Old Bore Frances Creek No. 4 (RN 5925) located on the eastern side of the tailings settlement area had a reported yield in excess of 60 L/s and Frances Creek No. 13 (RN 6332) north-east of the tailings settlement area yielded 25 L/s. With one exception, (RN 5924 at 2 L/s) all of the higher yielding bores (2 L/s or greater) are sited in the mineral processing/stockpile/tailings area approximately 200 to 500 m west of the ore body trend formerly exploited in the open pits at Helene 4, 5, and 6/7 (see Figure 11)[3].

Examination of air photos (see Figure 10; exploded part of composite ECW image supplied by MBS) suggests that there may be additional structural hiatus in the vicinity of the processing area to account for the clustering of high yielding bores (viz. more permeable ground). The area is complexly folded and faulted (axial plane orientations generally north – south). There appears to be compression of the syncline, that runs between the Helene 9 and 11 dams to the west (i.e. immediately west of the access road) and the Helene pit series to the east, against the anticline situated immediately east of these pits. A strike or bedding plane slip fault may be present here along the axial fold plane? See also discussion in Section 4.2.3.

*Figure 10 Aerial Photograph of Mine-site (Helene Pit series) illustrating Geological Structural complexity*

[3] One yield of 0 L/s reported on Figure 11 is believed to be wrong – the airlift yield was simply not measured.

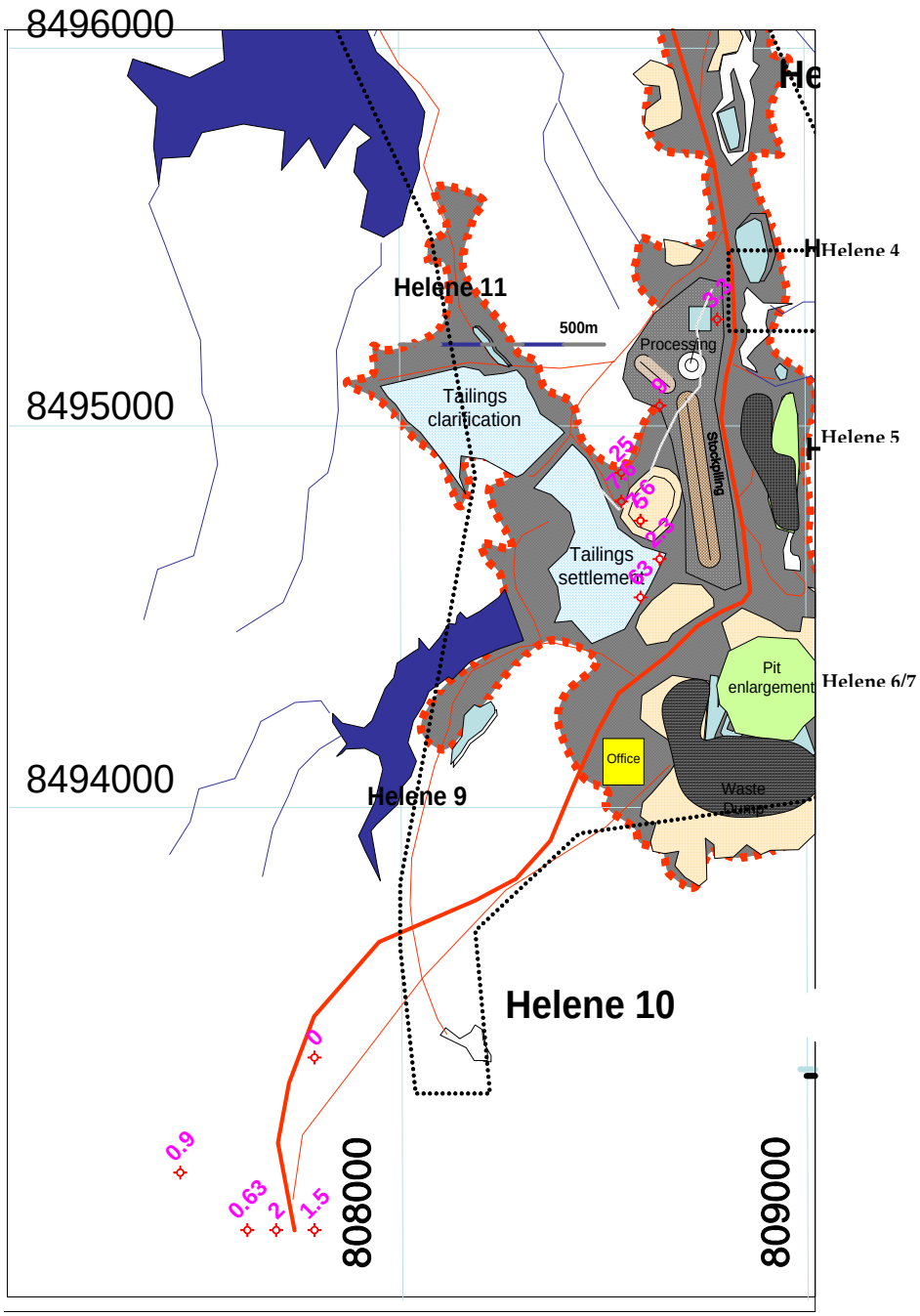


*Figure 11 Bore (Airlift) Yield (L/s) – Frances Creek Township and Mine-site*

### 3.1.1 Groundwater Levels

Depth to water (SWL) historical data is available for five bores in the township area and seven bores in the mine-site (Figure 12). Refer also to Table 3.

### 3.1.2 Township Area

Five bores have data; the SWL elevation ranges from 169.4 to 193.3 m AHD with an average SWL of 184.84 m AHD and average depth to water (SWL) below ground level (bgl)of 24.66 m.

The quoted values were recorded at different times in the 1960's and early 1970's as each bore was completed, which could account for the wide range of values.

The SWL in bore RN 6322 was measured in January 2006 as 13.15 m bgl compared with the October 1968 SWL of 39.6 m bgl. The groundwater has been relatively undisturbed by pumping for many years and, considering the high recharge potential of the area (refer Section 3.2.3) it seems likely that groundwater levels could have recovered to within 10 to 15 m of the surface since the site was vacated in 1976.

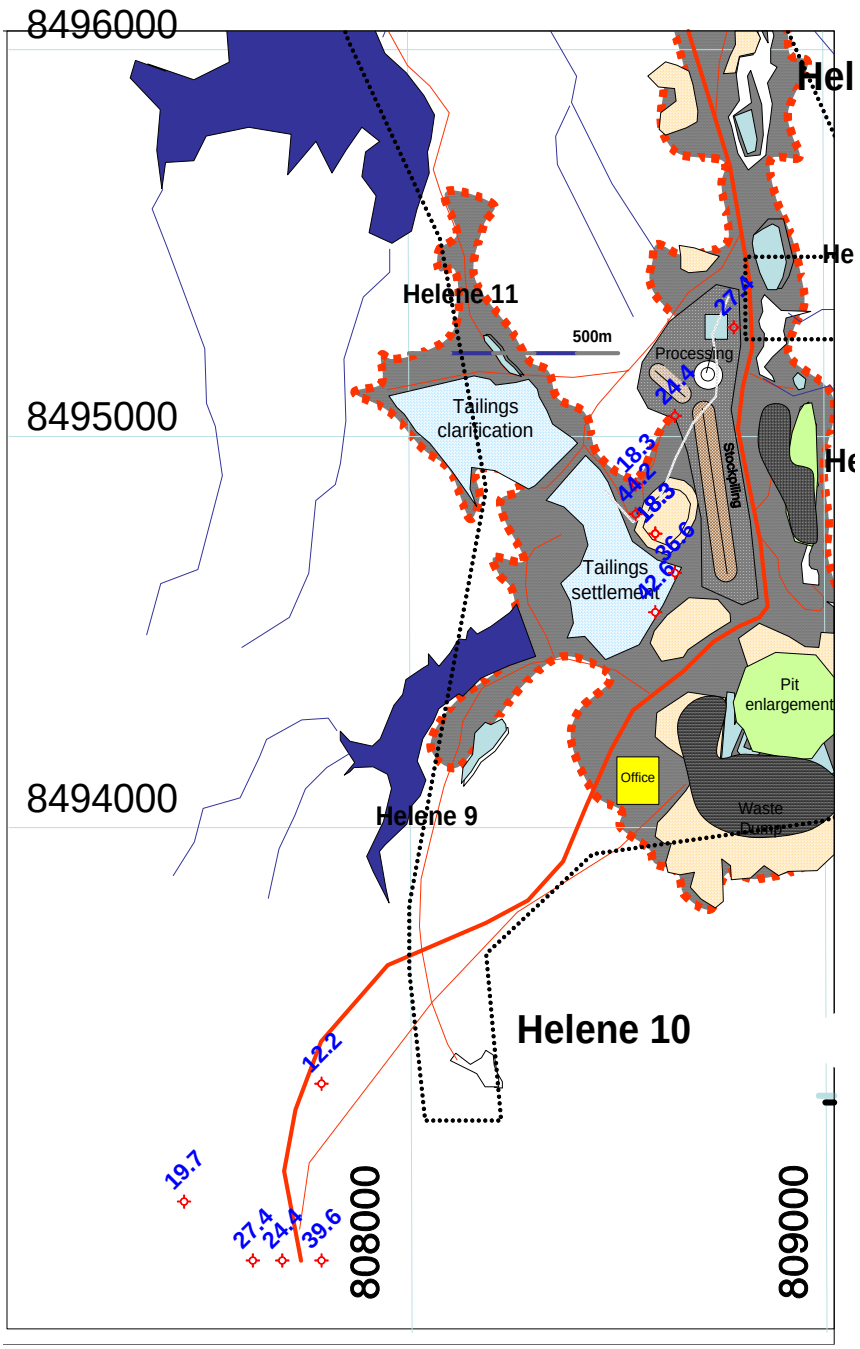


*Figure 12 Depth to Water (SWL m bgl) – Frances Creek Township and Mine-site*

### 3.1.3 Mine Area

For the seven bores with data, the SWL elevation ranges from 150.4 to 177.7 m AHD (average SWL of 164.9 m AHD and 28.95 m bgl).

These SWL recordings are again 1960's/early 1970's values as bores were completed. No current data could be obtained to determine the extent of groundwater recovery which could have been distorted by dewatering pumping from Helene 6/7 pit.

***Helene 6/7 Pit*** was full of water prior to 9thJune 2005 when pumping was carried out to dewater the pit to enable sampling and drilling from the pit bottom. An estimated 280 ML of water were discharged between 9thJune and 12th July 2005. Prior to dewatering the pit water level (believed to be similar to the local groundwater level) was around 200 m AHD. The level fell to a minimum of 172.3 m AHD at the end of dewatering when seepage rates of approximately 23 L/s (12th July 2005) fell to approximately 12 L/s (end November 2005). Seepage was observed from the northern and eastern steep walls of the pit.

