Extension of Warkworth Coal Mine

environmental impact statement

PART B

Surface and Groundwater Management Study

by Mackie Environmental Research

EXTENSION OF WARKWORTH COAL MINE
ASSESSMENT OF ENVIRONMENTAL IMPACTS
SURFACE & GROUNDWATER MANAGEMENT STUDIES

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prepared by ..

Mackie Environmental Research

4 Ross Pl., Wahroonga

Phone (02) 94875061

Fax (02) 94896809

on behalf of ..

Warkworth Mining Limited

PMB, Singleton 2330

SUMMARY OF FINDINGS

Warkworth Mine is seeking consent to continue open cut mining operations to the west of existing operations. The proposal provides for the extraction of between 15 and 18 million tonnes per annum (Mtpa) run of mine coal over a period of 18 years. Mining will continue within all existing pits with South and Woodlands Hill pits ceasing in 5 to 8 years.

Extended mining will result in continued depressurisation of groundwater within the coal seams and the adjacent interburden as the pressure wave induced by pit deepening expands. Spoils will be progressively emplaced in the pits as mining progresses and re-saturation in the long term will affect groundwater quality in the voids. During mining, pit dewatering and runoff will also lead to changes in supply and demand on the existing mine water management system. In order to address these issues, detailed water management studies have been conducted for the extension of mining. These studies have included an evaluation of the existing and proposed mine operations in respect of groundwater storage and seepage to current and future open pit operations. Studies have also included surface watershed assessments in relation to runoff, and mine water system modelling to assess future system response and management. Within the constraints and limitations imposed by the available database and analytical methods, the following conclusions can be drawn.

The hardrock coal measures aquifer system provides limited groundwater storage and transmission capacity. Interburden lithologies comprising sandstones, siltstones and shales are noted to possess extremely low permeabilities with groundwater transmission characteristics governed by the occurrence and frequency of jointing. Water quality in the coal seams is saline with dissolved salts concentrations ranging from 3000 to more than 12000 mg/l (18400 uS/cm EC units).

Proposed continuation of mining will access seams within the Jerrys Plains Subgroup on the westerly dipping limb of the Loder anticline. As the most westerly pits progress down dip, the zone of depressurisation within the coal measures will expand and continue to merge with depressurisation zones already established around neighbouring mines. It is also possible that the continued mining will induce leakage at an increasing rate from alluvial lands associated with Wollombi Brook and the Hunter River albeit at a very low rate.

A computer based aquifer model of the region has been developed in order to understand the many complex groundwater flow processes that will evolve during the pit deepening. Computer simulations demonstrate development will maintain inward draining hydraulic sinks around the existing mine pits for a distance of several kilometres from the pit highwall and end wall crests. Mine pit seam seepage is predicted to rise from a current rate of about 0.64 ML/day to 4.2 ML/day after 18 years although the final seepage may be lower depending upon prevailing climate and the effect of evaporative losses in the deeper areas of the pit(s). There are no identified boreholes or groundwater users within the predicted depressurisation zone that are likely to be affected by the depressurisation.

If operations cease after the 18 years of mining water will accumulate and water levels will recover in the North Pit final void. A period of more than 100 years would be required for an equilibrated system to re-establish based on groundwater seepage alone. The period will be reduced through contributions from final landform runoff. However water levels will never fully recover to pre-mining levels due to changed conditions within the coal measures where relatively permeable spoils have replaced impermeable intact coal measures. The elevation of the recovered water table is predicted to be lower than 45 mAHD due to sustained evaporative losses from the void water surface.

Recovery of water levels will re-saturate approximately 880 million cubic metres of spoils and this process is predicted to remobilise salts released by the fragmentation of interburden during mining. An estimate of the final void water quality has been calculated from salt load estimates generated through leachate trials on interburden core. This predominantly sodium bicarbonate load has been calculated to range between 0.96 and 2.36 kg per cubic metre of saturated spoils or 844800 to 2076800 tonnes depending on the fragmentation characteristics. The lower limit of this range reflects coarse materials distribution achieved through optimal blast fragmentation of spoils while the upper limit reflects a significant fines content through less efficient blasting or increased jointing in interburden. The calculated load is considered to be an 'instantaneous' load assuming all salts are remobilised and no salts are removed from the system during the mine life.

Mixing of rainfall, leachate and coal measures groundwaters during the void recovery period will produce a water quality between sodium-calcium and chloride-bicarbonate end types tending towards sodium chloride in the long term. Void groundwater salinity is calculated to fall in the range 4667 to 7559 mg/l at the commencement of recovery and to rise steadily with evaporative concentration.

In respect of surface water, clean water runoff will continue to be segregated from mine water via the maintenance of contour drains, sedimentation and mine water dams.. The diversion channel between Sandy Hollow and Longford creeks will continue to divert runoff. Extended mining will have negligible impact on local and regional watersheds. Parts of Sandy Hollow, Dights and Doctors Creek catchments previously consumed by mining will be rehabilitated and runoff from rehabilitated spoils will be returned to these creeks in eastern and north eastern areas.

Continued mining to greater depths will attract more groundwater into the mine water system than is currently managed. This increase can be offset in part by a diversion of runoff from from areas scheduled for rehabilitation. However system modelling indicates the likelihood of surplus water that will need to be removed from site. Testing of the mine water system against 100 years of daily rainfall records indicates surpluses can be managed providing most HRSTS high and flood flow discharge opportunities arising in the future, are utilised. Water sharing between Warkworth Mine, Mount Thorley Operations, Hunter Valley Operations and Mount Thorley Coal Loader will also reduce the need for discharges. Water sharing will also reduce the need for make up water that is currently drawn from the Mount Thorley Scheme.

In order to update knowledge and understanding in respect of surface/groundwater interactions, an expanded groundwater and surface monitoring programme is recommended throughout the remaining mine life. Existing groundwater monitoring bore locations should be maintained and a number of additional bores constructed to the west of the areas planned for mining. Monitoring bores should also be constructed in spoils following reshaping to verify and validate water seepage and quality predictions. Surface water monitoring should continue for key pit sumps and dam storages. Monitoring data should continue to be retained in existing databases and data transferred at appropriate reporting intervals to the Department of Land and Water Conservation.

