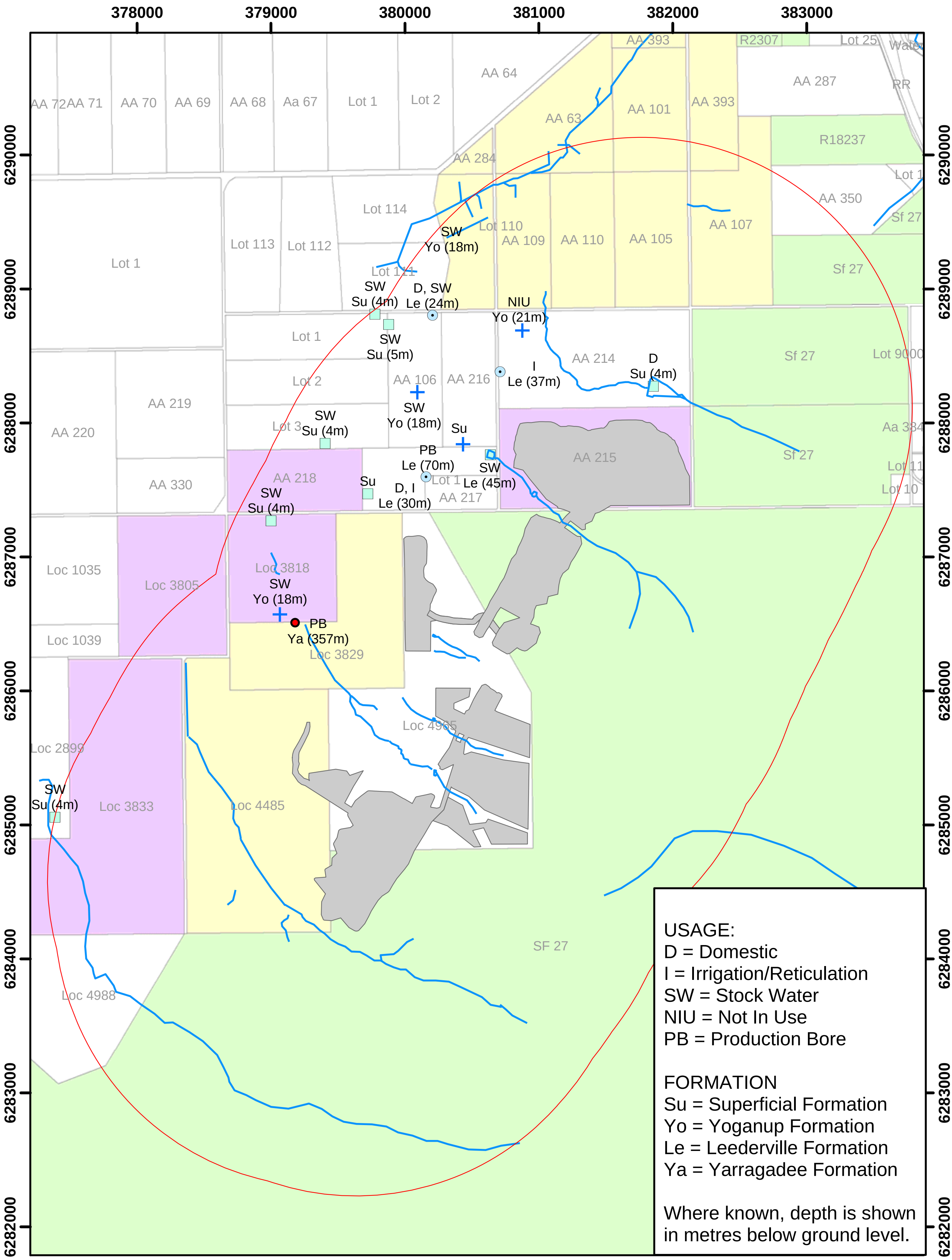

Figure 7-4:
Other groundwater users within 2km of the proposal.

Legend

- Bore
- Dam
- Production Bore
- Windmill
- Creeks
- 2Km Buffer
- Disturbance

Landowner

- Bemax Land
- State Forest/Reserve
- Iluka Land

0 375 750 1,500
Meters

Datum: GDA 94 MGA Zone 50
Drawn: DH
Date: 9/4/09

BEMAX INCORPORATING CABLE SANDS