The pit water level had recovered almost completely by early January 2006 (AGT field visit).

The pit water level of 200 m AHD is consistent with a depth to water of greater than 20 m beneath the higher ground which rises to in excess of 225 m along the ore body trend.

***Other Pits Containing Water*** were sampled in November 2005. They included Helene 4, Thelma 2 and Jasmine 1. No data on pit water levels at these sites was available.

The question of origin of water contained in pits remains unresolved. Either accumulation of rainwater, seepage of groundwater or a combination of both could account for the water stored in old pits.

The groundwater option can be eliminated if the pit is shallow (perhaps < 20 m) and does not provide a "window" to the water-table. Water quality from some pits is discussed below in this context.

The ore tends to form higher ground and new pits start as quarries into the hillsides before extending beneath the level of the surrounding lower ground where water-tables are likely to be around 20 m bgl.

**Pumping Test Data** have been located for two bores RN 6149 and (probably) RN 6332, at the mine site, although the records are somewhat confused regarding the second bore.

Analysis of the time drawdown data for each bore yields the following Transmissivity (T) values:

RN 6149 T = 220 $m^2$/day

RN 6332 T = 390 $m^2$/day

Although strictly speaking the concept of transmissivity has little real meaning in fractured rock aquifers, these values indicate that, in part, the aquifers at the mine site are capable of transmitting water, within restricted zones, as well as reasonable porous media aquifers. In the absence of any detailed knowledge of the hydraulic properties of the fractured rock domain and for the purposes of this exercise the T values may be applied to obtain an indication of possible extent of impacts from pumping for water supply or dewatering.

## 3.2 Groundwater Quality

### *3.2.1 Bore water*

Groundwater quality data from historic bores at the town and mine sites have been extracted from the NT database and included in Table 4. Only the most recent sample from each bore has been presented. At least one of the reported values is obviously incorrect[4].

The water is of good quality with a maximum TDS of 310 mg/L, high bicarbonate content and generally slightly alkaline pH (greater than 7.0).

High bicarbonate is an indicator of an actively recharging groundwater system (refer Section 3.2.3), a process governed by high seasonal rainfall and relatively easy access for infiltration from the ground surface via frequent open joints.

The groundwaters beneath the town and mine sites may be broadly characterised as a 'calcium-bicarbonate type' with relatively high hardness but suitable for most purposes including use as drinking water for both human and livestock consumption.

A physico-chemistry analysis of groundwater sampled from Bore RN 6322 on 10th January 2006 for major ions and a limited suite of minor ions including heavy metals for is given as Table 5. Of the heavy metals analysed for, Cu and Pb exceed the guideline values in this sample.

### *3.2.2 Pit water*

Pit water quality is considered to be a reflection of groundwater plus varying amounts of rainwater accumulated in the deeper pits that result in a low salinity signature.

Analyses, including some of the common ions usually reported in groundwater and the common "heavy metals" As, Cd, Cu, Pb, Zn are presented in Table 6.

[4] possibly a units problem – micrograms/L reported as milligrams/L

Full analytical suites of analyses are reported for Helene 6/7 (all trace elements) and Helene 4, Jasmine and Thelma (selected trace, heavy metals) pits in Appendix B.

Table 4 Historic Groundwater Quality Data from Frances Creek Township and Mine-sites

| Bore RN | Bore Name | Date | EC (uS/cm) | pH | Alkalinity (mg/L) | Bicarbonate (mg/L) | Hardness total (mg/L) | TDS (mg/L) | Calcium (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| 4990 | TOWN SITE NO.1 | Aug-68 | 480 | 7.1 | 244 | 298 | 10 | 310 | 74 |
| 5922 | NO.1 FRANCES CK. | Aug-67 | 810 | 7.1 | 432 | 264 | 316 | 207 | 6.5 |
| 5924 | NO.3 FRANCES CK. | Jun-70 | 455 | 7.5 | 250 | 305 | | 290 | 44 |
| 5925 | NO. 4 FRANCES CK. | Aug-68 | 310 | 6.7 | 70 | 43 | 86 | 188 | 26 |
| 6151 | NO. 9 FRANCES CK. | Jul-68 | 350 | 7.7 | 34 | 21 | 196 | 205 | 25 |
| 6249 | FRANCES CK NO.7A | Jun-70 | 495 | 7.3 | 258 | 315 | 269 | 3 | 70 |
| 6250 | FRANCES CK NO.7 | Jun-70 | 380 | 7.8 | 226 | 276 | | 250 | 32 |
| 6322 | FRANCES CK. NO.15 | Jul-68 | 302 | 6.9 | 134 | 82 | 158 | 199 | 36 |
| 6322 | | Jan-06 | 198 | 6.0 | | | | | |
| 6487 | NO.11 FRANCES CK. | Apr-78 | 390 | 7.8 | 214 | 262 | 184 | 250 | 36 |
| 7436 | FRANCES CK=NO.3 | Sep-70 | 180 | 7.4 | 86 | 105 | 58 | 130 | 8 |
| 8011 | RAILWAY, FRANCES CK | Sep-72 | 390 | 8.3 | 209 | 255 | 213 | 210 | 36 |
| 8012 | CAUSEWAY, FRANCES CK | Sep-72 | 420 | 7.8 | 213 | 260 | 228 | 260 | 45 |

| | | | Chloride (mg/L) | Magnesium (mg/L) | Potassium (mg/L) | Sodium (mg/L) | Sulphate (mg/L) | Fluoride (mg/L) | Iron - total (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| 4990 | TOWN SITE NO.1 | Aug-68 | 8 | 21 | 6 | 7 | 24 | 0.5 | 0.2 |
| 5922 | NO.1 FRANCES CK. | Aug-67 | 24 | 72 | 2.5 | 92 | | 0.7 | 0.5 |
| 5924 | NO.3 FRANCES CK. | Jun-70 | 5 | 25 | 3 | 19 | 16 | 1.3 | 0.3 |
| 5925 | NO. 4 FRANCES CK. | Aug-68 | 24 | | 8.3 | 13 | (1755**) | 0.5 | 1.8 |
| 6151 | NO. 9 FRANCES CK. | Jul-68 | 8 | 17 | 3.8 | 5 | 2 | 0.1 | 0.1 |
| 6249 | FRANCES CK NO.7A | Jun-70 | 6 | 22 | 6 | 6 | 30 | 0.4 | 0.1 |
| 6250 | FRANCES CK NO.7 | Jun-70 | 8 | 25 | 4 | 20 | 12 | 0.7 | 0.9 |
| 6322 | FRANCES CK. NO.15 | Jul-68 | 30 | 13 | 4.4 | 7 | 32 | 0.4 | 0.1 |
| 6487 | NO.11 FRANCES CK. | Apr-78 | 6 | 23 | 4 | 14 | 6 | 0.5 | 0.2 |
| 7436 | FRANCES CK, NO.3 | Sep-70 | 7 | 9 | 5 | 10 | 2 | 0.4 | 10 |
| 8011 | RAILWAY, FRANCES CK | Sep-72 | 6 | 30 | 3 | 2 | 11 | 0.5 | 0.3 |
| 8012 | CAUSEWAY, FRANCES CK | Sep-72 | 9 | 28 | 6 | 10 | 31 | 0.5 | 2.2 |

** **Sulphate reported to be 9 x TDS in RN005925**

Table 5 Groundwater Quality – Bore RN 6322, Frances Creek Township (sampled 10th January 2006)

| Bore RN | pH | EC | Alkalinity | CO3 | HCO3 | OH | Turbidity | TSS | TDS | NO2_N | NO2 | NO3_N | NO3 | Cl | PO4_P | NH3_N | F | Hardness | Ca | K | Mg | Na | SO4 | SiO2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | units | µS/cm | | | | | NTU | | | | | | | | | | | | | | | | | |
| **6322** | 6.3 | 144 | 73 | <1 | 73 | <1 | 160 | 240 | 80 | <0.005 | <0.02 | 0.01 | 0.04 | 2.9 | 0.01 | 0.34 | 0.2 | 55 | 3 | 1.8 | 11.6 | 5.2 | 0.4 | 17.2 |
| ANZECC | 6.5-9 | | | | | | 20 | 20 | | | | 5 | | | 0.5 | | | | | | | | | |

| | As | B | Br | Cr | Cu | Fe | I | Li | Mn | Ni | Pb | Se | Sr | U | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | µg/L | µg/L | µg/L | µg/L | µg/L | | µg/L | µg/L | | µg/L | µg/L | µg/L | µg/L | µg/L | µg/L | |
| **6322** | 4.1 | 14.5 | 28 | 79.8 | 40.5 | 88 | 10 | 26 | 1.51 | 22.8 | 400 | 0.4 | 30.6 | 0.644 | 4 | 7.82 |
| ANZECC | 50 | | | | 2.0-5.0 | | | | | 150 | 1.0-5.0 | 5.0 | | | | 5-50 |

Units mg/L unless otherwise stated

Table 6 Old Mine-site Pits, Water Quality Data, Year 2005

| Sample | | TDS | pH | EC | Alkalinity | CO3 | HCO3 | NO3 | Cl | SO4 | SiO2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | Date | mg/L | units | µS/cm | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L |
| Helene Pit 6/7 | 15-Apr-05 | 60 | 7.9 | 106 | 51 | <1 | 51 | <0.02 | 4.9 | 1.2 | 8 |
| Helene 4 Pit | 14-Nov-05 | 20 | 7.4 | 43 | nd | nd | 16 | 0.005 | 2.5 | 0.06* | 5.7 |
| Jasmin Pit 1 | 14-Nov-05 | 30 | 6.9 | 40 | nd | nd | 9 | <0.005 | 3.3 | 1.24* | 10.6 |
| Thelma Pit 2 | 14-Nov-05 | 100 | 3.5 | 279 | nd | nd | nd | 0.035 | 3 | 25* | 14.2 |
| | | | | | | | | | | * as S | |

| | | Ca | K | Mg | Na | As | Cd | Cu | Pb | Zn |
|---|---|---|---|---|---|---|---|---|---|---|
| Location | Date | mg/L | mg/L | mg/L | mg/L | µg/L | µg/L | µg/L | µg/L | µg/L |
| Helene Pit 6/7 | 15-Apr-05 | 1.1 | 2.5 | 9.2 | 7.5 | 1.05 | <0.02 | 0.92 | 0.06 | 7 |
| Helene 4 Pit | 14-Nov-05 | 0.5 | 1.4 | 0.15 | 3 | 2.4 | 0.02 | <0.5 | 0.21 | 15 |
| Jasmin Pit 1 | 14-Nov-05 | 0.9 | 1.8 | 0.05 | 3.6 | 1.55 | 0.1 | 5 | 0.2 | 10 |
| Thelma Pit 2 | 14-Nov-05 | 1.1 | 4.1 | <0.05 | 3.9 | 0.4 | 0.16 | 35 | 0.33 | 110 |

| | | EC | TDS | pH | Redox |
|---|---|---|---|---|---|
| Location | Date | (uS/cm) | (mg/L)* | | (mV) |
| Helene 6/7 Pit | 10-Jan-06 | 143 | 86 | 7.04 | -35 |
| Helene 6/7 Pit | 10-Jan-06 | nd | nd | 6.1 | nd |
| Jasmine | 10-Jan-06 | 36 | 22 | 6.72 | -18 |
| Jasmine | 10-Jan-06 | 72 | 43 | 6.31 | 7 |

* estimated from EC

All samples have low TDS. All but one has pH values greater than 6.1 and generally low abundances of As, Cd, Cu, Pb and Zn.