All data accumulated during the next 12 years should be reviewed and utilised in refining final void designs and close out strategies 5 to 7 years in advance of closure. A subsequent care and control period will be required for monitoring and analysis of void water level recovery in order to provide for implementation of appropriate strategies to mitigate impacts of void water salinity.

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1. INTRODUCTION

Warkworth Mine is seeking consent to continue mining operations to the west of current operations. The continuation of mining provides for the extraction of 15 to 18 Million tonnes of ROM coal per annum (Mtpa) over a period of 18 years to 2020. Mining will consolidate the current four pit operations into a single pit advancing westward and down dip for a distance of about 1.6 kilometres beyond the current limit of mining towards Wallaby Scrub Road. The north-south extent of the pit will remain at about 4.3 kilometres length. Coal will be won from numerous seams, the pit floor being located at the base of the Piercefield seam.

Mine pit development will result in continued depressurisation of all exposed coal seams and interburdens. Such depressurisation while relatively localised over the period of mining to-date, may induce more widespread dewatering. This may lead to changed groundwater flow directions within the coal measures and the potential for increased leakage from surface drainages and water storages. Spoils will continue to be emplaced in the pit as mining progresses and re-saturation will change the long term 'recovered' pit water level and water quality. In addition to potential impacts arising from continuing operations below the regional water table, the mine pit(s) will also affect local surface hydrology as watershed areas are mined, back filled and rehabilitated. Mine water runoff and pit dewatering will lead to changes in supply and demand on the existing mine water management system.

The Environmental Planning & Assessment Act requires the impact of mining on regional groundwater and surface water systems to addressed. Potential areas of concern in relation to water management have been summarised by the Director General for Planning NSW, and are broadly identified as follows:

- assessments in relation to groundwater aquifers including predicted hydrogeologic and hydrochemical impacts during and post mining;
- assessments in relation to surface hydrology including existing watersheds, stored waters, changes to the local hydrology and management of runoff via diversions and storages;
- mine water management assessments including storage and details of the locations and structures including candidate structures that may be used in the future for discharge of mine water as part of the Hunter River Salinity Trading Scheme (HRSTS);

Mackie Environmental Research (MER – environmental hydrologists) was commissioned by Warkworth Mine in March 2002 to undertake water management studies and to provide advice in respect of future measurement and monitoring of aquifer conditions, surface drainages and mine water management. The contained report provides results of those studies and includes groundwater and surface water hydrological data, computer simulations of aquifer systems, assessment of impacts on aquifers and drainages, and detailed analysis of the mine water management system.

2. REGIONAL SETTING

The physiography of the region has been changed through the history of mining of Permian coal measures at Warkworth Mine and at other mines in the vicinity including Mount Thorley Operations (neighbouring) and Bulga open cut to the south, and Hunter Valley Operations (previously South Lemington) mine to the north-west. In a regional context, the area comprises undulating hills and sediment filled valleys with the mine site being located at the headwaters of Sandy Hollow Ck, Dights Ck., and Doctors Ck. (see Figures 1 and 2).

Warkworth Mine currently conducts open pit mining operations in the Jerrys Plains Subgroup of coal measures at depths of 70 to 100 m below surface in four pit areas known as the North pit, the West pit, the South pit and the Woodlands Hill pit.

Mount Thorley Operations (MTO) is situated immediately south of Warkworth Mine and has also historically mined the Jerrys Plains Subgroup of coal measures.

2.1 Climate

The regional climate is temperate. Rainfall is summer dominated and averages about 620 to 640mm per annum. Useful gauging stations in the region include Broke, Singleton and Jerrys Plains and all exhibit a high cross correlation. Broke offers the nearest record for the region however Jerrys Plains provides the most complete long term record and has therefore been used in long term statistical assessments of rainfall. Appendix A provides a summary of rainfall data for Broke, Singleton and Jerrys Plains.

Evaporation data is more restricted in availability with the nearest monitoring location being Cessnock. However this location is influenced by coastal climate. A more representative location offering an extensive record is considered to be Scone Research Station. Average monthly evaporation data for this station is also provided in Appendix A (evaporation potentials for each month in the year). Monthly pan evaporation losses typically range from about 280mm in January to less than 70mm in July.

The last decade has witnessed variable but often below average annual rainfalls in the Upper Hunter region with mostly dry years occurring from 1990 to 1996. This period equated to a persistent El Nino type climate that affected much of the south-eastern Pacific and east Australian region. More recent highly variable and sometimes extreme rainfalls can be attributed to the emergence of a La Nina period in late 1998. Since then, extended periods of moderate to high rainfall, have led to recharge of local shallow aquifer systems. However the cyclicity is of the order of 3 to 5 years and current climate predictions support the re-emergence of an El Nino phase of generally below average rainfalls.

2.2 Drainage and runoff

The mine site is situated east of a drainage divide that separates runoff towards the Hunter River on the east side, from runoff towards Wollombi Brook west of the divide (Figures 1 and 2). Creek discharges to the Hunter River include Sandy Hollow (part diverted into Longford Creek) and Dights Creek draining northward, and Doctors Creek that is diverted southward then eastward around the site. The remaining catchments for these creeks will be consumed as operations progress westward to the catchment divide. Westerly discharging drainages are sparse and include only a few un-named creeks.

All creeks are ephemeral and may be receptors in their lower reaches for upward leakage of saline groundwater from the underlying coal measures.

2.3 Aquifer systems

The Upper Hunter Region hosts three recognised types of aquifer systems – the coal measures, the shallow weathered zone or regolith, and alluvial deposits adjacent to major drainages like the Hunter River. Alluvial and colluvial deposits of limited extent are also encountered along minor drainages.

The main aquifer systems in the area around Warkworth Mine include the low permeability, low storage coal measures often referred to as aquitards, parts of the overlying weathered zone/regolith, and the alluvial lands associated with both Wollombi Brook and the Hunter River.

Due to the relatively low order (1st and 2nd) drainages in the area, valley infill deposits comprising colluvial and alluvial materials are fairly limited. As such, valley infill deposits do not constitute a significant aquifer resource.

