SURFACE WATER 11

11.1 INTRODUCTION

The area around Olympic Dam receives very little rainfall (the annual average is 167 mm) and has a high evaporation rate (the annual average is around 3,000 mm). However, when it does rain it is often in high intensity events, which can lead to localised flooding given the flat terrain of the area. Stormwater is held temporarily in swales or clay pans before it evaporates or infiltrates. In large events it may fill the saline lakes that occur in the region; for example, the flooding event of 1989 filled Lake Torrens for the first time in 100 years.

Records of floods dating from 1836, and incidental observations of surface water flows during the last 20 years of operation at Olympic Dam, have provided an understanding of flooding and drainage patterns in the area.

This chapter describes the natural and constructed landform features that currently influence stormwater drainage patterns, and identifies how the various components of the proposed expansion have been designed to reduce impacts and how they may change surface water flows.

The chapter also explains the potential for water to accumulate in the bottom of the open pit and, should this occur, the predicted depth and quality of such water. Stormwater management around proposed infrastructure is also discussed within the SML, for the expanded Roxby Downs, along the infrastructure corridors, and at the site of the desalination plant.

The current Olympic Dam EM Program records the effectiveness of the existing stormwater management controls in achieving compliance with applicable limits. The amendments required to the program to account for the expanded operation are addressed in Chapter 24, Environmental Management Framework.

11.2 ASSESSMENT METHODS

11.2.1 SURFACE WATER ASSESSMENT

The assessment of surface water for the gas pipeline corridor options was undertaken by RPS Ecos Pty Ltd, and the assessment for the southern infrastructure corridor was conducted by ENSR Australia Pty Ltd (ENSR). The methods employed are described below and detailed in Appendix J1.

The broad physiographic features of the Andamooka–Torrens region in the northern portion of the project area have been examined by Johns (1968), and detailed terrain mapping has been undertaken in the vicinity of Roxby Downs and the mine site as part of the 1982 EIS (Kinhill-Stearns Roger 1982). More recently, detailed digital elevation models have been produced for the expanded SML. Finer-scaled work on land systems undertaken by the Department of Primary Industries and Resources, South Australia (PIRSA) provides a consistent approach to defining and mapping recurring patterns of topography, soil, geology and vegetation. The descriptions of land systems and mapping for the project area are provided in Chapter 10, Topography and Soils.

In addition to reviewing the above publications, the desktop investigation undertaken for the Draft EIS involved:

- reviewing the surface water chapters and appendices from the 1982 and 1997 Olympic Dam EIS (Kinhill-Stearns Roger 1982; Kinhill 1997)
- reviewing the BHP Billiton annual environmental reports to obtain information relevant to the surface water assessment
- discussions with Olympic Dam site personnel to gain a first hand understanding of rainfall intensities and durations, and the existing water catchments and flow paths on-site and at Roxby Downs

- identifying legislation, policies and guidelines including water resource plans, and/or land management plans of relevance to the EIS Study Area. The primary sources of relevance are the South Australian Government Environmental Protection (Water Quality) Policy 2003 and Natural Resources Management Plan 2006
- reviewing the drainage basins developed by the Department of Water, Land and Biodiversity Conservation
- reviewing the topographic maps and aerial photography for the project area to identify existing creeks, rivers, wetlands and surface drainage patterns within each drainage basin, and to assess channel slope
- reviewing the Bureau of Meteorology (BOM) data to gain an appreciation of flooding history and flood levels across the project area
- reviewing stream gauging stations and previous water quality monitoring data where available (e.g. AUSRIVAS program)
- identifying sensitive downstream environments based on information obtained during the ecological assessments for the Draft EIS
- identifying present surface water users within the EIS Study Area and downstream areas through the stakeholder consultation and engagement program and discipline-specific field surveys
- gaining an appreciation of the climate change information collated for the Draft EIS to establish the implications for stormwater management for the expanded operation.

Field survey

Rainfall sufficient to create widespread ponding of surface waters is not a common occurrence in the Olympic Dam region. However, such an event occurred in mid-July of 2006 during an eight-day field survey of the southern infrastructure corridor (undertaken from 10 to 17 July) and this allowed a better understanding of stormwater flows.

During the survey, 19.6 mm of rainfall was recorded at Andamooka on 14 July, 15 mm at Roxby Downs and 24 mm at Woomera on 14 and 15 July, and 17.8 mm at Port Augusta between 14 and 16 July. The survey areas investigated during this period were the Olympic Dam SML, the Municipality of Roxby Downs and the southern infrastructure corridor to Port Augusta.

The field survey entailed:

- measuring the water quality of terminal lakes for dissolved oxygen, electrical conductivity, pH, temperature and turbidity
- examining and photographing the receiving environments of catchments and collecting water samples (where possible)
- digging auger holes to a maximum depth of 3 m in receiving environments to identify the presence or absence of shallow groundwater and to assess water quality
- measuring the electrical conductivity and pH of bed sediments to assess the salinity of the receiving environments and enable commentary on likely groundwater/surface water interaction.

Catchments and watercourses on the gas pipeline corridor options were examined and photographed during a ground-based ecological survey undertaken in October 2006 and a helicopter and ground-based survey in January 2008. Conditions were dry during these surveys, so sampling was restricted to collecting surface water samples at four locations in the EIS Study Area, where it was present in waterholes or springs.

11.2.2 WATER ACCUMULATION IN THE OPEN PIT

The size of the proposed open pit would grow over time, ultimately spanning an area 3.5 km long, 4.1 km wide and about 1 km deep (see Chapter 5, Description of the Proposed Expansion, Section 5.4.1 for details). An assessment was undertaken to predict the volume of water entering the open pit after mine closure in order to determine whether water would accumulate at the bottom of the pit and eventually form a permanent pit lake. The possibility of this outcome depends on the relationship between incident rainfall, surface run-off from local catchments draining to the pit, groundwater inflow to the pit, and evaporation. An assessment of potential impacts to fauna from the accumulation of water in the open pit after closure is provided in Chapter 15, Terrestrial Environment.

A water balance model was developed to predict the likely rate at which water would enter the pit, whether evaporation would exceed water entry and, if it doesn't, the steady state water level condition that would eventually develop. The model was run to simulate the water balance for 3,000 years, which was found to be well in excess of the required duration to reach steady state conditions in all scenarios considered.

The key components of the assessment methods were (see Appendix J2 for details):

- estimating water inputs into the pit from groundwater, incident rainfall and surface water run-off from the pit walls and small external catchments
- estimating evaporative loss of water within the pit
- conducting sensitivity analysis to assess the effect of uncertainty regarding the input parameters on the model outputs. Consideration was also given to the impact of changing weather conditions due to climate change
- characterising the chemistry of input waters (groundwater, surface water run-off, incident rainfall) based on groundwater and surface water monitoring and tailings storage facility (TSF) and rock storage facility (RSF) seepage predictions (see Chapter 12, Groundwater)
- undertaking limnological analysis to estimate the physical characteristics (salinity gradient, temperature gradient and circulation patterns) of a potential pit lake
- estimating the chemical characteristics (i.e. pH, redox, major anions and cations, and metal concentrations) of pit waters using a geochemical model, including sensitivity analysis.

11.2.3 IMPACT AND RISK ASSESSMENT

The assessment of impacts and risks for the proposed expansion has been undertaken as two separate, but related, processes (see Section 1.6.2 of Chapter 1, Introduction, and Figure 1.11).

Impacts and benefits are the consequence of a known event. They are described in this chapter and categorised as high, moderate, low or negligible in accordance with the criteria presented in Table 1.3 (Chapter 1, Introduction). A risk assessment describes and categorises the likelihood and consequence of an unplanned event. These are presented in Chapter 26, Hazard and Risk.

11.3 EXISTING ENVIRONMENT

11.3.1 DRAINAGE REGIONS

The Olympic Dam operation and associated infrastructure are located in the Cooper Creek, Lake Frome, Gairdner, Torrens and North St Vincent–Spencer Gulf drainage regions (see Figure 11.1). These regions, particularly Cooper Creek, Lake Frome, Gairdner and Torrens are lowland interior basins of Australia where rainfall generally ponds on the surface for short periods of time, prior to infiltration or evaporation. Following large rainfall events, surface water collects in terminal surface water features such as clay pans, small fresh or brackish lakes (e.g. Coorlay Lagoon) and ephemeral salt lakes such as Lake Eyre South and Lake Gregory (along the gas pipeline corridor options) and Lake Torrens, Lake Windabout, Pernatty Lagoon and Island Lagoon (along the southern infrastructure corridor) (see Plates 11.1, 11.2 and 11.3). In dunefield areas, typical of the areas surrounding Olympic Dam, stormwater flows often occur at very low velocities and over short distances, a result of the flat terrain and small closed catchments formed by the dune-swale systems. Rainfall in the North St Vincent–Spencer Gulf drainage region is generally higher and more seasonal than the Gairdner and Torrens regions, with surface water run-off trending towards the sea via Spencer Gulf.

Darwin is located within the Timor Sea drainage region, an area which drains more than 50 million megalitres of water from the Northern Territory each year. Surface water run-off in the tropical areas of the Northern Territory is dominated by well defined rivers and drainage features, rather than by surface ponding and evaporation. River flow and surface water run-off is highly seasonal, being highest during October and April, when more than 95% of the annual rainfall occurs.

On a local scale, the Port of Darwin lies within the Darwin Harbour catchment. This catchment can be further divided into the sub-catchments of the Howard River, Elizabeth River, Blackmore River and the minor creeks and streams of the West Arm and Woods Inlet (Haig and Townsend 2003). The East Arm of the Port of Darwin is located within the Elizabeth River sub-catchment.

11.3.2 SURFACE WATER CATCHMENTS

While the drainage regions identify broad drainage boundaries, greater definition of surface water catchments on a local scale is required to understand the implications for the proposed expansion. As surface water flow in much of the South Australian portion of the EIS Study Area is not dominated by drainage to defined channels and rivers, the finer-scaled land system mapping developed by PIRSA better represents the local catchment characteristics. Land systems in the region were described in Chapter 10, Topography and Soils, and the location and extent of each land system was shown in Figures 10.3 and 10.4.