The one exception is a sample collected from Thelma Pit 2 in November 2005 which recorded a pH of 3.5 and the "Heavy Metals" listed in Table 7 with ANZECC (1992) guideline values for comparison.

This sample is also reported to contain 25 mg/L S (equivalent to 75 mg/L $SO_4$) which accounts for the very low pH of 3.5; a pH typical of Acid Mine Drainage (AMD).

Cu and Zn exceed the guideline values in this sample but the other Heavy Metals are within acceptable limits.

*Table 7 Common Heavy Metals – Thelma Pit No. 2*

| | **As** | **Cd** | **Cu** | **Pb** | **Zn** |
|---|---|---|---|---|---|
| | µg/L | µg/L | µg/L | µg/L | µg/L |
| ANZECC (1992) GUIDELINE | 50 | 0.2-2.0 | 2.0-5.0 | 1.0-5.0 | 5.0-50.0 |
| **Thelma Pit 2**<br><br>Disturbed pit sample - blue water (acidic and some copper) | **0.4** | **0.16** | **35** | **0.33** | **110** |

The blue colour attributed to Thelma Pit 2 water may be due to dissolved copper (Cu) but 35 µg/L is a very low concentration.

Although the soil/rock materials in the walls of Thelma Pit 2, and waste deposited above the pit can be regarded as a potential source of AMD, it is not planned to extract the small amount of ore remaining.

If similar situations develop in other flooded pits, direct discharge into an actively flowing surface drainage system will probably reduce the Cu and Zinc (Zn) values to acceptable levels within a relatively short distance from the source by dilution.

In sensitive areas, where Cu and Zn are in the toxic range, wetland treatment can be employed to attenuate these contaminants before discharge to the natural environment.

### 3.2.3 Groundwater Recharge and Groundwater Flow in the Town and Mine-sites

An estimation of the average annual recharge rate by application of the Chloride Mass Balance method (Cook and Herczeg, 1998) is presented below[5].

Recharge = Cl in rainwater x Average annual Rainfall / Cl in groundwater

Average annual rainfall = 1,250mm; Cl in rainwater (refer Figure 14) is approximately 0.35 mg/L; Cl in groundwater (from Table 4 excluding the anomalously higher values) is 7 mg/L.

Annual Recharge = 0.35 $mgL^{-1}$ x 1,250 mm $yr^{-1}$ / 7 $mgL^{-1}$ = 62.5 mm $yr^{-1}$

In the absence of widely distributed groundwater surface elevation data the flow system must be inferred from the likely driving mechanisms operating in the area.

The driving force governing flow in the fractured rock aquifers beneath the town and mine-sites is believed to be the recharge from seasonal rainfall coupled with discharge to surface drainage lines running in a general north-south direction within 1 km on each side of the project site at Helene (refer Figure 13).

During the wet season there may be a component of recharge from the surface drainage system into the fractured rock aquifers as infiltration and bank storage but in the lengthy dry season the predominant flow direction is expected to be towards the drainage lines.

Thelma 1 and 2, Thelma-Rosemary and Jasmine are likely to have a local groundwater flow system "bounded" by drainage lines running towards the north and north-west.

All of these small drainage lines are tributaries of Frances Creek which ultimately drains into the Mary River to the north-east (refer Section 1.4).

The Ochre Hill deposit is also bounded by near surface drainage to the north, west, and south. These drainages all join the headwaters of Frances Creek north of the Thelma/Jasmine area.

On the basis of this hypothesis, all water delivered to the town/mine site by rainfall will ultimately find its way into the headwaters of the Frances Creek and eventually into the Mary River to the east.

---

[5] Chloride, Cl is a conservative ion and, as such, in the following calculation is assumed not to be sourced from weathered bedrock but is input from rainfall.

## 3.3 Hydrogeological Conceptual Model

To summarise Chapter 3, a hydrogeological conceptual model is presented as a schematic section in Figure 13. Essentially, recharge over the pit areas [elevated local (ridge) topography] drives local groundwater throughflow to lower elevations in the landscape, namely Frances Creek and its numerous creek tributaries.

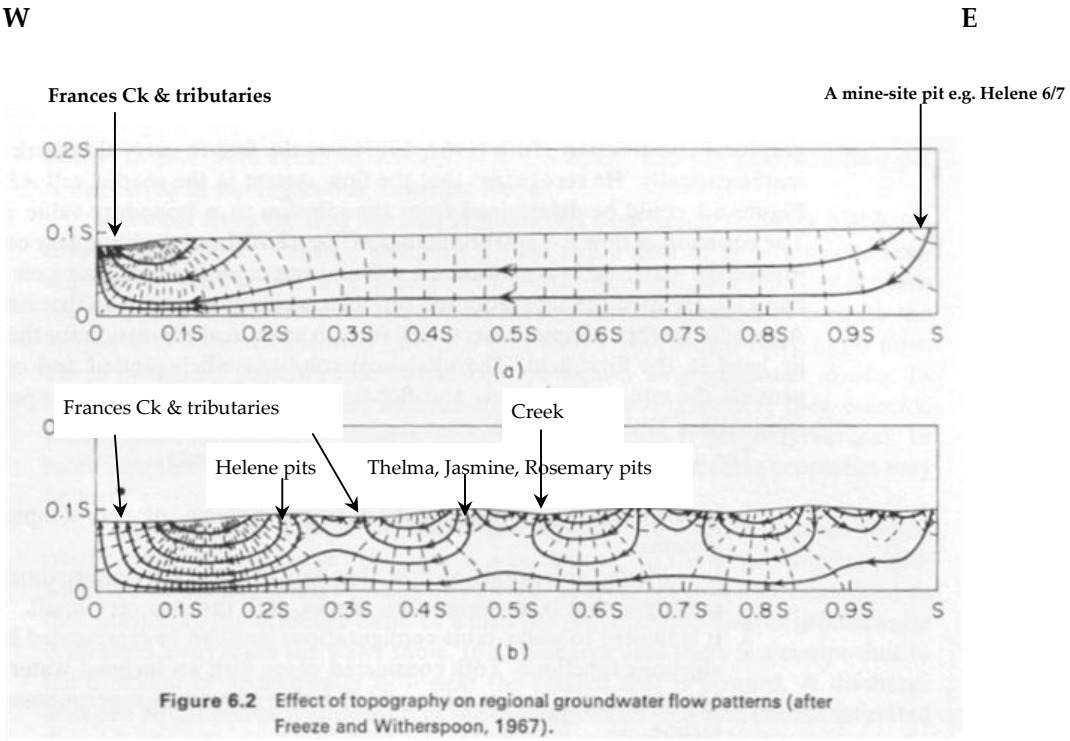


*Figure 13 Hydrogeological Conceptual Model – Frances Creek Project Area*

The lower diagram depicts 'mine-site scale' groundwater 'flow cells', whilst the upper diagram explodes one of the flow cells from the lower diagram to present a highly localized representation (viz. a single groundwater flow cell).

To put this conceptualisation into context one should examine Appendix C. The project area's hydrogeological conceptual model constitutes the "region of local system of groundwater flow" of the regional-scale representation depicted in Appendix C.

# 4. POTENTIAL IMPACTS ON SITE AND REGIONAL GROUNDWATER SYSTEMS

Short term (transient) impacts due to pumping bores for water supply and pit dewatering have been estimated and are reported in Sections 4.3, 4.4 and 4.5 below.

## 4.1 Preamble

Some "general principles" of mining impact risk assessment to groundwater *per se* and the potential impacts relating to the Frances Creek mine-site are discussed below (Sections 4.1.1 and 4.1.2.).

### *4.1.1 Short Term Impacts due to Mining Activities*

There are three activities associated with the mining process which may impact upon regional groundwater systems:

- Mine Dewatering – may result in a lowering of the water table and focusing of local flow pattern towards the excavations. Water levels should recover on completion of mining.
- Disposal of water produced by dewatering operations – impacts depend crucially upon the quantity and quality of the pumped water and the ability of the local environment to accept/ utilise that water.
- Mine Water Supply (which may be obtained from bores or existing dams) – may result in temporary drawdown of local groundwater levels and disposal of domestic wastes and sewage may impact upon local groundwater quality.

### *4.1.2 Longer Term Impacts*

According to Figure 2, the proposed mining and treatment activities appear to be largely restricted to areas where previous mining/disposal activities have already created some disturbance to the natural environment. Hence this study concentrates on determining the extent of any adverse impacts which may have been developed at the old Frances Creek mining centre due to mining and since abandonment of the original mining and disposal works on the premise that such impacts are also likely to develop during and after the proposed mining phase.

Disposal of waste rock and tailings from ore beneficiation/washing operations may impact upon groundwater quality especially if there is any pyrite, other sulphide minerals present or soluble heavy metals in the waste rock or tailings. The presence of sulphide minerals is likely to result in the development of Acid Mine Drainage (AMD – low pH, sulphate rich drainage water) which could reach the groundwater body if pathways of high permeability exist beneath or close to the dump or tailings retention area.

Water quality results from samples collected at the Helene 6/7 pit during recent dewatering for exploration purposes are tabulated in Appendix B.

## 4.2 Field Visit Observations

A site visit was conducted to the Frances Creek project area by AGT on 10th January 2006. A photographic record of this visit is depicted in Appendix A.

A previous visit in November 2005 had been made by Low Ecological Services supplemented by sampling carried out by Bob Reed (data relayed via MBS Environmental) as summarised in the following:

Visual inspection of tailings disposal areas and waste rock dumps were made and no signs of colour changes were observed which might suggest the development of AMD. Seepage was checked for pH and no low pH values were encountered. Water filling abandoned pits was sampled for EC and pH on site and water quality in all of the pits sampled was found to be good.