Water tables in the low permeability coal measures aquifers/aquitards are sustained by rainfall percolation at a generally low rate with estimates of rainfall recharge varying from zero to no more than 2% of annual rainfall based upon previous studies in the region. In contrast, the alluvial lands are recharged at much higher rates through infiltration of rainfall, downwards percolation of runoff, and lateral seepage from the brook or the river via extensive sand deposits.

2.4 Geology

Regional geology is summarised on the published 1:100,000 Geological Map (Dept. Mineral Resources) and described by Beckett (1988).

The Middle Permian coal measures stratigraphy comprises westerly dipping seams of the Jerrys Plains Group (Wittingham Coal Measures). The basal seam of this group is the Bayswater Seam (Figure 3) that rests upon the Archerfield Sandstone - a recognised marker lithology throughout the region. The Bayswater seam subcrops east of the mine operations. Figure 4 illustrates the local geology and shows the structure contours on the floor of the Woodlands Hill seam. A west south-westerly dip prevails at three to five degrees.

Exploited coal seams and seams planned to be mined across the entire site include (from deep to shallow), the Piercefield, Mt. Arthur, Warkworth, Bowfield, Arrowfield, Woodlands Hill, Glen Munro, Blakefield, Whynot, Wambo and Redbank Creek, together with associated splits. This sequence of coal and interburden was deposited during the Permian period (+250 million years ago) under depositional conditions ranging from lower to upper deltaic (Beckett, 1988) and including inter-distributary bay regimes, overbank and swamp environments and emerging beach conditions. Upper deltaic conditions were more prevalent following deposition of the Vaux and Piercefield seams and were sustained until deposition of the Glen Munro seam at a time when marine incursions were more prevalent.

2.4.1 Structural features

Regional east-west compression of the coal measures has resulted in the development of a number of structural features. Most significant in a hydrogeological context is the occurrence of the Loder anticline and the Mt. Thorley monocline. The proximity of the anticline to the east of Warkworth Mine has resulted in exposure of deeper stratigraphy near and beneath the alluvial lands, in particular the Vane Subgroup members, the underlying Saltwater Creek Formation and the deeper Mulbring Siltstone subcrop (Figure 3). The latter provides a thick and relatively impermeable succession of siltstones and claystones that probably serve to isolate groundwater movement in the Jerrys Plains Group from the shallow alluvial aquifer systems overlying the Mulbring Siltstone to the east and associated with the Hunter River.

Groundwater storage and movement within the coal measures is poor but locally enhanced in areas where jointing is more pronounced. The occurrence of historical groundwater movements is only indicated in some areas along joints and fractures where siderite staining and calcite infilling have been occasionally observed in pit. Siderite occurs either as staining concentrates on certain seam partings or as rare discrete nodules in other seams.

The mapped extents of local fault(s) and dykes are indicated on Figure 4. The Lemington fault is in proximity to the north-west corner of North pit; hydraulic implications are unknown at the present time. Faulting is also known in the southern area of West pit where artesian pressures are sometimes evident in blast holes. A dyke with a thickness of about 1 metre is situated near the centre ramp of the North pit and strikes east-west. No significant igneous silling has been identified.

The dominant joint direction is north-north-west with the conjugate set east-north-east. Joints are vertical to sub vertical with a frequency of about 1 joint per 5 metres in the more massive and coarser sandstone units rising to 5 or more per metre in thinner units. Although groundwater seepage is difficult to observe on any pit walls due to low seepage rates and high evaporative losses, the joints are known to act as the main groundwater transmission mechanism. Seepage is most evident in shallower high wall areas after extended rain periods when vertical infiltration through the regolith initiates weeps.

2.5 History of mining

Mining has been conducted by Warkworth Mine since 1981. During this time, coal has been progressively extracted through the development of four pits – the North, West, South and Woodlands Hill pits. The current floor plan for these pits showing the area of mined coal measures (spoils emplacements not shown) is provided as Figure 5. The different pit orientations have facilitated mining around a localised fold as indicated by the structure contours for the Woodlands Hill seam. During the 21 years of mining to-date, operations have progressed without major groundwater influx – most observed seepage is through the floor and most is lost to evaporation in pit.

3. GROUNDWATER HYDROLOGY

Groundwater occurrence within the region has been mapped as part of the current study. The main groundwater resource is contained within the alluvium adjacent to the Hunter River and Wollombi Brook. This resource is exploited by the regional farming community for stock and irrigation supply via wells and bores that are most often located close to the river or the brook in order to access rapid recharge and improved quality water. While detailed survey has not been conducted on the alluvial lands due to the significant distances between these resources and current mining operations, it is most likely that the alluvial lands act as sinks to saline groundwaters migrating from the coal measures under natural pressure gradients. Deeper zones within the alluvium should therefore exhibit more saline conditions.

Mining operations are located typically more than one kilometre from the alluvial lands. The exception is the Doctors Ck area where alluvial deposits are about 350 m distant from the initial box cut entry to South Pit.

The regional coal measures aquifers constitute the principal aquitard system. Information relating to this system has been gained through discussions with geological and environmental staff at Warkworth Mine, observations of aquifer pressure movements at monitoring piezometers, and experience at other mine sites in the region.

Groundwater storage and transmission in the coal measures is predominantly within coal seams (cleats) or within occasional joints in interburden and overburden. The frequency of joints in regional unmined areas cannot be established easily and is best estimated from observations in the mine highwalls (see Section 2.4). Un-jointed or intergranular permeability of interburden is likely to be negligible since core exhibits high rock strength and low porosity.

The occurrence and pressure distribution of groundwater within the coal measures has changed since mining commenced in 1981. Originally the piezometric surface within the mine lease undoubtedly reflected topography with elevated water levels/pressures in areas distant from the two major drainages (Wollombi Brook and the Hunter River) drainages, and reduced levels in areas adjacent to the alluvial lands. Pit development has now created a groundwater sink around the mine site that merges with the depressurisation sinks developed around both MTO and Bulga mines to the south thereby generating a regional depressurisation envelope.

3.1 Existing bores and wells

A records search has been conducted in order to determine the locations of existing wells and bores in the area. Department of Land and Water Conservation (DLWC) database provides a schedule of registered bores/wells and includes both exploration test wells which may not have been completed as pumping structures or observation and production bores and wells currently or previously in use.