Plate 11.1 Lake Torrens

Plate 11.2 Lake Windabout

Plate 11.3 Lake Gregory and the dunefields of the Strzelecki Desert

Figure 11.1 Surface water drainage regions and basins

There are 28 land systems in the EIS Study Area within South Australia. Twelve of these cover the Olympic Dam region and the project area south to Point Lowly, and a further 16 occur to the north, within the gas pipeline corridor options.

The Olympic Dam area and southern infrastructure corridor mainly fall within four land systems:

- Roxby – this includes the existing SML, Roxby Downs township and the adjacent sections of the southern infrastructure corridor
- Arcoona – this includes the proposed Hiltaba Village, relocated airport, large sections of the southern infrastructure corridor between kilometre points (kp) 170 and 270 and a small section of the gas pipeline corridor options
- Hesso – this includes the southern infrastructure corridor between kp 80 and 170
- Tent Hill – this includes the southern infrastructure corridor between kp 30 and 80 and the proposed desalination plant at Point Lowly.

The gas pipeline corridor options traverse two broad groups of land systems with similar landforms and drainage patterns:

- Stony plains and tablelands – Oodnadatta, Kalatinka, Mumpie, Flint, Kopi and Cooryaninna
- Dunefields – Stuarts Creek, Wirringina, Collina, Hope, Tingana, Strzelecki and Cooper.

The relationships between these land systems and surface water catchments is described below.

Roxby land system

The Roxby land system is characterised by many small, enclosed catchments, individually bound by east–west trending dunes, generally up to eight metres high. Typically, each catchment contains a boundary formed by the crest of sand dunes, an upper interdunal corridor (swale) and a lower depression, often a clay pan (see Plates 11.4 and 11.5 and Chapter 10, Topography and Soils, Plate 10.1).

The sand ridges are highly permeable. Rainfall infiltrates quickly through the sandy profile, draining into the swale and clay pan after being redirected by a thick layer of clayey soil under the sand dunes. The clayey soils of the swales and clay pans are less permeable and, in periods of significant rainfall, collect water in low depressions. These dune-swale and clay pan catchments vary in size from 10–300 ha and are typically 1–3 km long. Figure 11.2 shows examples of small, enclosed catchment boundaries associated with the Roxby land system.

Stormwater within the swales and clay pans infiltrates the surface cracks of the clay soils, causing them to swell. In most instances the swelling of the clay soils reduces infiltration significantly, leading to surface water ponding. Depending on the rainfall event, surface water may stay in the swales and clay pans from a few days to a few weeks, but only rainfall events of a significant intensity and duration result in ponding for more than one month. The ponded water in this land system is generally fresh and of high quality.

There are no defined watercourses in the EIS Study Area in the Roxby land system and surface waters from the small catchments very rarely flow into the neighbouring catchments. No stormwater from the area of the existing operation flows off the SML.

Arcoona, Hesso and Tent Hill land systems

The southern infrastructure corridor traverses these three main land systems.

The Arcoona land system has well defined drainage lines and catchments that have formed several large terminal salt lakes and ephemeral lagoons (such as Lake Torrens, Lake Windabout, Island Lagoon and Pernatty Lagoon; see Figure 11.1). Channel flow occurs in broad and poorly defined drainage lines during rainfall events (see Plate 11.6). Gully erosion, while not extensive, is evident in areas where stormwater flows are

Plate 11.4 Interdunal corridor

Plate 11.5 Clay pan showing surface water drainage lines

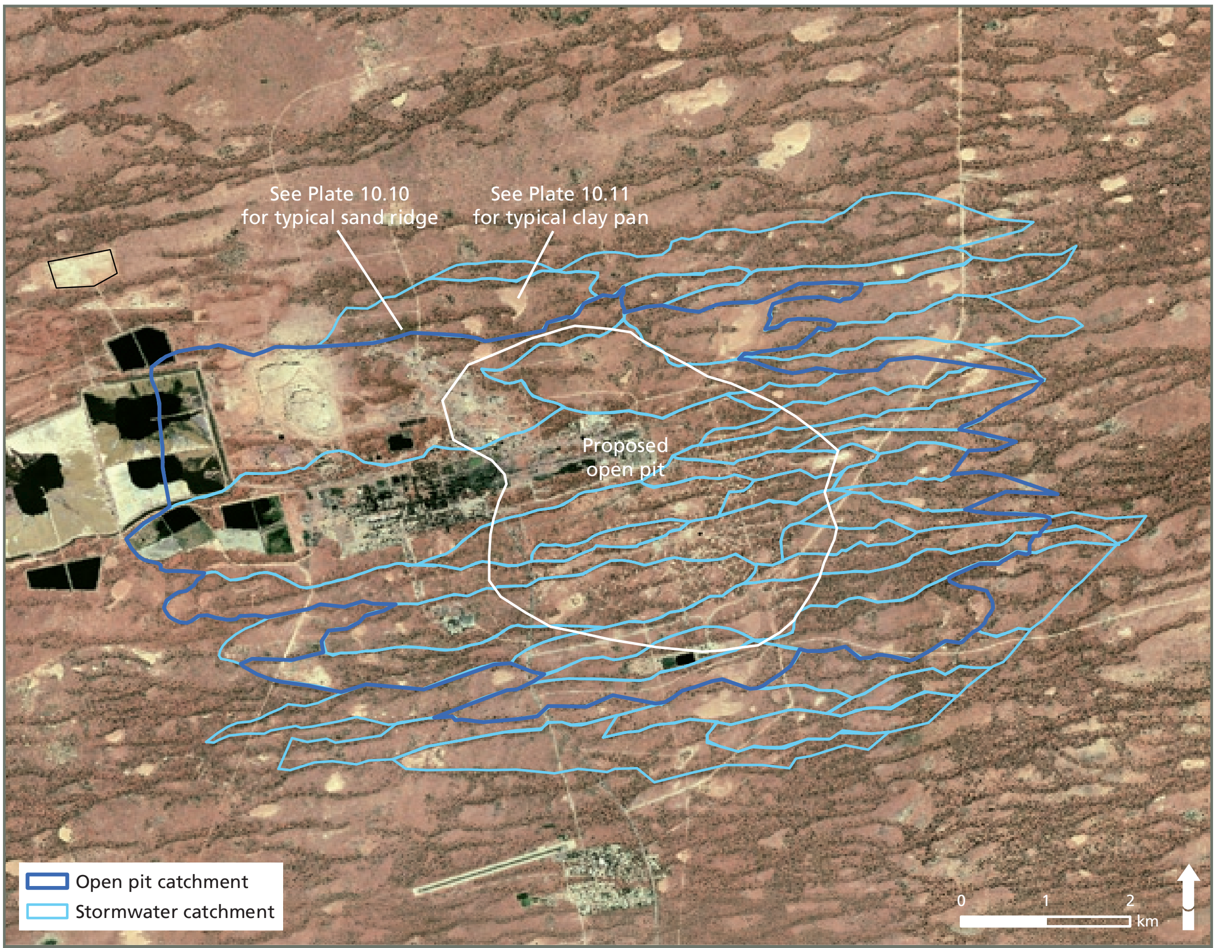

Figure 11.2 Surface water catchments surrounding the proposed open pit

concentrated, such as near roadside drains and culverts (see Plate 11.7). Water quality is highly variable and cyclic, ranging from fresh during rain events, to highly saline as a result of evapoconcentration (i.e. as evaporation occurs the concentration of salt in the remaining surface water increases).

The Hesso land system covers the area from just south of Pernatty Lagoon (kp 170) to Port Augusta (kp 80). This system is characterised by extensive flat sandy plains (see Plate 11.8). Infiltration is relatively high, therefore surface ponding occurs only after significant storm events. However, given the flat terrain, surface ponding is widespread when such events occur. Surface water is good quality, generally infiltrating to the groundwater before significant changes in salinity levels can occur.

The Tent Hill land system covers the area south of Port Augusta to Point Lowly. This system is characterised by steep escarpments and plateaus, separated by alluvial plains (see Plate 11.9). Well-defined drainage paths intercept these landforms. Minor creeks from elevated areas join to form large

Plate 11.6 Typical drainage pattern of the Arcoona land system

Plate 11.7 Erosion due to concentration of stormwater flow through culverts

incised creeks as they enter the broad, flat, floodplains. These large creeks carry high water flows during storm events. Overland flow and creek flows are often highly turbid and have low salinity levels. Myall Creek is the most extensive catchment in this part of the study area. The catchment terminates in a broad floodplain that discharges to the coast via a floodway across the Point Lowly access road. Coastal discharges also occur at Port Augusta from an unnamed creek that runs parallel to the Eyre Highway.

Stony plain and tableland land systems

The stony plain and tableland land systems of the gas pipeline corridor options (Oodnadatta, Kalatinka, Mumpie, Flint, Kopi and Cooryaninna) are characterised by undulating gibber (and some gypsum) plains with areas of tablelands and stony hills. Drainage lines are generally well defined and terminate in the large salt lakes of Lake Eyre, Lake Gregory, Lake Blanche and Lake Callabonna. Extensive networks of minor watercourses join to form large, broad and often braided watercourses as they traverse the stony plains and approach the terminal salt lakes. Drainage channels in elevated areas (e.g. the mesa slopes of the Flint land system) can be narrow and incised.

Stone free areas with cracking clay soil (i.e. Gilgai) form a major component of these land systems, and accept much of the run-off from the largely impermeable gibber areas during smaller rainfall events.

Plate 11.8 Typical catchment composition of Hesso land system

Plate 11.9 Typical catchment composition of Tent Hill land system

In the Oodnadatta and Kalatinka land systems, the gas pipeline corridor options cross several watercourses that drain into Lake Eyre South (including Gregory and Screech Owl Creeks; see Plate 11.10) and Lake Eyre North (including the Clayton and Frome Rivers). The Frome River originates in the North Flinders Ranges, and can flow as a result of heavy rainfall well outside the project area. The extensive Mumpie land system (see Plate 11.11) in the east of the project area is also crossed by a number of large watercourses that originate in the North Flinders Ranges (e.g. MacDonnell Creek, Twins Creek and Petermorra Creek) and drain into Lake Blanche.