Thelma 2 pit: clear with bluish tinge (see also Section 3.2.2); big waste stockpile of black material near entrance of pit, no revegetation).

### *4.2.1 Pits / Tailings*

Jasmine, Rosemary, Thelma Rosemary, Helene 5 and Helene 6/7 pits were accessed during the visit. Wet weather prevented access to the proposed Ochre Hill, and Jasmine East sites. A summary of field water quality and sampling locations can be found at the end of Appendix A.

Pits were generally elevated in the local landscape. No springs, or soakages were noticed (although the greenness of the vegetation precluded detailed observation).

Water was found in and around the Jasmine and Helene 6/7 pits and tested in the field for pH and EC, with water quality ranging from pH 6.1 to 7.04 and EC from 36 to 143 µS/cm, respectively. Water within the Helene 6/7 pit was brown

in colour and turbid. At the top of the western pit access ramp, orange/red shallow ponded water was found in shallow, dark grey, disturbed sediments containing local ore. The water was tested in the field and found to be pH 6.1 but water depth and sediment disturbance prevented EC determination. The orange /red colour of water associated with this pit is consistent with that reported during dewatering operations in 2005.

The Helene 6/7 pit is anticipated to have significant groundwater impacts, with water observed to enter the pit via the lower pit wall[6]demonstrated by filling to a depth of several metres since dewatering in 2005.

Water in the Jasmine pit was greenish in colour (possibly algae) and was observed to contain tadpoles. Possible seepage through the pit wall appears to have resulted in water collecting to the west of the pit adjacent the wall and access road.

The Helene 5 pit and rock dumps associated with the Thelma pits were investigated but groundwater sources, such as springs or seeps, were not observed.

### 4.2.2 Water Bores

Five bores were located during the field visit and descriptions of their locations can be found at the end of Appendix A.

Two bores were located in the township. The first (B001; RN 6322) had a diameter of approximately 130 mm and was constructed with steel casing. SWL in the bore was 13.15 m BGL, with field pH and EC of the groundwater 6.05 and 198 µS/cm, respectively. Water samples were collected from B001 and delivered to Northern Territory Environmental Laboratories (NTEL) for analysis. The second bore within the township (B003) was dry.

Investigating the Rosemary mine areas revealed a bore located in the middle of the access road (B004). The bore appeared to be dry but total depth could not be determined due to equipment limitations. One bore was located adjacent to the tailings settlement area, west of Helene 5 (B006). This bore was located in thick grass and could not be accessed due to an inability to remove the bore cap. It is anticipated that several other bores may still exist to the south and west of the site but time consideration and safety concerns prevented further investigation.

[6] Pers. Comm. D. Beggs

### 4.2.3 Rocks

Siltstone and shales were commonly associated with the mining areas, with siltstone principally forming the upper strata, overlying, or adjacent to darker shales.

In rocks associated with the Helene 5 and Jasmine pits, folded siltstone typically had a non-uniform fracture orientation and appeared to be a 'tight' formation in terms of formation transmissivity. Where shales were present, a joint / fracture strike was typically to the north – north-west and dipping steeply to the west. Fracturing in the shale formations was generally more uniform than in the siltstone but fractures still appeared tight.

Formations associated with Helene 6/7 showed some different characteristics than the other locations. Around this pit, siltstones and shales exhibited more intense fracturing, possibly due to an unloading effect of the mining activity, removing overburden or destabilising the formation. Fractures in shales located in some lower sections of the Helene 6/7 pit wall appeared to be more connected and open and could possibly be more transmissive than in other locations.

## 4.3 Town and Mine Water Supplies

The fractured rock aquifers are sufficiently permeable in several locations to permit extraction of groundwater for camp, township and mining purposes. The groundwater quality is suitable for both drinking and industrial uses.

Drawdown of the water-table due to pumping is likely to be the only impact arising from local use of the water.

On the basis of the Transmissivity values described in Section 3.1.3 of 220 and 390m2/day, and the application of Equation 1, Section 4.5, the impact of pumping would be expected to extend, as a zero drawdown contour, to a radial distance from the pumped bore of approximately 940 m after 10 days continuous pumping and 2,960 m after 100 days. In the case of intermittent pumping the "cone of drawdown" would fluctuate with pumping cycles. Pumping for one day at a time would result in a cone fluctuating between zero and 300 m radially from a pumped bore. Should the boundary of the cone of drawdown reach a surface drainage system which is acting as a linear discharge for groundwater, the discharge rate will be reduced as flow is diverted towards the pumping bore.

Drawdowns of greater than 25 m have been reported in the pumping bores during testing. The decline in drawdown with increasing distance from the

pumping bore follows a logarithmic pattern. In the case of 1 day's pumping, 25 m of drawdown is distributed logarithmically over 300 m of radial distance such that at 30 m, drawdown would be no more than 10 m and at 3 m drawdown, would be less than 20 m (assuming radial flow conditions pertain).

Unless enormous amounts of groundwater are extracted; i.e. sufficient to cause dewatering of the fractured rock aquifer on a semi-regional scale, the impacts of pumping bores will be restricted to a local level. These impacts are completely reversible. Groundwater levels recover when pumping stops.

## 4.4 Mine Dewatering

Exploration work in October 2005 at the Helene 6/7 Pit required dewatering rates of almost 100 L/s (228 ML water discharged in 33 days) with an average seepage rate to the dewatered pit bottom of 15 L/s.

Helene 6/7 Pit will be the deepest of the proposed pits.

The status of the other pits to be redeveloped, with regard to pit lakes were determined by visual inspection.

It is possible that old pits did not reach the water-table in which case dewatering would consist only of pumping out stored stormwater at rates determined by pumping and disposal capacities.

Proposed final depths of pits available at time of writing are:

- Helene 6/7 122.5m
- Helene 5 70.0m
- Jasmine East 57.5m
- Rosemary 75.0m
- Ochre Hill 82.5m

The maximum elevation of the water in Helene 6/7 pit was observed to be 200 m AHD compared with an average water-table elevation of 165 m AHD at the old plant area in the adjacent valley where the "average" ground elevation was around 195 m AHD. If we assume that the pit water elevation is the same as the local water table elevation, it is about 5 m higher than the ground elevation in the adjacent valley and at least 50 m below the highest ridges abutting the pit.

Based on the experience at Helene 6/7, where the water table at the pit is about 5 m higher than the ground level of the adjacent valley, estimated conditions at the other pits are set out in Table 8

Table 8 Estimated Pit Water-table Levels

| | Proposed pit bottom EL (m AHD) | Valley EL (m AHD) | Estimated water-table EL (m AHD) | Estimated depth below water-table (m) | Comments |
|---|---|---|---|---|---|
| **Helene 6/7** | 127.5 | 195 | 200* | 72.5 | * observed |
| **Helene 5** | 180 | 200 | 205 | 25.0 | |
| **Jasmine East** | 200 | 180 | 185 | - 15.0 | Likely dry pit |
| **Thelma Rosemary** | 185 | 182 | 187 | 2.0 | Almost dry pit |
| **Ochre Hill** | 152.5 | 150 | 155 | 2.5 | Almost dry pit |

Thus some pits may be expected to intersect the water-table and require dewatering at rates governed by the local permeability of the fractured rock aquifer, the depth of penetration below the water-table, and the area of the pit floor.

Potential impacts of these dewatering activities are those associated with drawdown of the water-table around the pits and impacts arising out of disposal of the pumped water at the surface.

The mining operation often results in a reduction in water quality. There may be impacts due to increased turbidity in discharging water as well as possible increase in nitrate content as a result of the use of ANFO type explosives.

Longer term impacts associated with the potential for the development of Acid Mine Drainage (AMD) may occur where sulphide minerals are exposed in the pit walls.

## 4.5 Drawdown Impacts

Assuming Transmissivity (T) remains the same (essentially, the aquifer does not dewater during pumping), the "radius of influence" of the drawdown due

to extraction of groundwater can be estimated given T and Effective Porosity (Sy) of the aquifer.

$r_0$ = sqrt(2.25.T. t/Sy) …….. Eqn 1

Using the higher T obtained from pumping tests at the mine site of 390 m2/day, where t = duration of pumping in days and assuming Sy = 0.01 (i.e. 1 %), the radius of pumping influence, (r0) is calculated to be:

| **t (days)** | **$r_0$ (m)** |
|---|---|
| 180 | 3,974 |
| 365 | 5,660 |
| 548 | 6,934 |

The above listed values are also based on the assumption that no recharge occurs within the pumping period. At Frances Creek a major recharge event is expected annually. Major recharge can replace the water lost from the outer parts of the cone of dewatering leading to a stabilisation in the radius of influence, in the above case at a maximum of around 4000 m (assuming a 6 months' dry season of nil recharge).

If the natural water-table is assumed to be at the elevations listed in Table 8, drawdown estimates at the pit faces, at 500, 1,000, 2,000 and 3,000 m radius from the pit face are tabulated below (Table 9).

Table 9 Theoretical Drawdown of Aquifer at given Radial Distances from a Pit at Frances Creek

| **Mine Pit**[7] | **Drawdown (m) at Radial Distance of: (m) at time (t) of 6months** | | | | |
|---|---|---|---|---|---|
| | Pit Face 0 | 500 | 1,000 | 2,000 | 3,000 |
| Helene 6/7 | 75 | 24.6 | 15.2 | 7.2 | 2.9 |
| Helene 5 | 25 | 8.5 | 5.2 | 2.5 | 1.0 |
| Thelma Rosemary | 2 | 0.7 | 0.4 | 0.2 | 0.1 |

These estimated drawdown values indicate that the drawdown impact of pit dewatering at Frances Creek is expected to be of limited extent and totally reversible with full recovery of water levels anticipated within one wet season after pumping stops.

## 4.6 Disposal of Dewatering Discharge

Relatively large flow rates may arise from dewatering of the deeper pits e.g. in excess of 23 L/s was estimated as the seepage into Helene 6/7 immediately after pumping out the stored water in November 2005.

Provided that turbidity falls within acceptable limits and high levels of nitrate are not introduced by blasting, the majority of analysed pit waters could be disposed directly into surface drainage.

High turbidity can be addressed by pumping to a temporary surface storage to permit settlement of fines before discharging to the environment.

The impact of disposal of good quality dewatering discharges into the surface drainage system would be locally increased stream flows with possible increased infiltration to groundwater during the dry season.

### *4.6.1 Seepage from Tailings Storage and Waste Dumps*

The beneficiation of the raw iron ore consists essentially of physical processes without the addition of environmentally undesirable reagents.