The adopted search area extended several kilometres from the perimeter of the current and proposed mining operations. Results of the search indicated only 1 bore west of Wallaby Scrub Road GW-17462 as shown on Figure 6. This bore has not been located and may be erroneously co-ordinated. More distant bores are situated within the alluvial lands close to either Wollombi Brook or the Hunter River.

3.2 Observation piezometers

Warkworth Mine currently maintains a network of 15 observation piezometers within and around the mine lease. These piezometers are used to monitor water levels in the coal measures at different seam horizons and in the alluvial lands to the east. A schedule of current monitoring piezometers is provided in Appendix B while locations are also shown on Figure 6.

Reference to monitoring data in Appendix B shows piezometers located to the east of mining operations in the alluvial lands generally exhibit stable conditions unaffected by pit development. Similarly, piezometers to the north and north-east exhibit fairly stable water levels although this may be attributed to the relatively shallow depth of construction at some locations and the influence of rapid recharge within the alluvial lands. Only 3 piezometers OH1122, OH1123, and OH1125 show declining pressures. OH1122 is located to the south-west between Warkworth Mine and MTO pits and reflects the cumulative responses of depressurisation arising from these pits. OH1123 is located nearly 2 kilometres west of the West pit and exhibits a pressure decline of the order of 10 metres in all piezometers (leakage suspected between piezometers) while OH125 deepest piezometer P3 exhibits a decline of about 6 metres. Shallow piezometers are stable without decline.

The reason for the decline in piezometers OH1123 and OH1125 is attributed to a combination of depressurisation within more transmissive seams at depth and falling shallow water tables due to reduced rainfall recharge in recent times.

3.3 Regional piezometric surface

As noted, regional water levels (pressures) within the coal measures are the result of interactions between rainfall recharge and topography over a very long period of time. Rainfall percolation has sustained an elevated water table while drainage channels have incised the water table and provided a leakage pathway thereby constraining maximum aquifer pressures to the drainage bed elevations or root zones. In rainfall recharge periods, water levels in shallow aquifer systems respond by rising several metres. During subsequent dry periods, levels decline through natural seepage into local water courses. At these times salinity in surface drainages normally rises.

In order to generate a regional piezometric surface with the limited availability of water level measurements, a 'probable' pressure distribution has been generated by utilising aquifer modelling methodologies (see Section 4) with regionally distributed rainfall, brook and river bed elevations (interpolated for all relevant reaches) and the current mine pit development. Figure 7 provides an estimate of the surface in the shallow interburden zone (approx. 20 to 50 metres depth). Reference to this plot shows elevated pressures (+60mAHD) west of the mine pits with flow paths directed towards Wollombi Brook or flow paths attracted towards the mine pits where pit floor elevations range from about 5m in North pit to –40m in West pit.

Depressurisation is limited to the east due to the presence of alluvium that probably supports downward leakage via occasional joints in the strata although this is expected to be relatively minor due to westward dipping stratigraphy and sub cropping low permeability strata associated with the Archerfield Sandstone and the Mulbring Siltstone.

3.4 Coal measures hydraulic properties

Hydraulic properties for specific coal seams have not been measured within the immediate area of interest. However testing has been conducted in adjacent areas over a number of years and this data together with back analysis of the observed depressurisation response around the existing mine pits has been used to develop an understanding of the likely bulk permeability of coal measures. The following Table 1 provides a summary of measured seam permeabilities. Further details are provided in Appendix C.

Table 1: Coal measures permeability estimates

Strata	K (m/day)
Whybrow seam	2.50E-02
Whynot seam	4.40E-02
Blakefield seam	1.00E-02
Glen Munro seam	6.50E-03
Woodlands Hill (4) seam	1.20E-02
Arrowfield seam	5.10E-02
Bowfield seam	5.00E-02
Warkworth (1/2) seam	1.00E-02
Piercefield seam	1.41E-01
Vaux seam	1.48E-01
Broonie seam	3.70E-02
Bayswater seam	2.30E-02
interburden (siltstone-sandstone)	1.00E-06

K = horizontal permeability

3.5 Coal measures water quality

Coal measures water quality has been monitored for several years through sampling of piezometer groundwater and sampling of mine pit water. pH and TSS and speciated ions have also been determined at piezometer locations. Data has been summarised in Appendix D. Groundwaters broadly reflect a very poor quality highly saline water in coal measures and in alluvial lands areas near the Hunter River. This is in part attributed to the completion o piezometers in specific coal seams or at the base of the alluvium.

The coal seams groundwater in the area planned for westward extensions of the mine pit, has no beneficial use. Future piezometers constructed in interburden may reflect a lower salinity more typical of the region. Established water quality guideline data are provided in the following Table 2 together with typical mine water and piezometer groundwater for comparison.

Table 2: Generalised water quality criteria and comparison with local water

TDS (mg/L)	Equivalent EC (uS/cm)	Beneficial use
1000 [1]	1540	acceptable taste limit for humans
1500	2300	general upper limit based on taste
1300 [2]	2000	approx. limit for lucerne on alluvial lands
3000 [2]	4600	limit for poultry and pasture/fodder
4000 [2]	6100	limit for dairy cattle
32500	50000	sea water
4230	6500	*typical main water storage dam*
8670	13340	*typical borehole groundwater (OH1122)*

Source: 1=ADWG - 1996, 2=ANZECC, 2000

Salinity data (Appendix D) for dams and borehole locations are shown on Figure 8. Since the data is both discrete (boreholes at specific seam depths) and composite (dam water) it is not feasible to develop an interpolated salinity distribution. Values at specific locations are therefore provided. Reference to this figure indicates a range in salinity for coal measures piezometers from 2900 to more than 18000 uS/cm with salinities above 12000 uS/cm dominating. Surface water sampling exhibits a range from 3930 to 9400uS/cm, the main water storage dam ranging from 4000 to more than 6500 us/cm.