All watercourses in these land systems are truly ephemeral. However waterholes can persist on many of the larger watercourses for many months after flow occurs. Permanent surface water is present in the gas pipeline corridor options on Murnpeowie Station at Reedy Springs (GAB springs), Saint Mary Pool and at bore-drains including Clayton Station and Montecollina Bore.

Plate 11.10 Screech Owl Creek and floodout area

Plate 11.11 Koortanyaninna Creek draining through Mumpie land system

Dunefield land systems

The extensive dunefield land systems (Stuarts Creek, Wirringina, Collina, Hope, Tingana, Strzelecki and Cooper) are characterised by parallel sand ridges with interdune corridors ranging in width from several hundred metres to over a kilometre. Clay pan swamps may be present in any interdune, but are largest and most frequent in wider interdunes. Small salt lakes also occur in some interdune corridors.

Although interdune corridors and the dunes themselves are typically larger in these land systems than in the Roxby land system, patterns of flow, infiltration and inundation are similar to those described for the Roxby land system above. Surface waters pond in interdune corridors and rarely flow into neighbouring catchments or land systems. Notable exceptions are Strzelecki Creek (see Plate 11.12) and the broad interdune floodplain corridors in the Cooper land system. Large Cooper Creek floods result in flooding of the adjacent interdune corridors, which can extend for tens of kilometres. Very large Cooper Creek flows can result in the Strzelecki Creek flowing southwards to Lake Blanche through the Cooper, Tingana and Collina land systems. This has been estimated to occur (on average) once in every 10 years (Puckridge et al. 1999). Temporary waterholes on the Strzelecki can persist for many months or more after filling.

11.3.3 FLOODING

Although the project area is predominantly arid (with the exception of Darwin), flooding still occurs at various scales and frequencies. This section provides a summary of local and regional flooding and its implications for the project. Detailed descriptions of flood events in the project area can be found in the recent publication *Floods in South Australia: 1836–2005* (McCarthy et al. 2006).

Plate 11.12 Strzelecki Creek on the gas pipeline corridors

Flooding mechanisms

Flooding in the project area occurs as:

- Mainstream flooding – caused when the volume of water exceeds the channel's conveyance capacity and the water flows out on to the floodplain. The floodplain may or may not convey flow, but will contribute to flood storage. Floodwaters recede as water moves downstream which in most catchments, usually occurs relatively quickly (i.e. within hours or days) following the storm event.
- Surface ponding – caused by either regional inundation of flat areas, or surface run-off collecting in terminal catchment depressions. These depressions range from small clay pans to large salt lakes. There is no, or very little, movement of floodwater. It recedes by infiltration and evaporation, and may be present for long periods of time (typically weeks, occasionally months, and rarely years).

Flooding frequency, intensity and duration

The closure of unsealed roads because of flood inundation, particularly north of Olympic Dam, is relatively common during rainfall events. However, flooding has also contributed to closures of major roads and the trans-Australian rail line on a number of occasions, such as in December 1992 and February 2000. These structures are generally designed for a flood immunity of a 50-year ARI (i.e. a 1-in-50-year average recurrence interval rainfall event).

The most notable flooding event of the last twenty years occurred in March 1989 and caused widespread flooding throughout the arid region. Olympic Way, between Woomera and Roxby Downs, was closed and sections of the road were washed away. The road has since been upgraded and enlarged culverts installed. The storm event was significant in a regional context, as Lake Torrens filled for the first time in more than 100 years.

More recently (January 2007), widespread thunderstorms and heavy rain over much of South Australia produced localised flash flooding within the project area. Arcoona homestead, near Woomera, recorded 143 mm in a 24-hour period, with much of this falling within four hours (BOM 2007).

Rainfall patterns and intensity-frequency-duration data for the project area were obtained from the Bureau of Meteorology (BOM) and used in the design of stormwater management systems for the proposed expansion. Data for high intensity (five minutes) and long (72-hour) duration storm events are summarised in Chapter 8, Meteorological Environment and Climate, Table 8.2. The data indicate that there is little variation across the project area, although intensities are marginally higher in the northern sections.

The implications of global climate change on rainfall patterns and surface water conditions are addressed in Chapter 8. In general, the region around Olympic Dam is predicted to experience a lower annual average rainfall. However, the intensity of heavy rain events is likely to increase slightly.

11.3.4 CURRENT WATER USE AND DOWNSTREAM USERS

Although surface water is normally very scarce throughout most of the project area (with the exception of Darwin), it does play an important role for pastoralists and native fauna. Surface water is also used for recreational activities on an opportunistic basis.

There are many small dams present throughout the project area. In the dune-swale landscape of the Roxby land system, pastoralists may create small dams by connecting adjacent swales using culverts, and up to two years' water supply can be produced from a large storm event using such an arrangement (Kinhill-Stearns Roger 1982). Sheep and cattle also use ponded water within clay pans following storm events. Waterholes on larger creeks in the northern part of the project area, which can persist for many months after filling, also represent an important water source for sheep, cattle and native fauna.

Despite measures to harvest surface water, the variability of supply and high evaporation rates mean that surface water is only used opportunistically.

11.3.5 WATER QUALITY

There are no recorded data or surface water monitoring sites in the vicinity of Olympic Dam or along the infrastructure corridors, most likely due to the general lack of permanent surface water, the difficulty in accessing surface water sampling locations during storm events, and the inherent variability of water quality in ephemeral systems. For these reasons, it has not been possible to analyse water quality with detailed reference to the policies and guidelines set out in the EIS Guidelines. Due to the ephemeral nature of the watercourses in the EIS Study Area, there is no riparian vegetation to be considered.

However, generalisations can be made of expected water quality based on processes that occur during and following rainfall events. Changes occur in water quality in both the creeks and drainage lines, and the receiving environment. These changes generally go through the following stages:

- Stream flow – this occurs after initial wetting of the catchment and surface run-off begins. Stream flow is likely to be fresh, highly turbid, slightly alkaline, and have a high dissolved oxygen concentration due to turbulence.
- Pool phase – this occurs when the flow in drainage lines has ceased, but isolated pools remain. The still water allows suspended sediment to settle out of the water column and the decomposition of organic matter in some pools may release nutrients into the water. Where seepage is negligible, the salinity may increase due to evapoconcentration effects.
- Dry phase – this involves the absence of surface water. The dry phase occurs most of the time throughout the region.

The water quality in receiving waters undergoes a similar sequence of changes:

- Filling phase – this occurs when lakes and swamps receive highly turbid, slightly alkaline waters, as described above. As the salt lakes fill they become highly saline. Then as the lakes fill further, salts become diluted.
- Evapoconcentration phase – this occurs when there is no further input of water into the lake, and water is lost either due to evaporation or seepage. Dissolved oxygen is likely to decline as stranded plants, animals and algae die and decompose. This may also increase nutrient concentrations. The salinity in the lakes slowly increases as water is lost to evaporation. The evapoconcentration phase typically lasts for weeks or months, but after very large storm events receiving waters can hold water for long periods (e.g. up to three years following the 1989 event).
- Dry phase – this phase follows complete evaporation or seepage. In freshwater lakes and clays pans the surface becomes highly desiccated. The dry phase occurs most of the time throughout the region.

These stages are most important in the Roxby and Arcoona land systems and most land systems in the gas pipeline corridor options, where low gradients and the nature of the terminal drainage features (i.e. clay pans and salt lakes) means that surface water generally pools for longer periods. In contrast, the Hesso land system is characterised by sandy soils that are likely to have high infiltration rates, and surface water held in localised depressions is likely to be lost very quickly to seepage, probably before significant changes to water quality can occur.

The Tent Hill land system contains several large catchments and well-defined creeks. Following significant rainfall events, surface water is likely to be conveyed quickly and is more likely to represent the water quality of the input waters (i.e. rainfall), with low salinity and near-neutral pH. Water in areas subject to inundation is expected to be lost primarily through seepage, but also evaporation.

Rainfall occurred across the project area during the field survey of the southern infrastructure corridor, enabling some opportunistic water sampling. Although a 'grab sample' only provides an indication of water quality, these samples generally confirmed the above assumptions. Mason Creek and Woocalla Creek are freshwater drainage features (as indicated by the generally low total electrical conductivity, and concentrations of major ions, particularly chloride and sodium), while Ironstone Lagoon and Lake Windabout are salt lakes.

Opportunistic water samples were also collected at four sites along the gas pipeline corridor options. Two of these sites were waterholes that had filled some months before sampling, and the remaining sites were at sources of permanent water on Murnpeowie Station – Reedy Springs (a group of GAB springs) and St Mary's Pool. Tables 11.1 and 11.2 show water quality results, and Figure 11.1 shows the sample locations.

Surface waters in the Darwin Harbour catchment are generally characterised by low salinity and neutral pH. The concentration of metals, nutrients and suspended materials is typically higher in run-off from urbanised and industrial areas compared to undisturbed areas (Padovan 2003).