[7] Jasmine East, Ochre Hill

Vertical seepage from tailings areas may contain slightly elevated levels of iron due to the solubility induced by abrasion. The "Heavy Metals" may be similarly slightly enriched but the current natural revegetation over the Tailings Settlement area suggests that there is little or no development of chemicals in solution which are toxic to vegetation.

Several of the old water supply bores are located very close to the Tailings Settlement area. Provided they can be re-equipped or new bores drilled close to the old sites, any dissolved salts in the seepage water would eventually report to the Pumping Bores which would act as a collector system to "harvest" seepage losses.

Waste Dumps tend to be developed alongside each pit and in the short term any seepage from the dumps to groundwater would report to the pit. In the longer term the materials in the waste dumps will be subject to oxidation and any sulphides present will tend to form sulphate. Drainage from the waste dumps should, wherever possible be arranged so that it returns to the nearest pit rather than directly to the environment.

In this context it must be noted that after 30 years of abandonment, there do not appear to be any marked adverse impacts arising from the old waste dumps.

### *4.6.2 Potential Impact of Pit Lakes after Mine Closure*

Abandoned open pits which have been dewatered during mining will fill with groundwater (and stormwater in the wet season) and, depending on the regional groundwater flow regime, may remain as groundwater "sinks" gradually concentrating any dissolved salts by evaporation. Alternatively, an active groundwater system could result in the pit lakes being of the "through flow" type in which the residence time of inflowing groundwater is sufficiently short for relatively little evaporative concentration to occur. Exposure of any sulphide minerals in an abandoned pit could produce some AMD which would either remain in the pit lake or move into the regional groundwater system depending on the type of flow regime around the pit lake. Chemical reactions may occur between the AMD and the rock forming minerals in the host rock which could attenuate any plume of AMD solutions.

Knowing the TDS and Chloride (Cl) ion in rainfall allows an assessment of the role of rainfall in determining the quality of water in the four pits sampled to date.

Table 10 Comparison of Average Groundwater and Pit Water

| | G/water Averages | Pits |
|---|---|---|
| TDS | 233 | 53 |
| Cl | 14 | 4 |
| HCO3 | 207 | 25 |
| Na | 17 | 4.5 |
| Ca | 36 | 1 |
| Mg | 24 | 2.4 |

The native Groundwater has low TDS, only approximately 4.4 times that of the average Pit Water (Table 10). Very approximately the same applies to the conservative chloride (Cl) ion.

Rainwater is estimated, by comparison with reported values at:

- Darwin (Ayers et al, 1993);
- Jabiru 95 km south of the ocean (Noller et al, 1985); and,
- Katherine, 240 km south of the ocean (Likens et al, 1987),

to have a TDS of about 1 mg/L and Cl content of 0.3 mg/L as shown below in Figure 14.

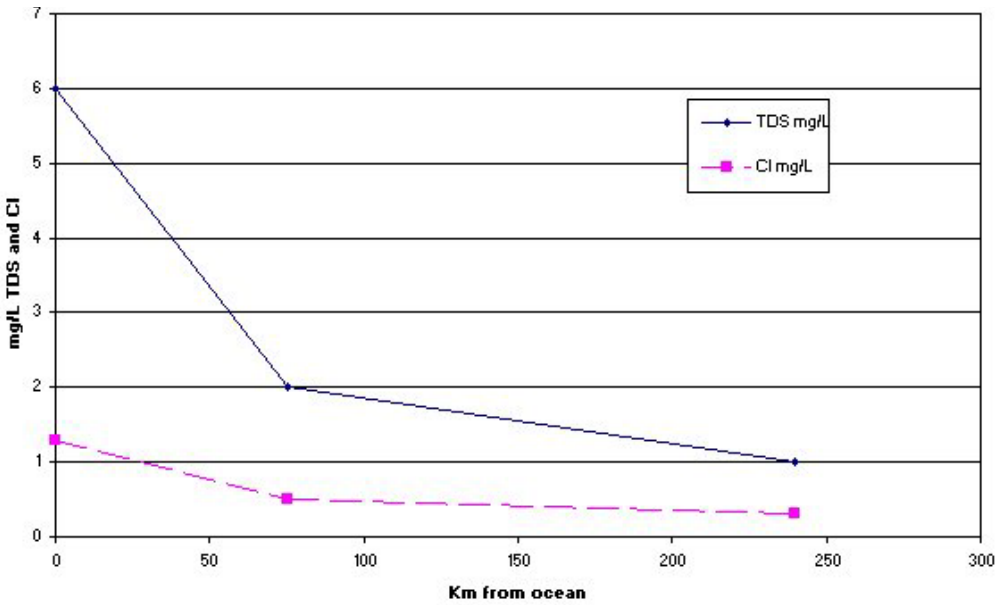


*Figure 14 Northern Territory – Rainfall Salinity*

A mixture of 3 to 4 parts rainwater with 1 part groundwater would yield a salinity and Cl level comparable with average pit water. This also applies to Na, which largely may arrive with the Cl in rainwater.

The other components in Table 10 are the products of rock/soil – rainwater interaction where the mildly acidic rainwater, carrying $CO_2$, reacts with rock and soil minerals dissolving Ca and Mg and where sulphides are present the oxygenated recharge water can react to produce $SO_4$, the main component of AMD.

The low salinity of pit waters suggests that the pits act as collectors and groundwater recharge points (groundwater sources) during the wet season and evaporative discharges (groundwater sinks) during the dry with very little throughflow; presumably because the local impact of the pit lake levels on groundwater flow is greater than that of the topographically dependant hydraulic gradients.

Assuming this analysis is correct, then any contaminants residing in a pit lake are likely to remain there or to move only a short distance into the surrounding fractured rock aquifer when driven by a recharge event. Subsequent evaporative discharge from the lake will tend to reverse this movement back towards the pit. The ultimate fate of any contaminants would depend on the relative magnitudes of seasonal flows into and out of the pit lakes. If recharge fluxes out of the lake are greater than the evaporative fluxes then some dissolved salts will "leak" into the active groundwater flow system and will ultimately report to the surface drainage, probably with significant dilution.

# 5. IMPACTS ON BENEFICIAL USES INCLUDING THE ENVIRONMENT

## 5.1 Groundwater Users

The sole town water supply (from the Burrell Creek Formation aquifer aligned along the Pine Creek Shear Zone) in the region is Pine Creek, situated 25 km south of Frances Creek; well outside the area of influence or impact on the groundwater resource.

The nearest other historical (?) users of the water resource, as indicated by the existence of water bores recorded in the NRETA database, are as follows:

- Union Extended Mine – 8 km to west of the township.
- Spring Hill – 13 km west of the Township.
- McKeddes Gold Mine – 3.5 km north east of Ochre Hill.
- Mt.Wells Garden Lease – 13 km west of Ochre Hill.

As well as the iron mines, mines in the region are closed including the Enterprise Mine (gold) and associated deposits at Pine Creek; Union Extended, 7 km to the west of the township; the Watts Creek Mine (actually on a tributary of Frances Creek) 7 km to the NNW; and at the Frances Creek Gold Mine 14 km to the north-east. There are plans to reopen the Union Reef gold mine in 2006, located 15 km SSW of Frances Creek; the 'Burnside Project' (in the ex-Cosmo Howley area?) to process ore from several of its satellite gold ore bodies in the Pine Creek area; and open the Mount Porter Mine situated 4 km south-west of Frances Creek as a small open cut gold mine (Department of Primary Industry, Fisheries and Mines, 2005).

Agriculture consists of rangeland grazing of cattle on the Mary River West and Ban Ban Springs Pastoral leases and as such is low intensity with scattered watering points; dams, soaks and bores. Pastoral bore water yields will not be affected. Esmeralda Farm is located 11 km south of Frances Creek and 5 km east of Union Reef Siding (abandoned). A bore search of this property (NT Portion 1041) by NRETA (S. Tickell, pers. comm.) indicated that there are no registered bores. It is situated on granite country that is classified as having minor groundwater resources (Dames & Moore, 1989).

All of these locations are believed to be beyond the range of any physical impact due to extraction of groundwater for water supply or pit dewatering at

any of the proposed Frances Creek mining sites. This interaction has been estimated by simple analytical methods to be 4 km (refer to Section 4.5)

The groundwater within a range of a few kilometres of the project site is generally suitable for all normal purposes, including domestic, agricultural and industrial.

## 5.2 Discharge to the Environment

Discharges from pit dewatering should only be released to the surface drainage system if the quality is acceptable for aquatic ecosystems otherwise temporary retention in a wetland treatment system, or where volumes are small, temporary surface storage and subsequent return to the pit is recommended.

Increased flow of a stream due to disposal of pit dewatering water is not expected to result in any significant deterioration of aquatic environmental conditions and will essentially be a one-off event terminating at the same time as mining.

One possible minor impact may be the die-off of vegetation which has been encouraged to flourish in the presence of increased flows due to dewatering discharges.

The springs located in a tributary of Nellie Creek, approximately 10 km to the East of the township are believed to be sufficiently far from the mine site to be unaffected by any drawdown around pits or water supply bores at Frances Creek.

The material constituting the dumps is generally low grade iron bearing rocks, shale and slate. There is some scattered pyrite, but not enough to cause obvious problems so far.

Pit lakes, left behind after mining ceases may provide additional refuge for aquatic life including water birds and freshwater crocodiles.

A risk-based matrix is presented as Table 11.

Table 11 Risk Matrix of Potential Impacts of Mining Activities – Frances Creek Project Area

| ACTIVITY | PERCEIVED RISK | ANTICIPATED LEVEL | | | | COMMENTS |
|---|---|---|---|---|---|---|
| | | ZERO TO VERY LOW | LOW | MODERATE | HIGH | |
| MINE DEWATERING<br><br>Pumping | Falling water levels impacting upon other users | X | | | | Conservative estimates of maximum impacts do not extend to other users or significantly impact on environment |
| | Falling water levels impacting upon springs | X | | | | Conservative estimates of maximum impacts do not extend to the Nellie Creek headwaters where known springs occur |
| | Water quality problems in surface drainage. | | X | | | Temporary on-site storage if quality unsatisfactory |
| Disposal | Die-off of vegetation on completion of disposal | | | X | | A one-off situation for each pit restricted to creek lines |
| WATER SUPPLY BORES | Falling water levels impacting upon other users | X | | | | Conservative estimates of maximum impacts do not extend to other users or significantly impact on environment |
| SEPTIC TANK SEEPAGE | Public health issues (Faecal bacteria seeping to groundwater) | | X | | | Can be risk-free with appropriate management<br>(lined evaporation trenches) |

| ACTIVITY | PERCEIVED RISK | ANTICIPATED LEVEL | | | | COMMENTS |
|---|---|---|---|---|---|---|
| | | ZERO TO VERY LOW | LOW | MODERATE | HIGH | |
| TAILINGS DISPOSAL | Heavy Metals in seepage | | X | | | Current areas well re-vegetated after 30 years |
| | AMD development | | X | | | Attention should be given to areas where sulphide minerals are present in pit walls and waste rock dumps |
| WASTE ROCK DUMPS | Heavy Metals in seepage | | X | | | Current areas well re-vegetated after 30 years |
| | AMD development | X | | | | |
| ABANDONED PIT LAKES | Evaporative concentration of Heavy Metals | X | | | | Depends upon type of lake, i.e. whether it is: Sink, source or through-flow. Monitoring simple |
| | AMD development | | X | | | ***Thelma 2 pit should be checked for AMD*** |
| FUEL STORAGE TANKS | Hydrocarbon leakage to groundwater | | | X | | Commonest mine-site problem after spills in plant |

## 5.3 The Regulatory Environment

Reference should be made to Appendix D in assisting to assimilate the discussion below.