Speciated groundwater is represented on the tri-linear plot (Figure 9). This representation facilitates classing of the water types. Ionic speciation for major cations and anions indicates a classing of waters where sodium chloride or primary salinity dominates in the hardrock areas.

pH values ranging from 7 to 8.5 are also consistently recorded at sampling locations. The high pH reflects an environment offering significant buffering (mitigating acid generation) as is observed in most mining areas of the Upper Hunter region.

4. PREDICTION OF GROUNDWATER IMPACTS

Continued mining of coal seams will expand the depressurisation surface to the west of the current pit areas. The extent to which depressurisation will become more 'regionalised' depends upon a number of factors including aquifer/aquitard hydraulic properties, variation in stratigraphy, structural features including dykes, faults and bedding flexure, and recharge sources. The spatial distribution and interaction of these various components cannot be evaluated using simple mathematical (analytical) expressions. Rather, mathematical methods that permit the introduction of spatial and temporal variability must be employed (computer based numerical models).

An aquifer model of the region has been developed in order to assess the likely impacts arising from continued mining. The model employs a finite difference scheme (ModFlow) for solving a set of differential equations known to govern groundwater flow. The simulation method requires dividing the overall area of interest into rectangular cells or blocks with the number of cells in the model grid being determined by the general juxtaposition of existing and proposed mining operations, and the expected hydraulic gradients developed in the course of mining.

The simulation model is a simplified representation of the aquifers and comprises 7 layers of cells with 9500 cells in each layer. The extent of the regional model is indicated in Appendix E - Figure E1 and includes most of MTO to the south for cumulative impacts assessment. Hunter Valley Operations (HV)) South Lemington is considered too distant and has not been included.

Model layers, stratigraphy and assigned permeability values are provided in the following Table 3. Horizontal permeabilities (hydraulic conductivities) have been calculated as the harmonic means of known seam values and interburden estimates provided in Appendix C. Values have not been adjusted/reduced with increasing depth to account for increasing effective stress and are therefore considered to reflect conditions nearer an upper bound and likely to generate higher pit seepage estimates than for adjusted values. Vertical permeabilities have been assigned at one tenth the horizontal value although in many instances this could be much lower due to the frequently observed presence of siltstones, claystones and laminites. Use of a 10:1 ratio also supports conservative (high) estimates of depressurisations and pit seepage.

Table 3: Model layer-stratigraphy and assigned permeability

Layer	Stratigraphic boundary zones	Horizontal K (m/day)
1	arbitrary base including coal measures + alluvium	8.0×10^{-3} (alluv = 10.0)
2	arbitrary top down to floor of Woodlands Hill seam	4.0×10^{-3}
3	floor of Woodlands Hill to top of Bowfield seam	1.0×10^{-3}
4	top of Bowfield to floor of Vaux seam	1.3×10^{-2}
5	floor of Vaux seam to top of Archerfield sandstone	5.6×10^{-3}
5	top of Archerfield sandstone to top of Mulbring siltstone	1.4×10^{-2}
7	top to floor of Mulbring siltstone	1.0×10^{-3}

K = permeability

The arbitrary assignment of the base of layer 1 is governed mostly by the presence of alluvium. That is, where alluvium is mapped along the major drainages (Wollombi Brook and the Hunter River), layer 1 represents the base of the alluvium. In other areas the base is simply an interpolated surface across the model.

The alluvial aquifers within layer 1 have been represented by assuming a maximum thickness below river or brook bed elevations of between 18 and 26 metres depending on location and available bore data (DLWC database). Thickness has been pinched out along the alluvium boundaries.

Modelling has commenced in 1983 (below the water table) and progressed forward in time to 2002 with coal seam extraction to surveyed floor levels shown on Figure 5. Rainfall recharge across the model has been coarsely adjusted until simulated water levels within the model after 18 years of mining, compared approximately to the few piezometer locations that are currently monitored in the coal measures.

4.1 Model properties and initial conditions

Properties assigned to the model include permeability, storativity, porosity and leakage parameters. As noted above initial permeability values were adopted from values determined at regional locations (Appendix C). Horizontal permeabilities have been assigned constant within each layer.

River type cells have been assigned to the Hunter River and Wollombi Brook as these drainages maintain some flow at all times. Bed elevations have been calculated for separate reaches based on limited survey data. Drainage type cells have been located over regional ephemeral creeks with bed elevations estimated from the 5m digital terrain model or 1:25000 topographic maps with a uniform negative adjustment of 4m to account for localised drainage profiles or root zone extinction. Rainfall recharge has been applied at an average rate of 3mm/year in coal measures equivalent to about 0.5% of annual rainfall. This order of recharge is slightly lower than values adopted at other sites in the Upper Hunter region but a higher value would generally elevate modelled water levels above measured regional levels. A much higher rate of 90mm/year has been assigned to alluvial lands (14% of annual rainfall).

4.2 Open cut depressurisation

The aquifer model has been used to simulate past and future depressurisation of the coal measures. The commencement of simulations (penetration of the shallow water table) is 1984. Thus the model has been run for a period of 18 years before 2002 in order to generate estimates of seepage and formation depressurisation to the present time. Simulations have then been completed for a further period of 18 years to generate estimates of aquifer depressurisation and pit seepage over the proposed mine life. MTO has been simulated in a similar manner with about 10 years of mine life remaining.

Pressure/drawdown distributions have been determined at 2002 (current), 2004, 2007, 2012, 2017 and 2020 (end of mining). Simulated development has been scheduled by assigning seam floor elevations to pit cells in accordance with planning data supplied by Coal & Allied. The resulting pressure distributions have then been computed for all 7 model layers.

Figure 10a/b shows the simulated progressive loss of aquifer pressures from an initial condition representing mine development in 2002 and a final condition in 2020 for both aquifer pressures (left plot) and drawdowns (right plot). Appendix E, Figures E3 to E5 provide model responses at the times indicated above. Reference to Figure 10 and Appendix E illustrates a regional depressurisation surface extending westward to Wollombi Brook alluvium and eastward to the Hunter River alluvium. Depressurisation beneath these unconsolidated deposits is predicted to establish a reversal of the original upward leakage of saline groundwater to these deposits, resulting in a downward ward leakage from the alluvium to the coal measures.