Table 11.1 Water quality results – southern infrastructure corridor

Parameter	Units	LOR[1]	SW1 Mason Creek	SW2 Ironstone Lagoon	SW3 Woocalla Creek	SW4 Lake Windabout
pH value	pH unit	0.01	7.1	6.76	7.52	6.84
Electrical conductivity	µS/cm	1	81	–	231	41,100
Total dissolved solids	mg/L	1	85	140,000	468	22,300
Total anions	meq/L	0.01	1.1	2,510	1.32	457
Total cations	meq/L	0.01	0.96	2,300	1.37	464
Ionic balance	%	0.01	–	4.38	–	0.81
Hydroxide alkalinity as $CaCO_3$	mg/L	1	<LOR	<LOR	<LOR	<LOR
Carbonate alkalinity as $CaCO_3$	mg/L	1	<LOR	<LOR	<LOR	<LOR
Bicarbonate alkalinity as $CaCO_3$	mg/L	1	29	33	34	12
Total alkalinity as $CaCO_3$	mg/L	1	29	33	34	12
Acidity as $CaCO_3$	mg/L	1	6	29	6	12
Sulphate as SO_4^{2-}	mg/L	1	2	2,550	12	572
Chloride	mg/L	1	17	87,000	14	15,800
Calcium	mg/L	1	1	304	1	99
Magnesium	mg/L	1	<LOR	2,100	1	539
Sodium	mg/L	1	20	48,300	26	9,510
Potassium	mg/L	1	1	256	4	64
Arsenic	mg/L	0.001	<LOR	<LOR	<LOR	<LOR
Cadmium	mg/L	0.0001	0.0002	0.0006	0.0004	0.0003
Chromium	mg/L	0.001	<LOR	<LOR	<LOR	0.001
Copper	mg/L	0.001	0.004	<LOR	0.006	0.002
Lead	mg/L	0.001	0.002	<LOR	0.001	<LOR
Nickel	mg/L	0.001	0.002	<LOR	0.002	0.002
Zinc	mg/L	0.005	0.018	<LOR	0.045	0.006
Mercury	mg/L	0.0001	<LOR	<LOR	<LOR	<LOR

[1] Laboratory limits of reporting.

11.3.6 STORMWATER DRAINAGE

Mine area

The Olympic Dam mine currently operates on the basis of containing surface water flows in a defined management area, including both high-and low-quality waters. Run-off from operational areas is directed to various storage areas including evaporation ponds, tailings storage facilities (TSF), stormwater retention ponds, tertiary containment ponds and other minor storages across the site (see Figure 11.3). As these storages are not covered, they are influenced by rainfall and evaporation. This is important for the operation's water balance, especially in the large storages such as the TSF and evaporation ponds (see Chapter 5, Description of the Proposed Expansion, Section 5.7.10, for a description of the site's water balance).

Township of Roxby Downs

The natural profile of the land in the areas of the proposed township expansion and observations from previous stormwater flows, indicates rainfall run-off will flow predominantly from east to west utilising the natural low points within the existing dune–swale terrain. The current stormwater drainage system consists of a combination of pipes and open channels. The main network is predominantly piped. However, open channel drains exist along sections of Olympic Way, Stuart Road and Axehead Road, and throughout the southern residential area of Roxby Downs. Minor collector roads and local access roads are used throughout the township as open channel flow paths that feed into the main network during peak storm events.

The stormwater network ultimately drains into four lined stormwater ponds and one unlined basin. Water collected in the stormwater ponds is harvested for reuse by directing the water to the sewage treatment lagoons, while water collected in the basin pond is lost via evaporation and seepage to groundwater.

The current piped drainage network has been designed for two to five-year ARI rainfall events in residential areas, and for a 10-year ARI rainfall event in industrial and commercial districts. During higher intensity rainfall events (up to 100-year ARI), the current system overflows onto the road network, which acts as a 'floodway' and effectively provides a 1-in-100-year flood immunity to residential and industrial areas.

Port of Darwin

The East Arm of the Port of Darwin is characterised by alluvial and estuarine plains with extensive intertidal flats of saline muds, clays and silts, foreshore areas of deposited sands and

Table 11.2 Water quality results – gas pipeline corridor options

Parameter	Units	LOR[1]	GC1 Frome River	GC2 Cooryanna Ck Tributary	GC128 Reedy Springs	GC134 St Mary Pool
pH value	pH unit	0.1	9.3	8.1	8.1	7.9
Electrical conductivity	µS/cm	20	2450	355	2420	324
Total dissolved solids	mg/L	5	1400	1100	1400	210
Total anions	meq/L	0.2	22	4.8	11	5.1
Total cations	meq/L	0.2	26	3.9	28	3.4
Ionic balance	%	1	8.3	10	44	21
Hydroxide alkalinity as $CaCO_3$	mg/L	10	<LOR	<LOR	<LOR	<LOR
Carbonate alkalinity as $CaCO_3$	mg/L	10	214	<LOR	<LOR	<LOR
Bicarbonate alkalinity as $CaCO_3$	mg/L	10	631	152	225	186
Total alkalinity as $CaCO_3$	mg/L	20	844	152	225	186
Acidity as $CaCO_3$	mg/L	20	<LOR	<LOR	25	<LOR
Sulphate as SO_4^{2-}	mg/L	0.5	8.1	39	38	17
Chloride	mg/L	0.5	210	16	180	18
Calcium	mg/L	0.1	4.7	15.7	10.5	32.9
Magnesium	mg/L	0.1	1.2	4.33	1.26	4.92
Sodium	mg/L	0.1	581	56.4	621	26.7
Potassium	mg/L	1	13	11	8.19	5.92
Arsenic	mg/L	0.005	<LOR	6	<LOR	<LOR
Cadmium	mg/L	0.005	<LOR	<LOR	<LOR	<LOR
Chromium	mg/L	0.005	<LOR	<LOR	<LOR	<LOR
Copper	mg/L	0.005	<LOR	0.005	<LOR	<LOR
Lead	mg/L	0.005	<LOR	<LOR	<LOR	<LOR
Nickel	mg/L	0.005	<LOR	<LOR	<LOR	<LOR
Zinc	mg/L	0.005	0.09	<LOR	<LOR	<LOR
Mercury	mg/L	0.001	<LOR	<LOR	<LOR	<LOR

[1] Laboratory limits of reporting.

shells, and a hinterland of shallow gravelly, sandy soils (NRETA 2007; Haig and Townsend 2003). East Arm was constructed through the process of land reclamation and was formed from fill from the surrounding area. Surface water run-off from East Arm is managed through a series of stormwater drains and collection pits that ultimately discharge to the ocean.

11.4 DESIGN MODIFICATIONS TO PROTECT ENVIRONMENTAL VALUES

11.4.1 ENVIRONMENTAL VALUES

Section 11.3 noted that, although surface water is scarce, when available it is used:

- by pastoralists for stock water
- by native fauna for drinking water
- opportunistically for recreational activities.

Surface water is also part of aquatic ecosystems that have inherent biodiversity value. The design and operation of the proposed expansion addresses the protection of these uses and values.

11.4.2 MAJOR ELEMENTS OF THE PROJECT DESIGN

The water management system would accommodate the following regime:

- three sources of water (i.e. desalination plant, saline wellfield and GAB) and reuse. These waters are controlled by the water balance shown in Figure 5.26
- infrequent but sometimes heavy rain
- occasional surpluses of water of different qualities
- design safety standards for the TSF as a water-retaining structure.

The two components of the water management system are:

- the process and water balance
- stormwater drainage and treatment.

The project design has been modified, beyond standard engineering controls, to provide greater protection to the environmental values outlined in Section 11.3 and 11.4.1.

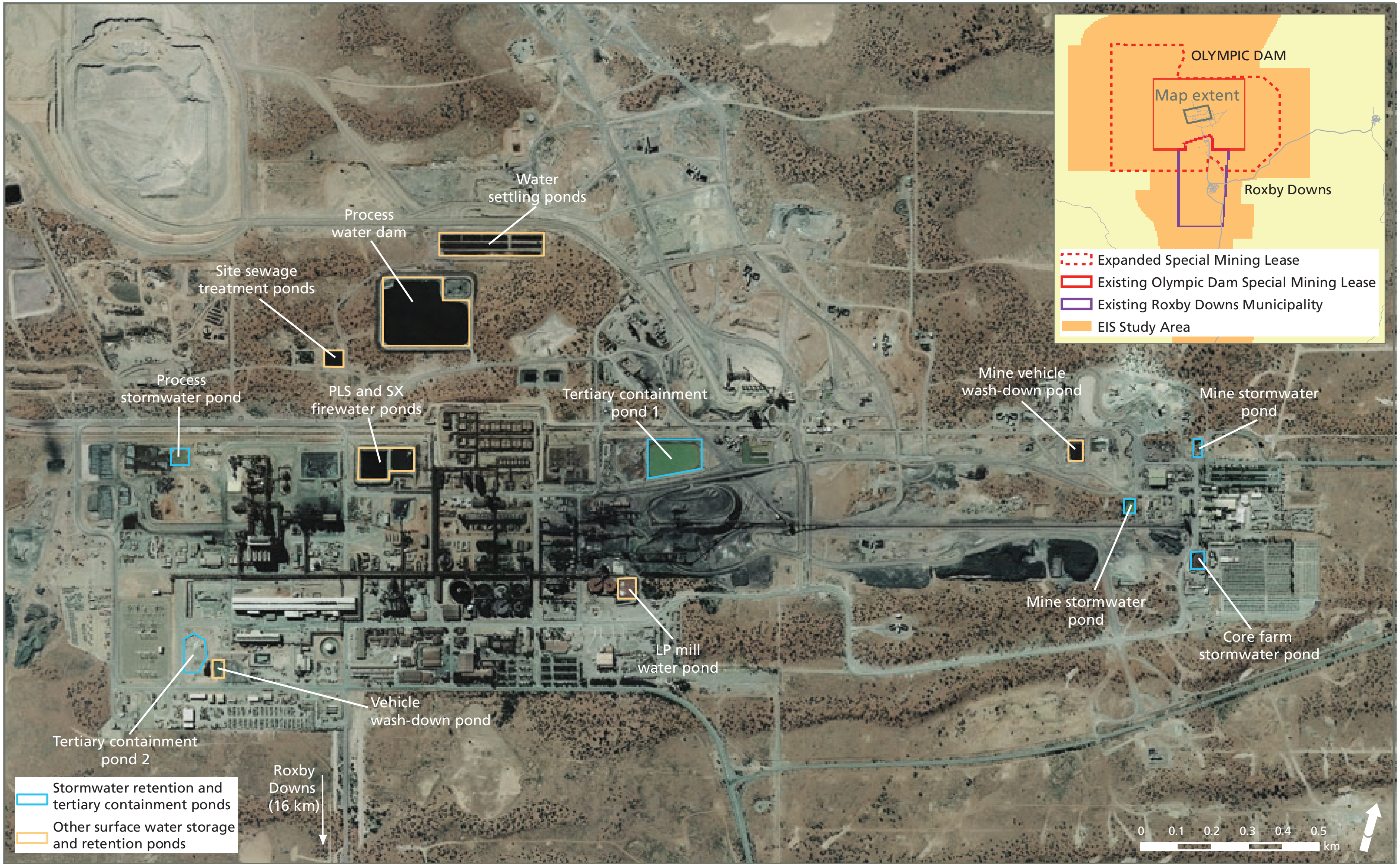

Figure 11.3 Existing stormwater retention and tertiary containment ponds

Process water balance

Stormwater management systems have been incorporated into the process water balance to ensure that on-site facilities, such as the TSF and stormwater retention ponds, would have sufficient capacity (freeboard) to accommodate protracted and heavy rainfall. Additional freeboard of 0.5 m has been incorporated into the TSF design to account for possible changes due to global climate change.