The NT *Mining Management Act 2001* addresses operational legislation. Under this act, essentially, an *operating mine* must satisfy the requirement for on-site containment of waste including wastewater. If such wastewater migrates off-site then the operator requires a Waste Discharge Licence (WDL) under the NT *Environmental Assessment Act*. AGT understands that such a WDL is issued by DNRETA ('Controller of Water' under the *NT Water Act, 1992)* who will stipulate the conditions including allowable quantity and quality of the wastewater to be discharged.

### *5.3.1 Wastewater Discharge Approvals and Licences*

Section 16 of the *NT Water Act* prohibits the pollution of water but allows for authorisation of waste discharge under Section 74 of the Act. This authorisation takes the form of a waste discharge licence. Waste discharge licences are regulatory instruments used to regulate the quality and quantity of wastewater created by industrial and commercial operations that are then discharged to receiving waters in the Northern Territory.

A Waste Discharge Licence may be necessary if, (amongst other industries) a mining activity generates significant amounts of wastewater that are discharged into receiving waters.

# 6. CONCLUSIONS

- The *study* area is bounded by Eastings 795000 and 824500 ($132^0$), and Northings 8490000 and 8505900 ($-13^030'$) Zones 52 and 53, MGA 94 (Pine Creek SD52-08, 1:50,000).

- The eastern and southern boundaries are considered to form 'no flow' groundwater hydraulic boundaries, whilst the western boundary is a potential small groundwater province, and the northern boundary is a groundwater 'sink' beyond which it is considered that there would be negligible impact from mining activities due to the substantial distance and 'dilution' by major river systems; viz. the Mary River and the McKinlay River.

- A hydrogeological conceptual model has been developed that hypothesizes a localized, rainfall-recharge-driven, groundwater flow system coupled with discharge to local creeks including Frances Creek. On this basis, all township/mine site runoff / groundwater throughflow would ultimately find its way into the headwaters of the Frances Creek and into the Mary River to the east.

- The formations of interest constitute fractured rock aquifers. They are the Wildman Siltstone, said by Dames and Moore (1989) to be low yielding (< 0.5 L/s), and possibly the Mundogie Sandstone (< 5 L/s) and Masson Formation (< 0.5 L/s).

- Around the Frances Creek mine-site, brittle rocks are highly fractured and weathered producing much greater bore yields than suggested above. Virtually all of the higher yielding bores are sited in the mineral processing/stockpile/tailings area approximately 200 to 500 m west of the ore body trend formerly exploited in the open pits at Helene 4, 5, and 6/7.

- The groundwaters of the *project* area may be characterised as a 'Calcium/magnesium-bicarbonate type' with relatively high hardness but suitable for most purposes including use as drinking water for both human and livestock consumption. The native Groundwater has low TDS, only three to four times that of the average Pit Water.

- Some pits (notably Helene 6/7 and 5) may be expected to intersect the water-table and require dewatering at rates governed by the local permeability of the fractured rock aquifer, the depth of penetration below the water-table and the area of the pit floor.

- Relatively large flow rates may arise from dewatering of the deeper pits e.g. in excess of 23 L/s was estimated as the seepage into Helene 6/7 immediately after pumping out the stored water in November 2005[8]

- Potential impacts of these dewatering activities are those associated with localized drawdown of the water-table around the pits and impacts arising out of disposal of the pumped water at the surface.

- Theoretical, analytical estimates of pumping-induced groundwater drawdown indicate that the drawdown impact of pit dewatering at Frances Creek is expected to be of limited extent and totally reversible with full recovery of water levels anticipated within one wet season after pumping stops.

- The low salinity of pit waters suggests that the pits act as collectors and groundwater recharge points (groundwater sources) during the wet season and evaporative discharges (groundwater sinks) during the dry with very little throughflow; presumably because the local impact of the pit lake levels on groundwater flow is greater than that of the topographically dependant hydraulic gradients. The ultimate fate of any contaminants would depend on the relative magnitudes of seasonal flows into and out of the pit lakes.

- If recharge fluxes out of the lake are greater than the evaporative fluxes then some dissolved salts will "leak" into the active groundwater flow system and will ultimately report to the surface drainage, probably with significant dilution

- Assuming this analysis is correct, then any contaminants residing in a pit lake are likely to remain there or to move only a short distance into the surrounding fractured rock aquifer when driven by a recharge event. Subsequent evaporative discharge from the lake will tend to reverse this movement back towards the pit.

- The mining operation often results in a reduction in water quality. There may be impacts due to increased turbidity in discharging water as well as possible increase in nitrate content as a result of the use of ANFO type explosives.

- Provided that turbidity falls within acceptable limits and high levels of nitrate are not introduced by blasting, the majority of analysed pit waters could be disposed directly into surface drainage.

8 According to information provided, this will be the deepest of the proposed pits.

- High turbidity can be addressed by pumping to a temporary surface storage to permit settlement of fines before discharging to the environment.
- The impact of disposal of good quality dewatering discharges into the surface drainage system would be locally increased stream flows with possible increased infiltration to groundwater during the dry season.
- The beneficiation of the raw iron ore consists essentially of physical processes without the addition of environmentally undesirable reagents.
- Vertical seepage from tailings areas may contain slightly elevated levels of iron due to the solubility induced by abrasion. The "Heavy Metals" may be similarly slightly enriched.
- Several of the old water supply bores are located very close to the Tailings Settlement area. Provided they can be re-equipped or new bores drilled close to the old sites, any dissolved salts in the seepage water would eventually report to the Pumping Bores which would act as a collector system to "harvest" seepage losses.
- Waste Dumps tend to be developed alongside each pit and in the short term any seepage from the dumps to groundwater would report to the pit. In the longer term the materials in the waste dumps will be subject to oxidation and any sulphides present will tend to form sulphate. Drainage from the waste dumps should, wherever possible be arranged so that it returns to the nearest pit rather than directly to the environment.
- The sole town water supply (from the Burrell Creek Formation aquifer aligned along the Pine Creek Shear Zone) in the region is Pine Creek, situated 25 km south of Frances Creek; well outside the area of influence or impact on the groundwater resource. All the other recorded users are historical (abandoned mines)[9]; and include:

  (a) Union Extended Mine – 8 km to west of the township

  (b) Spring Hill – 13 km west of the Township.

  (c) McKeddes Gold Mine – 3.5 km north east of Ochre Hill.

  (d) Mt.Wells Garden Lease – 13 km west of Ochre Hill.

[9] There are plans to reopen the Union Reef gold mine in 2006, located 15 km SSW of Frances Creek; the 'Burnside Project'; and open the Mount Porter Mine situated 4 km south-west of Frances Creek

- Agriculture consists of rangeland grazing of cattle on the Mary River West and Ban Ban Springs Pastoral leases and as such is low intensity with scattered watering points; dams, soaks and bores. Pastoral bore water yields will not be affected. Esmeralda Farm situated some 11 km south of Frances Creek has no recorded water bores.

- All of these locations are believed to be beyond the range of any physical impact due to extraction of groundwater for water supply or pit dewatering at any of the proposed Frances Creek mining sites.

- Discharges from pit dewatering should only be released to the surface drainage system if the quality is acceptable for aquatic ecosystems otherwise temporary storage and subsequent return to the pit is recommended.

- Increased flow of a stream due to disposal of pit dewatering water is not expected to result in any significant deterioration of aquatic environmental conditions and will essentially be a one-off event terminating at the same time as mining.

- One possible minor impact may be the die-off of vegetation which has been encouraged to flourish in the presence of increased flows due to dewatering discharges.

- The springs located in a tributary of Nellie Creek, approximately 10 km to the East of the township are believed to be sufficiently far from the mine site to be unaffected by any drawdown around pits or water supply bores at Frances Creek.

- Pit lakes, left behind after mining ceases may provide additional refuge for aquatic life including water birds and freshwater crocodiles.

- The NT *Mining Management Act 2001* addresses operational legislation. Under this act, essentially, an *operating mine* must satisfy the requirement for on-site containment of waste including wastewater. If such wastewater migrates off-site then the operator requires a Waste Discharge Licence (WDL) under the NT *Environmental Assessment Act*. AGT understands that such a WDL is issued by DNRETA ('Controller of Water' under the *NT Water Act, 1992)* who will stipulate the conditions including allowable quantity and quality of the wastewater to be discharged.