Figure 11 shows the calculated pit seepage rates over the mine life. Present seepage rates attributed to depressurisation of the coal measures (2001/2002) are estimated to be of the order of 1.4ML/day. However since the pit wall exposure is more than 18000 sq.m. a component of seepage is lost to evaporation (average rate of 4 mm/day) leaving less than 0.64 ML/day to enter the pit. Long term seepage is expected to rise to an estimated 5ML/day at the completion of mining and before evaporative losses accrue. The adjusted seepage entering the mine water system after evaporation is estimated to be about 4.2 ML/day at year 18 however this will depend to some extent upon prevailing climate at that time.

Figure 11 also shows the leakage balance between the river and brook, and the underlying coal measures. Upward leakage is shown to decline shortly after the commencement of mining below the regional water table. Downward leakage is shown to increase from Wollombi Brook at about year minus 10 or from about 1992 onwards, and from the Hunter at about year 10 (2012) onwards. The difference in delays for the onset of leakage is attributed to the presence of steeply dipping and relatively impermeable lithologies between the mine and the Hunter River that are simulated within the model. A total downward leakage rate of about 0.6ML/day is predicted at the end of mining.

4.2.1 Cumulative depressurisation impacts

The cumulative effects of MTO have been included in model estimations discussed above.

4.2.2 Mine pit groundwater quality

The quality of groundwater entering the mine pits will continue to reflect an average of water quality for the coal measures spoils (toe seepage and runoff), and contributions from the surrounding coal measures (ranging from 4000 to 6500uS/cm in the Main Water Storage dam). Future hydrochemistry is expected to be similar since interburden is similar although the influence of highly saline specific seams (piezometers) is unclear.

Since all pit water will remain within the mine water system and since an inward flow regime will prevail at all times, seepage water will not migrate beyond the pit area. Appendix C provides monitoring data for dams and piezometers.

4.3 Recovery of aquifer pressures post mining

Mining will continue to 2020. At that time mining will either continue or cease. If mining continues then further regional depressurisation of the coal measures can be expected. If mining ceases then spoils will be reshaped to establish stable high and end walls, and pit water levels may be permitted to recover.

The rate of recovery of water levels in the pit void will depend upon the remaining water held in storage in coal measures, the rate of strata seepage back to the mine pit, the rate of induced leakage from shallow alluvial deposits and the extent of recharge from rainfall runoff. An estimate of the rate of recovery of pressures and water levels has been made using the aquifer simulation model with the pressure distribution defined in Figure 10b at 2020 as the starting condition for recovery.

Within mined areas, the hydraulic properties of specific model cells have been changed to reflect increased permeability and porosity associated with spoils. Values of 1 m/day for permeability and 20% for consolidated porosity, have been adopted. For open pit areas a rainfall recharge rate of 3 mm/year remains over undisturbed coal measures. However spoil areas have been assigned an increased rate of 30mm/year assuming increased root zone permeability arising from rehabilitation. These properties have also been applied to MTO.

Recovery plots are provided in Appendix E, Figures E6 and E7 for 10, 20, 50 and 100 years post mining. From model responses it is apparent that depressurisation within the coal measures continues to expand for a number of years after mining ceases but hydraulic gradients towards the pit void reduce as the void fills. More than 100 years would be required for recovery to approach an equilibrated state assuming groundwater seepage is the primary source of water. Full recovery of original coal measures pressures will not occur since the pit void and spoils (including Mt. Thorley) have already established different hydraulic characteristics to those for insitu coal measures.

Recovery of pit water levels will be accelerated by contributions from rainfall and runoff. The extent to which these will contribute will depend in part upon closure planning to be undertaken during the last 5 years of mining and monitoring of runoff from rehabilitated areas prior to that time.

4.3.1 Final void groundwater quality

A closure strategy for the void will be prepared following detailed assessments of final landforms, monitoring of pit water seepage and evaporative losses approximately 5 years prior to closure. The current design provides for open water void conditions as shown on Figure 12 where a localised sink or groundwater attractor will prevail at the pit void and salinisation will occur in time. Void water/groundwater quality will be largely influenced by the re-saturation of spoils and leaching of salts from the saturated, fragmented interburden. As noted other contributing factors will include continuing coal measures seepage and contributions from direct rainfall runoff entering the void.

An estimate of the long term salinity of void water has been prepared using mass balance estimates and an average mobilisable salt load of between 0.96 and 2.36 kg per cubic metre of spoils. This mobilisable load is the estimated leached load over a period of at least 100 years and has been determined from leach trials conducted on interburden samples over a period of 12 weeks. Leachate trial results are provided in Appendix F.

Final void recovery levels will result in about 880 million cubic metres of spoils being re-saturated to a maximum 45 mAHD recovered void water level. If a final emplacement bulk porosity of 20% is assumed, then the calculated mobilisable salt load over the duration of recovery is estimated to lie between 844800 and 2076800 tonnes (Appendix F).

Mixing of the leachable load with the open void water derived from rainfall runoff and coal measures water leads to an estimate of void/spoils water quality in the range 4667 to 7559 mg/l before evaporative concentration is considered. Current salinity of mixed mine water observed in the Main Water Storage dam ranges from 2600 mg/l (4000 EC) to more than 4225 mg/l (6500 EC).

With the void runoff catchment areas indicated on Figure 12, runoff will be insufficient to balance evaporative losses (see Appendix F). A groundwater sink will be established and will continue to attract from the surrounding coal measures thereby impeding migration of saline water into the coal measures. Salinity will steadily rise.

Based on leachate trials, the void groundwater is expected to tend towards a sodium chloride/bicarbonate water groundwater with a pH in the range 7.5 to 9.0.

5. SURFACE WATER HYDROLOGY

Current operations at Warkworth Mine occur within a number of watersheds that either direct runoff into local water courses or disturbed watersheds that direct runoff into the mine water system. These watersheds include Sandy Hollow Creek, Dights Creek and Doctors Creek delimited on Figure 13. The upper part of Sandy Hollow Creek catchment is presently diverted northward into Longford Creek via a contour drain and a diversion channel. Dights Creek runoff is collected in a local dam and is pumped northward into the mine water system. Doctors Creek is diverted around the southern perimeter of the mine site via collection and pumping from a sedimentation dam in the south west.