The TSF design also includes structures, such as toe drains and internal curtain drains (see Appendix F1 for detail), to prevent lateral seepage from the base of the TSF.

Stormwater management

The new entry road to the mine site would be constructed as a levee to contain a 1-in-100-year flood. This would ensure containment of run-off from the low-grade ore stockpile and maintain the site's current status of no off-site release.

Transport, handling and storage of concentrate at the Port of Darwin would be managed in a 'closed' system because it contains low levels of uranium and triggers the requirement to be handled and transported as a radioactive substance. As part of the closed system, rail wagons would be enclosed, the transfer from rail wagon to the concentrate storage shed at the East Arm facility would be enclosed and the storage shed would be fitted with automatic doors, a negative pressure particulate filtration and building ventilation system. This would ensure that no stormwater from the site comes into contact with the concentrate product.

Additional mitigation measures and the standard controls that would be implemented are described in Section 11.5.

11.5 IMPACT ASSESSMENT AND MANAGEMENT

11.5.1 DRAINAGE PATTERNS

The various components of the proposed expansion have the potential to change existing drainage patterns and increase the area of impervious surfaces. This may in turn change flow paths within and between catchments, affect flood immunity, reduce infiltration of stormwater to the groundwater and increase velocities of surface water run-off leading to erosion. The potential for erosion and the resulting sedimentation was addressed in Chapter 10, Topography and Soils. The remaining issues are addressed below.

Stormwater, flow paths and flood immunity

Open pit

The proposed open pit would intercept many small sub-catchments (see Figure 11.2). Stormwater in the vicinity of the pit rim would be diverted to natural depressions of the dune-swale landscape (e.g. clay pans) by a pit-rim bund and elevated haul roads (see Figure 11.4 for the location of major haul roads). The relationship between the levels of the pit-drain and the haul road would afford protection for a 1-in-100-year storm event. During the construction period, the western side of the pit rim haul road would be more than 1 km away from the edge of the pit. During this time, levee banks would be used to capture and detain the water in low points. The levees would typically be up to 2 m high to detain a 1-in-100-year storm event.

Water may enter the pit directly from incident rainfall. Stormwater that reaches the pit floor, either directly or from the pit walls, would flow to a sump. This water would be used preferentially for dust suppression when the pit floor and haul roads are dry. During periods of prolonged rainfall or extreme rainfall events, when the stormwater collected exceeds the volume that could be used for mining operations, water would be pumped to the surface and directed into the natural depressions on-site, used to the extent possible, and allowed to evaporate or infiltrate.

Rock storage facility

Construction of the RSF would change the local sub-catchments in the immediate vicinity. Figure 11.4 shows the new catchments that would be created by the RSF. They include the RSF itself and the natural landscape from the RSF to which run-off would drain.

The natural dune system surrounding the RSF means that the catchments remain small and localised. Run-off would essentially be funnelled between the sand dunes and collect in the low depressions formed by clay pans where water would slowly evaporate or be collected for reuse where practicable. Even after a 1-in-100-year storm event, run-off from the RSF would be contained within the expanded SML sub-catchments (see Figure 11.4).

While most of the catchments surrounding the RSF have boundaries formed by the natural landscape, run-off from the low grade ore stockpile would be contained within a defined management area bounded by the new mine entry road. This road would be specifically constructed to a height (around 97 m AHD) that would contain run-off from a 1-in-100-year storm event.

Metallurgical plant and TSF

Stormwater in the areas of the metallurgical plant and TSF would be managed in a manner similar to that for the existing operation; stormwater would be controlled within defined management areas and there would be no discharge of stormwater from the SML.

Stormwater run-off would be directed from the metallurgical plant and other hardstand areas, via open, un-lined drains to tertiary containment ponds for reuse. The containment ponds would be sized for a 100-year ARI event.

Incident rainfall that falls on the TSF would move along the beaches to the central decant pond. The design of freeboard within the tailings cells as discussed in Section 11.4 above and detailed in Chapter 5, Description of the Proposed Expansion, allows for stormwater inflows within the process water balance. The TSF design also includes an additional 0.5 m of freeboard to accommodate the possibility of higher intensity rainfall events

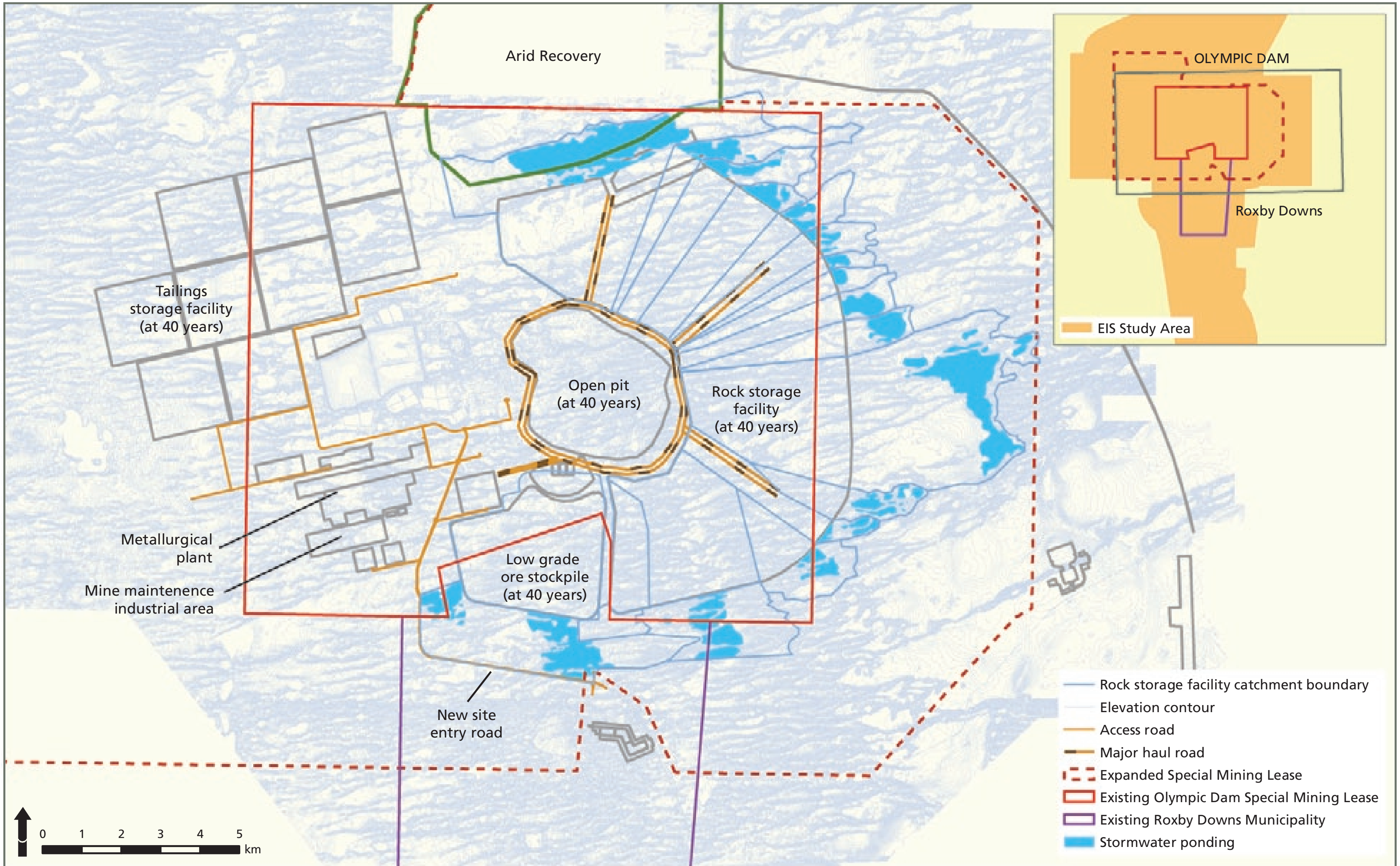

Figure 11.4 Extent of run-off from the rock storage facility for a 1-in-100-year storm event

(see Chapter 5, Description of the Proposed Expansion, Section 5.5.6 and Chapter 8, Meteorological Environment and Climate, Section 8.6.4).

Under-drainage of the TSF (see Appendix F1 for detail) would minimise lateral movement of seepage within the TSF and prevent the surface expression of seepage at the base of the TSF embankments.

The concepts discussed above would be refined during the detailed design phase of the project and documented within a stormwater management plan for the mine site.

Roxby Downs township

The township's development would change stormwater flows but they could be readily accommodated through engineering design.

The natural water flow in the vicinity of Roxby Downs is predominantly from east to west. Expanding the town in the east and increasing the area of impervious surfaces may result in higher run-off from this direction towards the existing infrastructure. New drainage networks and stormwater retention basins would be built to accommodate the increased flow from the proposed development (see Figure 11.5). As with the existing township, the piped stormwater network for the expanded Roxby Downs would accommodate a five-year ARI event and the road network would be designed to accommodate stormwater flows from the expansion area for a 100-year ARI event.