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# APPENDIX A

# PHOTOGRAPHS OF SITE VISIT

Jointing in Wildman Siltstone, railway cutting, 250 m NW of Bore RN 6322, at township

Jointing in Wildman Siltstone, 500 m N of Helene 5, adjacent access track

*Disturbed sediments adjacent Helene 6/7*

*Jasmine non uniform fracturing of upper sediments, sampling position*

*Jasmine pit and access ramp where water was sampled*

*Seepage from Jasmine adjacent access road (surface water?)*

*Looking west from across old dump to Thelma 2*

*B001 Frances Creek township bore – groundwater samples taken Jan. 2006*

*B006 adjacent to tailing settlement pond*

*Adjacent Helene 5, tight fractured shale located adjacent access road to west of Helene 5. Shale generally had a north – north westerly strike, dipping steeply to the west. Less uniform fractures can be seen in siltstone associated with Helene 5*

*Helene 5 In the pit, fractures were generally tight and non uniform*

*Dark shale surface at Helene 6/7 adjacent ramp*

*Looking to the south up the western Helene 6/7 pit road, note the synclinal folding in the siltstone and presence of dark shale strata adjacent the road*

*Helene 6/7 pit*

*Looking south towards ore body*

| | Name | Location | Description |
|---|---|---|---|
| **Frances Ck Township** | B001 | 807729E 8492946N | Bore B001 (NRETA bore RN006322?) SWL 13.15 mBGL, pH 6.05, EC 198 uS/cm, water sample collected |
| | B003 | 807617E 8492938N | Bore B003 (NRETA bore RN005924?) appeared to be backfilled or obstructed |
| **Helene 6/7 Pit** | FWQ1a | 808864E 8494331N | pit water, pH 7.04, EC 142.6 uS/cm |
| | FWQ1b | 808864E 8494331N | orange/red puddle at top of ramp pH 6.1 |
| **Tailings Settlement Pond** | B006 | 808574E 8494776N | (NNRETA bore RN005922?) couldn't remove cap to obtain water sample |
| **Rosemary** | B004 | 810508E 8497058N | (TI exploration bore TRRC040 or TRDD004) middle of track no water detected |
| **Jasmine** | JAS 1 | 810640E 8497670N | Jasmine Pit water, pH 6.72, EC 36.4 uS/cm, |
| | FWQ 2 | 810558E 8497720N | Potential seepage from Jasmine pit, pH 6.31, EC 72 uS/cm, |

# APPENDIX B

# PIT WATER QUALITY ANALYSES

# Helene 6/7 Pit Water Quality Full Physicochemical Analyses

| Sample Location | pH | EC | Alka-linity | CO3 | HCO3 | OH | Turb-idity | TSS | TDS | NO2_N | NO2 | NO3_N | NO3 | Cl | PO4_P | NH3_N | F | Hard-ness | Ca | K | Mg | Na | SO4 | SiO2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | units | µS/cm | | | | | NTU | | | | | | | | | | | | | | | | | |
| **HELENE PIT 6/7** Apr 05 | 7.9 | 106 | 51 | <1 | 51 | <1 | 5 | <10 | 60 | <0.005 | <0.02 | <0.005 | <0.02 | 4.9 | 0.01 | 0.005 | 0.4 | 40.5 | 1.1 | 2.5 | 9.2 | 7.5 | 1.2 | 8 |
| **ANZECC (1992) GUIDELINE** | 6.5-9.0 | <1500 | | | | | | | | | | | | | | | | | | | | | | |

| | Ag | Al | As | Au | B | Ba | Be | Bi | Br | Ca | Cd | Ce | Co | Cr | Cs | Cu | Dy | Er | Eu | Fe | Ga | Gd | Ge | Hf |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **HELENE PIT 6/7** Apr 05 | <0.05 | 6.8 | 1.05 | <0.01 | 19 | 11.6 | <0.05 | <0.05 | 9 | 970 | <0.02 | 0.01 | 0.11 | 0.2 | 0.01 | 0.92 | <0.01 | <0.01 | <0.01 | 60 | <0.01 | <0.01 | <0.1 | <0.01 |
| **ANZECC (1992) GUIDELINE** | | | 50 | | | | | | | | 0.2-2.0 | | | | | 2.0-5.0 | | | | | | | | |

| | Hg | Ho | I | La | Li | Lu | Mg | Mn | Mo | Nb | Nd | Ni | Os | Pb | Pd | Pr | Pt | Rb | Re | Sb | Sc | Se | Sm | Sn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **HELENE PIT 6/7** Apr 05 | <0.02 | <0.01 | 10 | <0.01 | 17 | <0.01 | 8070 | 11.4 | 0.2 | <0.02 | <0.01 | 1.77 | <0.1 | 0.06 | <0.05 | <0.01 | <0.01 | 2.49 | <0.05 | <0.05 | 1.5 | <0.2 | <0.01 | <0.1 |
| **ANZECC (1992) GUIDELINE** | | | | | | | | | | | | | | 1.0-5.0 | | | | | | | | | | |

| | Sr | Ta | Tb | Te | Th | Ti | Tl | Tm | U | V | W | Y | Yb | Zn | Zr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **HELENE PIT 6/7** Apr 05 | 5.18 | <0.05 | <0.01 | <0.1 | <0.01 | <2 | <0.01 | <0.01 | 0.045 | 0.5 | <0.05 | 0.01 | <0.01 | 7 | <0.05 |
| **ANZECC (1992) GUIDELINE** | | | | | | | | | | | | | | 5.0-50.0 | |

Units mg/L unless otherwise stated

| Sample ID | Easting | Northing | Location description | EC | pH | HCO3 | TDS | NO3_N | Cl | NH3_N | F | Al | As | B | Ba | Be | Bi | Ca | Cd | Co | Cr | Cu | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | µS/cm | units | | | | | | | | µg/L | | | µg/L | µg/L | | µg/L | | | | |
| F1 | 806298 | 8510266 | W side of road to Millers | 45 | 6.6 | 10 | 110 | <0.005 | 2.4 | 1.05 | 0.1 | 10.2 | 1.35 | 0.07 | 0.075 | 0.2 | <0.05 | 1.3 | 0.08 | 0.005 | <0.02 | 0.015 | Pristine area |
| F2 | 810641 | 8497660 | Jasmine Pit 1 | 40 | 6.9 | 9 | 30 | <0.005 | 3.3 | 0.06 | <0.1 | 0.06 | 1.55 | 0.07 | 0.01 | <0.05 | <0.05 | 0.9 | 0.1 | <0.005 | <0.02 | 0.005 | Disturbed pit sample - brown/red water (iron mineralization) |
| F3 | 809957 | 8497192 | Thelma Pit 2 | 279 | 3.5 | -- | 100 | 0.035 | 3 | 0.035 | 0.4 | 6.72 | 0.4 | 0.06 | 0.045 | 1.65 | <0.05 | 1.1 | 0.16 | 0.045 | <0.02 | 0.035 | Disturbed pit sample - blue water (acidic and some copper) |
| F4 | 808477 | 8494430 | Tailings swamp (Helene area) | 121 | 7.2 | 30 | 80 | <0.005 | 5.5 | 0.345 | 0.2 | 0.04 | 2.4 | 0.07 | 0.035 | <0.05 | <0.05 | 4 | 0.06 | <0.005 | <0.02 | <0.005 | pool of water under a culvert |
| F5 | 808435 | 8494350 | Upstream of tailings area (Helene) | 306 | 4.8 | <1 | 160 | 0.02 | 17.3 | 2.61 | 0.1 | 0.08 | 2.45 | 0.09 | 0.09 | 0.35 | <0.05 | 7.3 | 0.12 | 0.045 | <0.02 | <0.005 | ponded water on the south side of Dam wall. |
| F6 | 808875 | 8495268 | Helene 4 Dam area | 34 | 6.6 | 8 | 40 | 0.07 | 5.6 | 0.2 | <0.1 | 0.02 | 4.25 | 0.08 | 0.015 | <0.05 | <0.05 | 0.7 | <0.02 | <0.005 | <0.02 | <0.005 | Below ironstone waste dumps |
| F7 | 808814 | 8495410 | Helene 4 Pit | 43 | 7.4 | 16 | 20 | 0.005 | 2.5 | 0.37 | 0.1 | 0.62 | 2.4 | 0.07 | 0.02 | <0.05 | <0.05 | 0.5 | 0.02 | <0.005 | <0.02 | <0.005 | Below ironstone waste dumps |

| | | | | Fe | K | Li | Mg | Mn | Mo | Na | Ni | P | Pb | S | Sb | Se | Si | Sr | Tl | U | V | Zn | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | µg/L | | | µg/L | | | | µg/L | | µg/L | µg/L | | | µg/L | µg/L | | | |
| F1 | 806298 | 8510266 | W side of road to Millers | 4.15 | 5.5 | 2.15 | 1.2 | 0.11 | 0.25 | 2.7 | <0.01 | <0.1 | 7 | 0.5 | 0.1 | 0.4 | 14.7 | 0.005 | 0.09 | 0.758 | 0.02 | 0.03 | Pristine area |
| F2 | 810641 | 8497660 | Jasmine Pit 1 | 0.2 | 1.8 | 2.05 | 1 | 0.015 | 0.05 | 3.6 | <0.01 | <0.1 | 0.2 | 1.24 | 0.2 | <0.2 | 10.6 | <0.005 | 0.01 | 0.03 | <0.01 | 0.01 | Disturbed pit sample - brown/red water (iron mineralization) |
| F3 | 809957 | 8497192 | Thelma Pit 2 | 0.35 | 4.1 | 9 | 2.2 | 0.51 | <0.05 | 3.9 | 0.11 | <0.1 | 0.33 | 25 | <0.05 | 0.4 | 14.2 | 0.01 | 0.47 | 3.11 | <0.01 | 0.11 | Disturbed pit sample - blue water (acidic and some copper) |
| F4 | 808477 | 8494430 | Tailings swamp (Helene area) | 0.8 | 3.2 | 8.45 | 7.3 | 0.05 | 0.5 | 6.7 | <0.01 | <0.1 | 0.53 | 6 | 0.2 | 0.4 | 6.1 | 0.015 | 0.02 | 0.17 | <0.01 | 0.03 | pool of water under a culvert |
| F5 | 808435 | 8494350 | Upstream of tailings area (Helene) | 1.8 | 7.6 | 3.65 | 12.9 | 0.87 | 0.05 | 19.9 | 0.05 | <0.1 | 0.22 | 34.8 | <0.05 | 0.2 | 7 | 0.055 | 0.02 | 0.03 | <0.01 | 0.195 | ponded water on the south side of Dam wall. |
| F6 | 808875 | 8495268 | Helene 4 Dam area | 0.5 | 1.3 | 0.25 | 0.5 | 0.035 | 0.1 | 4.5 | <0.01 | <0.1 | 0.29 | 0.22 | 0.15 | 0.2 | 3.7 | 0.005 | 0.02 | 0.047 | <0.01 | <0.005 | Below ironstone waste dumps |
| F7 | 808814 | 8495410 | Helene 4 Pit | 0.5 | 1.4 | 2.4 | 2.9 | 0.04 | 0.15 | 3 | <0.01 | <0.1 | 0.21 | 0.06 | 0.15 | <0.2 | 5.7 | <0.005 | 0.01 | 0.133 | <0.01 | 0.015 | Below ironstone waste dumps |

Units mg/L unless otherwise stated

collected by Low Ecological Services

unpreserved 1 L glass sample bottles

analysed at NTEL

# APPENDIX C

# REGIONAL GROUNDWATER CONCEPTUAL MODEL

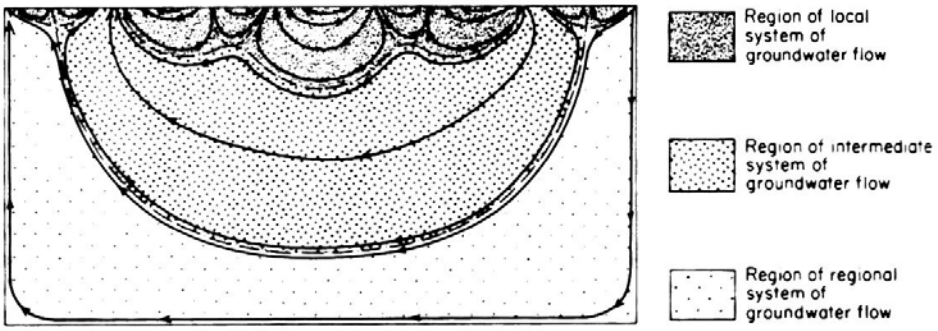


**Figure 6.3** Local, intermediate, and regional systems of groundwater flow (after Tóth, 1963).

Within the study area the majority of groundwater flow is believed to be occurring in "local" flow systems driven by topography and recharge/discharge processes. The scale of these local cells is generally less than 5 km.