Other drainages within the mine lease mostly drain westward or north-westward to Wollombi Brook. All are ephemeral and first or second order as identified from 1:25000 topographic map. Upper reaches of the western creeks and catchments often transgress outcrop while lower lying areas exhibit bank and rill erosion in places. Future mine operations will continue westward and eventually breach the main north-south catchment divide shown on Figure 13 as the most westerly limit of the mine catchments.

During the planned 18 years of mining, further catchment will be consumed east of the divide while rehabilitation will return runoff from large areas of spoils to the catchment. The following Table 4 provides a summary of impact on drainage catchments to-date and future impacts to 2020.

No creek diversions are planned. However a number of sedimentation dams will be constructed on the upper reaches of the westward draining (un-named) creeks prior to the commencement of earthworks between years 5 and 10 of the extended mining period. These sedimentation dams will be constructed in accordance with design criteria provided in Housing NSW, 1988. Existing contour drains situated east of the divide will be relocated up slope of the encroaching highwall crest at appropriate times in the mine life cycle in order to convey runoff around the mine site.

Table 4: Impact of continued mining on surface drainages (not including rehabilitation)

Watershed	Catchment area to 2002 (ha)	Area affected to 2011 (ha)	Percent consumed %
Sandy Hollow Creek	118.8	118.8	100
Dights Creek	58.8	58.8	100
Doctors Creek	278.7	158.1	56.7
Longford Creek	657.9	89.4	13.6
un-named creek 2	819.0	38.0	4.6

Typical water salinities in the drainages are monitored regularly and are indicated in the following Table 5.

Table 5: Average water quality parameters in local drainages

Watershed	pH	EC – uS/cm	TSS - mg/L
Hunter River	7.0 to 8.0	600 to 800	5 to +300
Doctors Creek	7.5 to 8.5	500 to +5000	10 to 150
Loders Creek	7.0 to 8.0	900 to +5000	10 to 200

6. MINE WATER MANAGEMENT

Future water management will utilise the existing water management system with minor changes and provisions for water sharing with MTO, Mt. Thorley coal loader and Hunter Valley Operations (via South Lemington pit). The main goals of the mine water management system include:

- diversion of natural catchment runoff around the mine site where practically feasible
- capture and storage of pit seepage and disturbed area runoff in order to maintain site workability
- efficient usage of stored water for process water supply in the coal preparation plant (CPP)
- watering for dust minimisation on haul roads, trafficable areas and stock piles
- minimisation of river make up water during dry and drought periods
- maximisation of surplus water utilisation and re-cycling across all operations.

6.1 Water management system description

Since mining commenced, the water management system has operated with both a deficit and a surplus in supply depending upon the prevailing climatic conditions. Any deficit in supply has been met by drawing water from the Hunter River via the Mt. Thorley Scheme while surpluses have been generally contained on site. However the mine retains a licensed discharge point to facilitate releases of mine water via the Hunter River Salinity Trading Scheme (HRSTS) at a maximum rate of 100ML/day to Doctors Creek.

Figure 13 provides a plan of the site layout in 2001 with the various pits, catchments and water storage dams identified. Figure 14 provides a simplified schematic of the mine water system. The schematic gives an overview of the mine 'dirty' water system with catchments identified on Figure 13 being assigned to specific storages. Figure G1 (Appendix G) shows the current mine plan with topography and main water management elements including dams, contour drains, Longford Creek diversion and pipelines. Operation of the system provides for the following:

- North easterly runoff from Dights Creek undisturbed catchment to the west of the North Pit is collected in a local catch dam and pumped to the North Pit Transfer dam via a 315mm dia. pipeline.
- Runoff in the lower part of the undisturbed catchment of Sandy Hollow Creek is pumped to the North Pit Transfer dam via a 200mm pipeline. Runoff from higher parts of the catchment is diverted to the north-west via a diversion channel and off site via Longford Ck.
- Runoff in Doctors Creek catchment immediately south and south-west of the West pit is contained by a runoff transfer dam and pumped eastward via a 315mm pipeline to a channel that discharges to Doctors Creek near the washery and off site.
- Rainfall and groundwater seepage arising from areas north of the North Pit ramp and including the northern benches and pit area, are pumped over the high wall (westward) into a 315mm pipeline that conveys water to the North Pit Transfer dam.
- Rainfall and seepage to the southern part of the North Pit is pumped up the pit ramp to Swan Lake. This seepage includes leakage from Tailings Dam 2 that migrates down the ramp.

- Rainfall and seepage to the West Pit generally migrates to the southern end of the pit where it is pumped up the end wall to the West Pit Settling Ponds before being transferred to CD void.
- Rainfall and seepage to the western part of Woodlands Pit (west of the pit ramp) migrates westward to enter the West Pit. Water collecting in the eastern part of the pit is pumped up the east end wall into undisturbed catchment where it migrates northward to CD void/pit.
- Rainfall and seepage to the South Pit(s) is pumped westward up the high wall and conveyed via undisturbed catchment to CD pit.
- Rainfall and runoff accumulating in Tailings Dam 1 can be siphoned over the southern wall to Sedimentation Dam 1 where it is subsequently conveyed to the Main Water Storage dam. A component of accumulated water is believed to percolate downwards through the dam floor and through spoils where it is deflected and migrates southward through spoils to CD pit.
- Rainfall, runoff and tailings decant entering Tailings Dam 2 can be collected and pumped via a 315mm pipeline to Sedimentation Dam 2 where it is subsequently conveyed to the Main Water Storage Dam. A component of decant is known to percolate downward through the dam floor and to then migrate in a southward direction (via the old Ramp 2), subsequently reporting to CD pit.
- Accumulated water in CD pit can be pumped to the CPP. Storage in this area includes open water currently estimated at about 800 ML and water stored in spoils and estimated to be about 1200 ML assuming a drainable porosity of about 20% for spoils. There is an upper bound to the amount of storage that can be contained in this pit whereby seepage would be initiated through spoils at about RL 0 mAHD in a south-easterly direction to the South Pit. This level equates to about 6000 ML.
- Water is pumped from the Main Water Storage dam for consumption in the washery (CPP). Make up water is drawn from the Mt. Thorley Scheme on a needs basis.
- Rainfall runoff in the CPP and stockpile area migrates to the Washery Settling Ponds from where surplus is drawn back to the washery (CPP).
- Rainfall runoff in the workshop-truck wash and office area is directed to a number of local settling ponds where it is pumped back to the washery for re-use.