The Roxby Downs Draft Master Plan outlines the key principles for stormwater design (see Appendix F3), and includes the reuse of stormwater wherever practicable. More detailed engineering assessments of flood immunity would be conducted during the detailed design phase.

Hiltaba Village

As with the Roxby Downs expansion, the construction of Hiltaba Village would result in changes to stormwater flows that could be readily accommodated through engineering design.

The village site would be graded to define five drainage catchments (see Figure 11.6). Rain that fell on the village would be directed by drainage pipes to shallow swales that line the internal roads and pathways. The internal village swales would be sized to manage a five-year ARI event. The swales would overtop onto the internal road network to convey storm waters up to a 100-year ARI event. Stormwater run-off from the northern portion of the site would be directed to a storage basin immediately north of the village. If overtopped, stormwater would flow into an existing stock dam further to the north (see Figure 11.6). Another storage basin would be created to the south of the village to capture surface water from the southern section of the site. Stormwater from Hiltaba Village would be reused wherever practicable.

The stormwater storage basins have been sized to meet two criteria – to retain the entire rainfall generated in an average year, and to limit the duration of water ponding to a maximum of six months, prior to loss from infiltration and evaporation. For all storage basins, the six months evaporation criteria governs the basin depth and exceeds the requirement for a 1-in-5-year ARI event.

Rail line

The northern section of the proposed rail line traverses the Roxby land system and changes to drainage patterns would be minor due to the intersection of small localised interdunal catchments.

The southern section of the rail line traverses the Arcoona land system, which is characterised by well-defined drainage paths and catchments that terminate in many ephemeral fresh and saltwater lakes, including Lake Windabout, Coorlay Lagoon and Pernatty Lagoon. Construction of the proposed rail line in these areas would use cross-drainage structures (i.e. culverts) to maintain the stormwater flow paths to receiving environments. The existing drainage patterns across the line would be maintained by constructing up to 140 cross-drainage structures (see Chapter 5, Section 5.9.3, for rail line construction details).

The use of culverts or similar cross-drainage structures would also avoid the potential for increasing flood levels in low-lying areas, which may otherwise occur if stormwater is backed-up against the rail embankment.

Other linear infrastructure

Constructing and operating the transmission line, water supply pipeline, gas supply pipeline and airport would have negligible effects on catchments and flow paths. The changes would either be short-term and be reinstated after a short construction period (such as for the transmission line towers and buried water supply pipeline and buried gas supply pipeline) or would affect an area small enough not to significantly change the contributing catchment area within which they are located (such as for the airport and the permanent towers of the transmission line). The final alignment of linear infrastructure would be selected to avoid surface water features of particular significance (e.g. Reedy Springs and Saint Mary Pool on the gas pipeline corridor options). Erosion protection measures would be implemented to limit the flow of sediment from the construction area into watercourses (see Section 10.5).

The infrastructure components would have negligible impact on flooding or flood storage capacity, again due to the relatively small area of the structures compared to the catchments within which they are located.

Desalination plant and landing facility

Construction of the desalination plant and landing facility would have negligible effects on local catchments and flow paths. Both facilities are located within the Tent Hill land system (see Section 11.3.2), which is characterised by well defined drainage paths and discharge features that would not be intersected by either facility.

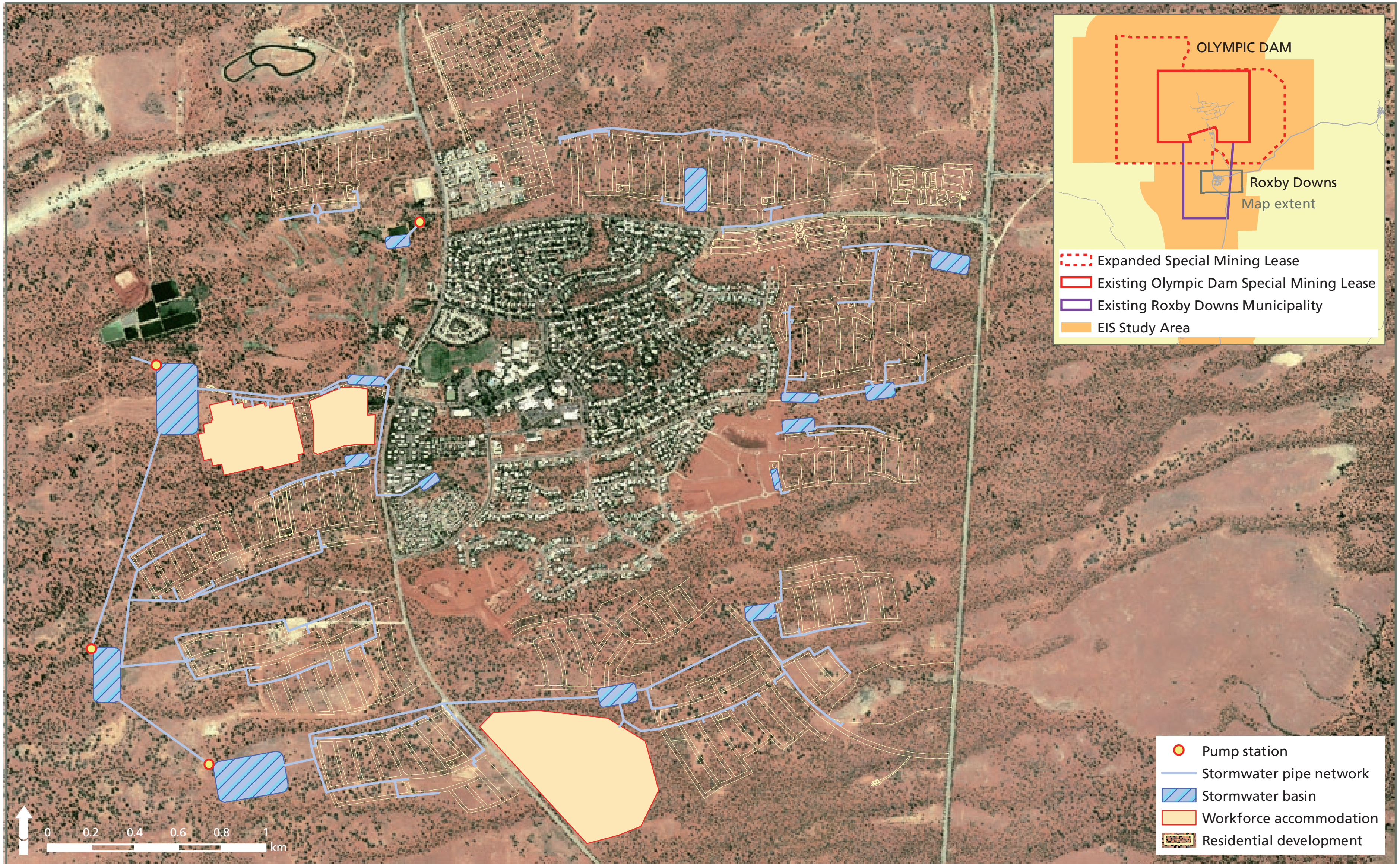

Figure 11.5 Conceptual stormwater network for Roxby Downs expansion

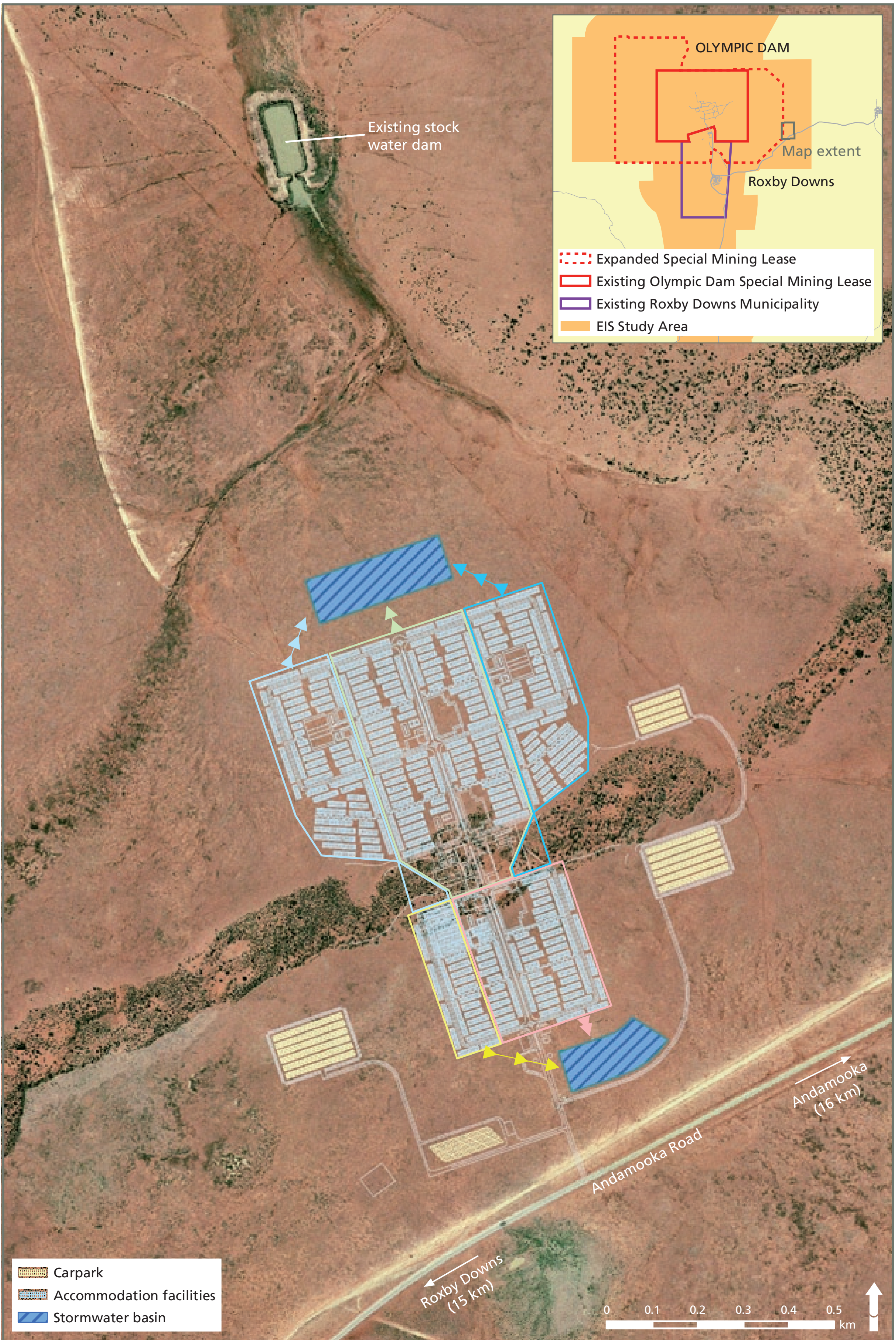

Figure 11.6 Conceptual stormwater network for Hiltaba Village

Furthermore, stormwater control plans would be developed for both facilities and the desalination plant would be designed so that:

- rainfall on disturbed areas of the site would be collected, treated and channelled to an on-site detention basin (sized to accommodate a 100-year ARI event)
- discharge from the on-site detention basin would match pre-development flows (i.e. large volumes of stormwater would not be discharged from the detention basin)
- rainfall landing above disturbed areas would be diverted around the site and discharged downstream of the detention basin.