The downwards extension of fractures is not known in the study area but if fracture permeability reduces significantly with increasing depth, the entire fractured rock domain may be made up of local flow cells.

# APPENDIX D

# NT ENVIRONMENTAL LEGISLATION

NORTHERN TERRITORY OF AUSTRALIA

# WATER ACT

As in force at 14 January 2004

TABLE OF PROVISIONS

## PART 2 – GENERAL PROVISIONS RELATING TO NATURAL WATER AND POLLUTION

### *Division 2 – Pollution*

### 16. Prohibition of pollution

(1) In this section, "water" means –

(a) water flowing or contained in a waterway;

(b) ground water; or

(c) tidal water.

(2) A person shall not, unless authorised to do so by or under this or any other law in force in the Territory and in accordance with that authorisation, willfully cause, either directly or indirectly –

(a) waste to come into contact with water; or

(b) water to be polluted,

causing serious environmental harm.

(2A) An offence against subsection (2) is an environmental offence level 1.

(2B) A person shall not, unless authorised to do so by or under this or any other law in force in the Territory and in accordance with that authorisation, cause, either directly or indirectly –

(a) waste to come into contact with water; or

(b) water to be polluted,

causing serious environmental harm.

(2C) An offence against subsection (2B) is an environmental offence level 2.

(2D) A person shall not, unless authorised to do so by or under this or any other law in force in the Territory and in accordance with that authorisation, cause, either directly or indirectly –

(a) waste to come into contact with water; or

(b) water to be polluted,

causing material environmental harm.

(2E) An offence against subsection (2D) is an environmental level 3 offence.

(2F) A person shall not, unless authorised to do so by or under this or any other law in force in the Territory and in accordance with that authorisation, cause, either directly or indirectly –

(a) waste to come into contact with water; or

(b) water to be polluted.

(2G) An offence against subsection (2F) is an environmental offence level 4.

(3) In a proceeding for an offence against this section, proof of the existence on land of a drain, pond, dump or other means (including mechanical means) whereby waste is capable of being conveyed, retained or deposited in such a manner as to come into contact directly or indirectly with water is prima facie evidence that waste came into contact with such water at the time that such drain, pond, dump or other means existed.

Default penalty: $500 or, in the case of a body corporate, $2,500.

**17. Rights to prevent pollution preserved**

(1) Subject to subsection (2), nothing in this Act affects a right that a person has under a law in force in the Territory to restrict or prevent, or to obtain damages in respect of, the pollution of water.

(2) In an action to restrict or prevent the pollution of water, it is a defence if it is proved that the pollution was authorised by a licence granted under section 63 or 74.

**Controls on Water Quality in the NT**

The following are abstracts from:
www.nt.gov.au/nreta/environment/water/index.html

Water quality is currently protected by the adoption of the community based beneficial use declarations and environmental values for each water body under the NT *Water Act*.

Water quality management goals, appropriate indicators of water quality and water quality objectives are developed to protect the required values and beneficial uses. Water quality objectives are the "numbers" which reflect the various physicochemical indicators of water quality (such as turbidity, pH, salt levels, and nutrient levels) that need to be maintained to sustain a particular value or use for water. Water quality monitoring is undertaken in the Territory as a partnership between industry, government and the community to assess whether water quality values and uses are being maintained.

Water quality monitoring can be in the form of physical and chemical testing undertaken in laboratories, or can be undertaken using biological indicators such as the AUSRIVAS rapid biological assessment system.

Water pollution can be grouped into two main components –*point source pollution*, or pollution from a single industry such as a sewage treatment plant, and *diffuse source pollution*, or low level pollution from large areas.

Point source pollution produced by large industries is regulated by waste discharge licences that set discharge limits, and establish mixing zones and environmental monitoring programs to verify the discharge limits are being met. Draft environmental guidelines for waste discharge management are available on request to the EPA to provide a framework for risk management, mixing zone management and environmental monitoring. Diffuse source pollution is managed through industry codes of practice and environmental guidelines.

## Beneficial Uses (abstracts from www.nt.gov.au/nreta)

Beneficial Use (water values) is a legislated process that reduces the effects of water pollution and assists in the protection and management of water. The community decides how a particular water body should be used by choosing on one or more Beneficial Use categories.

**NT Water Act 1992**

The management and protection of the Northern Territory's water resources is controlled under the Water Act 1992. The Water Act legislates the extent to which both surface & ground water can be used and for what purpose. Waste discharge to natural waters is prohibited unless licensed under the Act. Waste Discharge Licences are only available in areas where Beneficial Uses have been declared.

BENEFICIAL USE CATEGORIES

**Agricultural -** to provide irrigation water for primary production including related research;

**Cultural –** to provide water to meet aesthetic, recreational and cultural needs;

**Aquaculture –** to provide water for commercial production of aquatic animals including related research;

**Public Water Supply –** to provide source water for drinking purposes delivered through community water supply systems;

**Environment –** to provide water to maintain the health of aquatic ecosystems;

**Riparian –** public rights and ownership rights to take water for domestic and/or stock purposes;

**Manufacturing Industry –** to provide water for secondary industry including related research.

**National Water Quality Management Strategy (NWQMS)**

The Department works to the water quality guidelines and the Beneficial Use process set out in this document.

Beneficial Uses are decided after consultation with the community. Once Beneficial Uses have been legislated, it is then possible to implement water strategy plans which will ensure future protection of the water body.

*Natural Resources Division* will work with the community, industry and landholders to:

- identify water resources under threat;
- determine Beneficial Uses/Environment Values of the water body;
- implement water quality management plans, Waste Discharge Licensing and monitoring programs;
- monitor the water body in question - to make it is protected from pollution;

*Industry and Landholders* as well as being involved in deciding on what the water source should be used for, you can:

- assist in establishing your own waste and land management plans to minimise the risk of pollution;
- apply for Waste Discharge Licences if your actions are likely to affect the water quality;
- carry out monitoring, reporting and waste control as required under the conditions of a Waste Discharge Licence.

*Industry* can also:

- seek opportunities for better waste management - reduce, reuse and recycle, rather than discharge;
- support local community groups involved in the protection of our water resources, such as Waterwatch and Landcare groups.

*Community members* can:

- participate in the consultation process which leads to the decision of Beneficial Uses;
- report pollution of water resources
- become involved in community groups, Landcare and Waterwatch programs

# Guide to Waste Discharge Licences
www.nt.gov.au/nreta/environment/waste/pdf/wastedischargeguide.pdf

## What are Waste Discharge Licences?

Section 16 of the NT Water Act prohibits the pollution of water but allows for authorisation of waste discharge under Section 74 of the Act. This authorisation takes the form of a waste discharge licence. Waste discharge licences are regulatory instruments used to regulate the quality and quantity of wastewater created by industrial and commercial operations that are then discharged to receiving waters[1] in the Northern Territory.

Licences can only be issued where beneficial uses or water quality objectives for the receiving waters have been declared by notification in the Gazette pursuant with Section 73 of the *Water Act*. Beneficial uses (or environmental values) include ecosystem protection, drinking water, recreation and cultural use, agricultural supply and industrial use. The preferred process for selection of the beneficial uses is via public stakeholder consultation in accordance with the National Water Quality Management Strategy.

Licensing ensures that wastewater that has been generated by whatever process is subject to consideration for re-use, reduction in volume and/or pre-treatment. It is then allowed to be discharged to the environment under conditions that have been established to ensure the zone of mixing and duration of the waste discharge are minimised. The possession of a current licence does not absolve the licensee of responsibility to minimise environmental detriment, but is clearly a defence from prosecution in the event of a pollution event.

## When may a Waste Discharge Licence be needed?

A Waste Discharge Licence may be necessary if any of the following activities generate significant amounts of wastewater that are discharged into receiving waters.

_ Mining
_ Aquaculture
_ Dredging
_ Sewage effluent
_ Marina discharges
_ Manufacturing and industry
_ Other wastewater not disposed to sewer via a trade waste agreement with the service provider.

## What is considered to be a waste[2]?

Wastewater may contain the following:

_ Suspended Solids
_ Nutrients
_ Metals
_ Micro-organisms
_ Organic compounds such as pesticides
_ Petroleum based compounds

## What is contained in a Waste Discharge Licence?

The licence serves to provide information to the regulatory authority on the quality and quantity of the wastewater being discharged and its effect upon the receiving environment. Information that may be required in a licence includes:

_ Development of Environmental Management Plans
_ Water Management Plans

_ Structured Monitoring programs including hydrological, physical, chemical and biological elements.
_ Modelling scenarios
_ Contingency reporting in the event of an environmental incident.
It is a requirement of all Waste Discharge Licensees to submit regular reports that collate the data collected through the monitoring programs instituted under the licence. These reports should be interpretative and summarise the results obtained.

## How long is a Waste Discharge Licence valid for?

The period a licence is current varies but in most instances are valid for a maximum of two years. Licences can be of longer duration, subject to the Minister's discretion. All licences are reviewed for compliance with licence conditions. Licences are renewed where necessary to ensure continuity for on-going operations but otherwise lapse until a new licence is negotiated. For example, mining and dredging activities may respectively have a licence restricted to wet season discharges or only issued for the period of dredge operations.

[1] Section 72 *Water Act 2001*, "water" means
- water flowing or contained in a waterway;
- ground water; or
- tidal water.

[2] Waste includes matter or a thing, whether wholly or partly in a solid, liquid or gaseous state, which, if added to water, may pollute the water. Pollute, in relation to water, means directly or indirectly to alter the physical, thermal, chemical, biological or radioactive properties of the water so as to render it less fit for a prescribed beneficial use for which it is or may reasonably be used, or to cause a condition which is hazardous or potentially hazardous to -
(a) public health, safety or welfare;
(b) animals, birds, fish or aquatic life or other organisms; or
(c) plants

Refer to www.nt.gov.au/nreta/environment/waste/pdf/wastedischargeflowchart.pdf for flow chart on WDL issue process.