The combination of stormwater control measures and the natural drainage of the Tent Hill land system would result in a negligible residual impact on flooding and flood storage capacity in the areas surrounding the desalination plant and the landing facility.

Port of Darwin

The hardstand areas (i.e. concentrate storage shed and office buildings) would occupy about 4 ha. This is a relatively small area compared with the total area of East Arm (about 900 ha). Nevertheless, rainfall that falls on this new impervious area has the potential to change drainage patterns and increase flow velocities.

First-flush stormwater run-off from the site would be directed to on-site detention basin(s) for settling of sediments prior to discharge to the established Port of Darwin stormwater detention system (as per the Port of Darwin's Draft Stormwater Management Plan), thus allowing flow velocities to be controlled.

Some stormwater would be collected and recycled as wagon wash-down water, but this would be minimal in comparison to the rainfall on the site and would have a negligible impact on drainage patterns. No wagon wash-down water would be discharged to the natural environment. Rather this would occur in an enclosed building and water would be collected, reused and ultimately transported back to Olympic Dam in a rail wagon. The residual impact of the proposed facilities in relation to stormwater run-off and drainage patterns is therefore categorised as negligible.

Infiltration of stormwater to the groundwater

The aquifers of relevance to the project area (i.e. the Andamooka Limestone and Tent Hill aquifers) are described in detail in Chapter 12, Groundwater. Groundwater aquifers are, in part, 'recharged' (i.e. water is added to the aquifers) by a small amount (0.1–0.2 mm/y) through the infiltration of rainfall into the soils that overly the aquifer.

The aquifers of relevance to Olympic Dam cover an area of approximately 750,000 ha. As with the current operation, stormwater that fell on the mining and metallurgical facilities in the SML would be directed to various stormwater containment ponds within the SML.

It is estimated that the proposed expansion would increase the amount of impervious surfaces (including mining and processing facilities, Hiltaba Village and Roxby Downs township) by less than 5,000 ha, which would reduce the recharge zone of the relevant aquifers by less than 1%. This is considered to represent a negligible residual impact in terms of recharge to the regional groundwater system, as the regional recharge is estimated to be less than 1% of rainfall.

The area of impervious surfaces for the remaining components of the proposed expansion (e.g. the proposed desalination plant and laydown areas) are considerably smaller than those areas within the SML. The potential to reduce groundwater recharge from these areas is also considered to be negligible.

Although the naturally occurring aquifers in the Darwin Harbour catchment are highly dependent upon surface water recharge, groundwater beneath the reclaimed area of East Arm of the Port of Darwin is not naturally occurring. Saturation of the sediments occurs from seawater infiltration rather than surface water infiltration. Therefore the proposed facilities would have no impact on the aquifers in the vicinity of the Darwin Harbour catchment.

11.5.2 WATER QUALITY

As discussed previously, there are no permanent surface water or water monitoring sites in the vicinity of Olympic Dam and most of the infrastructure corridors. While the quality of surface water in ephemeral systems is inherently variable, concentrations of salts and metals in samples collected for the Draft EIS (see Section 11.3.5, Tables 11.1 and 11.2) are considered to be representative of the expected water quality following large rainfall events.

Stormwater run-off from on-site facilities such as the metallurgical plant, hardstand areas and the RSF may contain elevated concentrations of metals and other potential contaminants (including radionuclides), and convey excess sediment. As discussed above, haul roads and bunds would be used to intercept and convey stormwater run-off from these facilities to naturally low lying areas within the landscape where it would be collected for reuse or allowed to evaporate and infiltrate. Stormwater would not be discharged from the SML.

Run-off from the low grade ore stockpile also has the potential to contain metals and radionuclides. For a 1-in-100-year rain event, water run-off from this area would be contained within an area bounded by the raised mine entry road. Water potentially containing radionuclides from the low grade ore stockpile would be contained on the site for a 1-in-100-year rain event.

As stormwater run-off would be contained within the SML, and run-off potentially containing radionuclides would be contained within a defined area, the residual impact is categorised as low as there would be a short-term impact to a local receiver.

The closest surface water receiving environments to the SML that may contain fresh water for significant periods of time after large rainfall events are Coorlay Lagoon and Lake Mary, around 25 km and 45 km south of Olympic Dam respectively. Given the confined surface water catchments of the dune-swale terrain surrounding the mine site, there is no potential for stormwater run-off to reach these environments.

As discussed above, stormwater run-off from the facilities at the Port of Darwin would be collected and diverted to an on-site detention basin(s) and the closed system would ensure that no stormwater from the site comes into contact with the concentrate product. The residual impact of the proposed facilities in relation to stormwater run-off and water quality is therefore categorised as negligible.

In most of the project area, the risk of surface water contamination from spills and leaks is low due to the provision of bunding around chemical storages in accordance with the South Australian Environment Protection Authority requirements (see Chapter 22, Health and Safety, for details). Furthermore, in the event of an accidental spill outside of bunded areas, the general lack of permanent water bodies in the project area and the predominantly low topographic relief leading to little to no lateral conveyance of contaminants, also results in a low risk of surface water contamination and a low residual impact. As a consequence, accidental surface spills would generally be contained and remediated before reaching waterways or receiving environments of environmental significance.

There are four exceptions to this within the EIS Study Area: the section of the water supply pipeline that traverses the western edge of Lake Windabout; the sensitive receiving environments of Darwin Harbour and Upper Spencer Gulf in the vicinity of both the landing facility and desalination plant. For these areas, specific spill management procedures would be developed and detailed as part of the Environmental Management Program (EM Program). These procedures would ensure that spills are controlled at the source, contained on-site and cleaned up according to the requirements of the Material Safety Data Sheet. Spill containment and clean-up equipment would be available on-site at all times and personnel would be trained in the appropriate use of this equipment.

The findings of the risk assessment into the likelihood and consequence of accidental spills, including spills of uranium oxide and concentrate, is discussed in Chapter 26, Hazard and Risk. Further discussion of potential health and safety risks associated with accidental spills is provided in Chapter 22, Health and Safety. Potential changes to water quality resulting from erosion are discussed in Chapter 10, Topography and Soils. Chapter 16, Marine Environment, addresses the construction and operation of the off-shore components of the desalination plant, including discussion of return water discharge.

11.5.3 MONITORING, AUDITING AND MANAGEMENT PRACTICES

As the existing operations work under a 'no release' stormwater policy, and given that there are no permanent water bodies or defined water ways in the vicinity of Olympic Dam, there are currently no requirements for monitoring of surface water quality.

The only permanent surface water receiving environments within the study area for the proposed expansion are Darwin Harbour and Spencer Gulf. As discussed in Chapter 10, Topography and Soils, and above, erosion and sediment control plans and stormwater management and monitoring plans will be developed for all areas adjacent to marine environments. See Chapter 24, Environmental Management Framework, for further detail.

11.5.4 ACCUMULATION OF WATER IN THE OPEN PIT

While it is unlikely that mining at Olympic Dam would cease after 40 years of operation, this scenario has been assessed for the purpose of the Draft EIS. Based on the current mine closure scenario, it is predicted that a permanent lake would form within the open pit mine void, around 350 m deep and 650 m below ground surface (see Figure 11.7 and Appendix J2 for details). The primary source of water to the open pit would be groundwater seepage, followed by pit wall run-off and incident rainfall. Surface run-off from external catchments intersected by the perimeter of the pit would be a minor source of water.

Sensitivity analysis shows that there is no potential for the water in the pit to overtop or recharge to the groundwater system (reverse groundwater gradients), even under extreme climate change scenarios (see Appendix J2). The residual impact of the presence of a pit lake is categorised as moderate, reflecting a long-term impact to a common receiver.

The quality of water and mixing processes within the lake would change over time as a result of solute input, evapoconcentration, biological activity, hydrothermal inputs and climatic conditions. On the basis of the water balance, water quality and limnological modelling, the major stages of pit lake evolution are predicted to be as follows:

- lake formation (0–100 years post closure)
  - water levels would rise rapidly
  - metal concentrations would be low, but increase over time since the pit would act as a sink for groundwater and surface water inflows
  - ferrihydrite is predicted to readily precipitate and form a coating over the bed of the pit lake leading to a reduction in the concentration of a range of metals through adsorption
  - the lake may periodically stratify during summer, causing anoxic zones to form at depth, however the surface water inflows and increasing water levels may cause periodic mixing

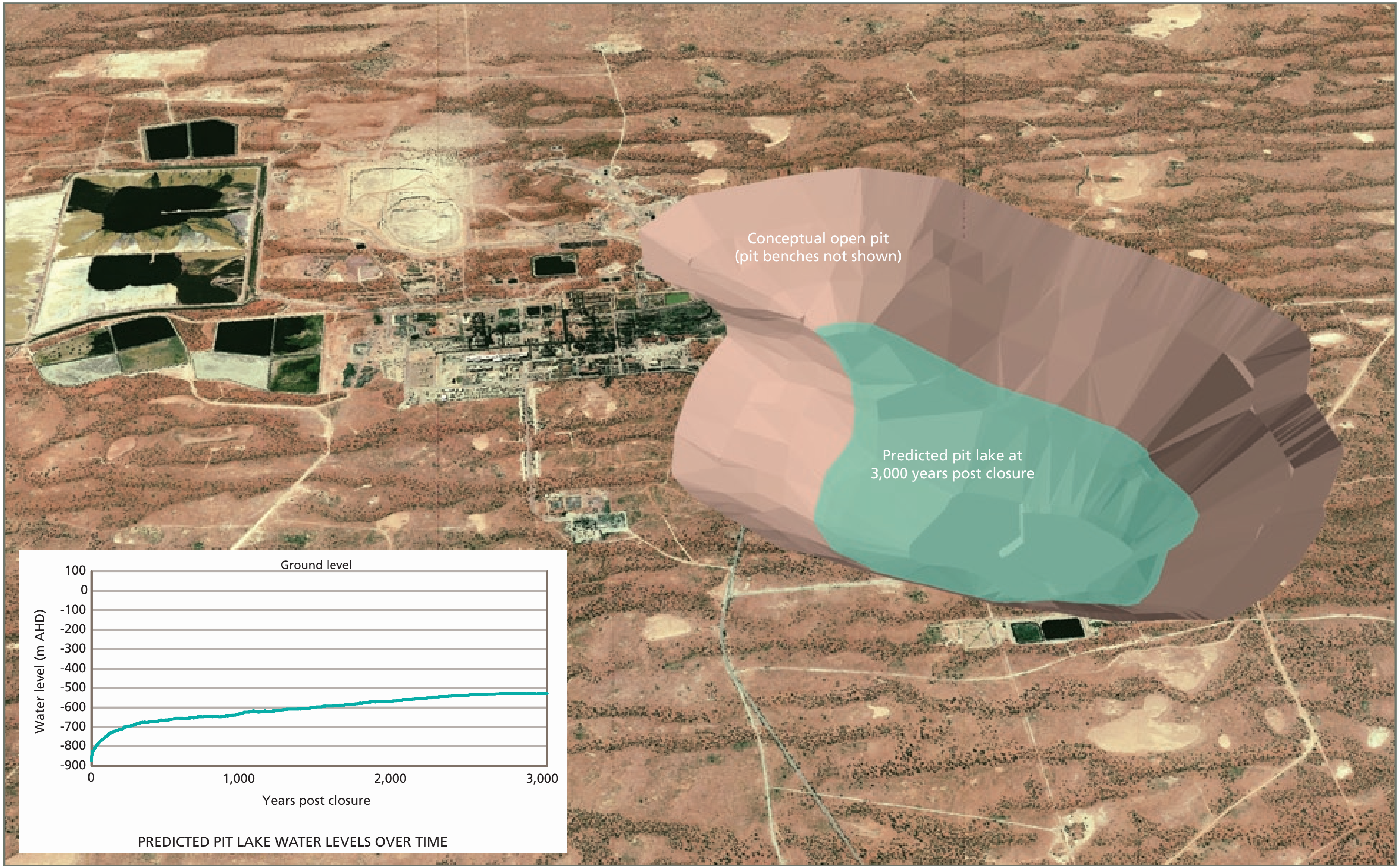

Figure 11.7 Predicted pit lake

- stratified lake (100–250 years post closure)
  - water level increases would begin to slow
  - crusts of calcite may form at the edges of the lake due to evapoconcentration, and co-precipitation of metals (e.g. manganese, zinc and nickel) may occur
  - stratification is likely to be pronounced during summer, with mixed conditions during winter
- periodic surface crust (250–3,000 years post closure)
  - salinity is expected to approach that of seawater by about 250 years post closure
  - salinity would become the dominant factor affecting water density, stratification during summer is expected to decline, and near mixed conditions would occur throughout the year (i.e. water parameters would be the same throughout the entire water column)
  - a relatively insoluble gypsum surface crust is expected to form, but may be periodically redissolved during large storm events
  - uranium concentrations may begin to decline in the latter part of this stage due to precipitation of sodium autinite
- extensive salt crusting (>3,000 years post closure)
  - an extensive halite salt crust is predicted to form at the surface
  - the salt crust is likely to be permanent, but could possibly dissolve during large storm events.

Table 11.3 presents water quality predictions during the major stages of pit lake evolution and Table 11.4 summarises the major minerals predicted to form within the pit lake, and the anticipated time at which they may form.

11.6 FINDINGS AND CONCLUSIONS

Drainage patterns

- Lateral surface water flow in and around the expanded SML is limited with drainage dominated by ponding and evaporation. The expanded operation (including the open pit, TSF and RSF) would intersect and change small local catchments within the SML but not beyond. The residual impact on drainage flow paths would be negligible.
- Stormwater drainage and treatment in Roxby Downs and Hiltaba Village would be accommodated by standard engineering practice and the residual impact is categorised as low.
- Potential changes to drainage patterns associated with the rail line can be readily accommodated through cross-drainage structures such as culverts. With the adoption of standard engineering practices for the sizing and placement of the cross-drainage structures, the residual impact is low.
- Changes to drainage from ancillary and temporary infrastructure would be negligible in the context of the catchments in which this infrastructure would be located. Residual impacts on the respective catchments would be negligible.

Table 11.3 Predicted pit lake water quality (mg/L, unless noted otherwise)

Parameter	100 years	500 years	1,000 years	3,000 years
pH (pH units)	7.8	7.7	7.5	7.3
pE	7.5	7.7	7.8	8.1
Salinity	25,900	71,100	123,000	247,000
Carbonate as HCO_3	36.6	31.3	24.8	16.3
Chloride	11,800	34,100	60,200	122,000
Sulphate	4,880	11,400	18,400	35,300
Aluminium	<0.001	<0.001	<0.001	<0.001
Arsenic	0.031	0.081	0.137	0.255
Barium	0.015	0.009	0.006	0.003
Calcium	612	742	604	363
Copper	0.051	0.136	0.236	0.463
Iron	0.001	0.001	0.001	0.001
Potassium	66.3	191	336	679
Magnesium	766	2,120	3,750	7,600
Manganese	0.543	1.290	3.010	6.32
Sodium	7,800	22,600	39,900	80,900
Nickel	0.017	0.047	0.083	0.166
Lead	0.006	0.019	0.034	0.061
Uranium	0.008	0.020	0.032	0.056
Zinc	0.170	0.484	0.851	1.70
Fluorine	8.84	16.5	22.6	36.0
Silicon as SiO_2	3.87	7.50	8.34	4.54
Phosphorus	<0.001	<0.001	<0.001	<0.001

Table 11.4 Predicted mineral precipitation

Mineral	Influences	Timing (post closure)
Barite	Barium, sulphate, arsenic[1], lead[1]	Throughout
Apatite phases	Aluminium, fluorine, calcium, carbonate, phosphorus, lead[1]	Throughout
Ferrihydrite	Iron, lead[2], zinc[2], copper[2], calcium[2], nickel[2], manganese[2], barium[2], uranium[2], magnesium[2], sulphate[2], fluorine[2], phosphorus[2], arsenic[2]	Throughout
Aluminium oxyhydroxides	Aluminium	Until 190 years
Calcite	Calcium, carbonate, manganese[1], zinc[1], nickel[1], magnesium[1], iron, cadmium and to a lesser extent barium and lead	Until 260 years
Smectite-like phases	Aluminium, magnesium, iron, silicon	20 years onwards
Gypsum	Calcium, sulphate, barium[1]	180 years onwards
Magnesite	Magnesium, carbonate	260 years onwards
Fluorite	Calcium, fluorine, lead[1]	200 years onwards
Malachite	Copper, carbonate	1,500–2,780 years
Amorphous silica	Silicon	680 years onwards
Manganese oxides	Manganese	Until 1,080 years
Sodium autinite	Uranium, phosphorus	3,100 years onwards
Halite	Sodium, chloride, lead[1]	>3,000 years onwards

[1] Co-precipitation.
[2] Adsorption.

- Additional impervious areas (for example new roads, waste facilities and buildings) would reduce groundwater recharge by rainfall infiltration by less than 1%. The residual impact on the recharge of the aquifer would therefore be negligible.

Water quality

- The principal contaminated waters on-site are in the process/tailings circuit and these would be contained and recycled where practicable, with the surplus lost to evaporation.
- Run-off from the RSF would be contained within the SML for up to a 1-in-100-year storm event. Run-off from the low grade ore stockpile would be contained within a defined management area and run-off from the remainder of the RSF would be contained in the natural dune-swale system.
- The confined surface water catchments surrounding the mine site mean that there is no potential for stormwater run-off to leave the SML and reach the nearest sensitive fresh-water (Coorlay Lagoon and Lake Mary) and salt-water (Lake Blanche clay pan) environments.
- First-flush stormwater from the East Arm facilities in Darwin would be collected and diverted into an on-site detention basin(s) and the closed system would ensure that no stormwater from the site comes into contact with the concentrate product.
- Accidental spills and leaks would be contained in bunds. Should spills occur outside of bunded areas, the lack of permanent water bodies and generally flat topography would limit lateral conveyance of contaminants.
- For infrastructure constructed in the vicinity of sensitive receiving environments of Darwin Harbour and Upper Spencer Gulf, specific spill management procedures would be developed and detailed as part of the EM Program.

Accumulation of water in the open pit

- A hypersaline lake would form in the pit void within 100 years of mine closure due to rainfall accumulation and groundwater inflow. Water would rise to a point several hundred meters below the pit rim with no chance of overtopping or reversal of groundwater flow directions.
- The salinity and concentration of metals would gradually increase through evapoconcentration. Over the very long term a permanent salt crust is predicted to form on the surface of the lake, essentially isolating the water underneath. The residual impact of the presence of a pit lake is categorised as moderate, reflecting a long-term impact to a common receiver.