In addition to the above and in order to maximise recycling, water may be transferred between Warkworth Mine and MTO.

6.2 Mine site water balance

The mine water balance is a representation of all inflows, ouflows and changes in storage for the water management system. It provides an understanding of the need for storage and the impacts of seasonal and climate change. In the current study, a computer based simulation model has been used to assess the dynamics of the system under conditions of varying rainfall and groundwater seepage rather than a simple wet and dry year water balance. The adopted approach provides a probabilistic outcome and is preferred to a simple balance type model as the latter cannot easily address varying catchment areas, varying groundwater seepage or rainfall runoff accumulations attributed to increasing soil moisture.

The model develops a daily water balance for the mine site for wide ranging climatic conditions by utilising historical rainfall and evaporation records to generate catchment runoff estimates. The model provides for pumping and accumulation of mine water, transfer of mine water between dams, losses related to the CPP, dust suppression etc. and discharges to the Hunter River in compliance with the HRSTS if required. Appendix G gives a summary of the main components of the water management simulation model.

6.2.1 CPP, dust suppression and other water usage rates

System water usage can be attributed to three areas – the washery (CPP), dust suppression including haul roads, other roadways and stockpile areas, and truck wash down. Estimates of these usage rates have been either calculated indirectly or determined from available pumping data.

Table 6: CPP water loss calculations

Annual ROM production	9.5	Mtpa	
Production weeks	52	weeks	
Scheduled ROM production	182692	t/week	
Equivalent day rate at pit moisture for model purposes	26027	t/day	
Equivalent day rate for model purposes – dry weight	24049	t/day	
Dilution of ROM (% to product) - dry weight	64	%	
Dilution of ROM (% to coarse rejects) - dry weight	21	%	
Dilution of ROM (% to tailings) - dry weight	11.1	%	
Dilution to benificiated dry tailings (BDT) – dry weight	3.9	%	
ROM moisture content	7.6	%	
Product moisture content	9.6	%	
Coarse rejects moisture content	8.3	%	
Tailings moisture content	76	%	
Supernatant return as % of rejects total moisture	13	%	
Tailings seepage return (infiltrated) as % of tails moisture	48	%	
Tailings percolation lost to spoils storage as % of tails moisture	12	%	
Supernatant + seepage return water to CPP	5157	kL/day	
Product tonnes per day – dry weight	15392	t/day	
Coarse rejects tonnes per day – dry weight	5050	t/day	
Tailings tonnes per day – dry weight	2669	t/day	
Product water content	1635	kL/day	
Coarse rejects water content	457	kL/day	
Tailings water content	8453	kL/day	
Evaporative losses from tailings dam (4Ha min & 4mm/day)	160	kL/day	
Supernatant bleed to tailings decant reservoir	1099	kL/day	
Infiltration/leakage of supernatant to CD pit	4058	kL/day	
Infiltration/leakage to spoils storage increase	1014	kL/day	
Initial moisture retained in tailings	2122	kL/day	(44% moisture)
Key usage figures			
CHPP water consumption daily (no supernatant return)	8567	kL/day	
CHPP water consumption per tonne (without supernat. return)	329	L/t	
CHPP water consumption with supernatant return	**3410**	**kL/day**	
CHPP water consumption per tonne with supernatant return	**131**	**L/t**	

Note: Figures averaged to daily rate for modelling purposes

The increase in moisture content from ROM to product and waste represents the major component of mine water usage. Losses on a per tonne (ROM) basis have been estimated by calculating the mass balance for CPP operations. Table 6 provides a CPP balance for a production rate of 9.5 Mtpa (ROM) with tailings being pumped at about 1.18 SG and having an initial 44% residual moisture content following beaching, supernatant bleed and percolation to spoils. Results of the balance indicate an average make up water requirement of about 131 litres per tonne of processed ROM. This estimate is expected to vary seasonally with higher (evaporative) losses in mid summer and lower losses in mid winter.

Dust suppression on haul roads and other areas is estimated to range from 1.2 to more than 1.6 ML/day depending upon prevailing weather conditions. Future usage is calculated to average about 1.4 ML/day. Stockpile usage is estimated at about 0.12 ML/day while truck wash down is of the order of 0.03 ML/day. Table 7 provides a summary of usage/loss rates.

Table 7: Summary of current and future mine water usage rates

CPP (6 Mtpa) – current loss rate	2.15	ML/day
CPP (9.5 Mtp) – future loss rate	3.4	ML/day
Dust suppression on haul roads	1.4	ML/day
Stockpile watering	0.12	ML/day
Truck wash down	0.03	ML/day

6.2.2 Water management simulation model

As noted, the water balance simulation has been designed to include variable catchment areas over the mine life. That is, changing pit operations including stripped and benched areas, pit floors, spoils etc. have been included as variable catchments based on mine planning supplied by Warkworth Mine. Table 8 provides a summary of catchment types prescribed in the model.

Table 8: Mine catchment types assigned to model

Type	Code	Characteristics
undisturbed	UD	grassed with occasional tree cover, dispersive soils, low infiltration
pre strip and bench	SB	stripped, broken ground with high infiltration in shallow zone
pit floor	PF	compacted ground, with low infiltration potential
unshaped spoils	US	high infiltration and percolation to base of spoils
shaped spoils	SS	moderate to low infiltration (dispersive) , high percolation
rehabilitated	RH	grassed, immature tree development, low infiltration, high percolation
hardstand	HS	permeable stockpiles and impermeable base, admin + plant areas
stock pile	STK	low to moderately low infiltration capacity, limited storage

6.2.3 Assessment of future system response

Simulation of the mine water management system has been conducted for projected future mine/pit catchments over the next 18 years (to 2020) using historical rainfall periods extracted from the Singleton rainfall record. Figures G1 to G5 in Appendix G provide mine plans, topography and main water management elements from year 5 to year 18. Figure 15 shows the mine water catchments at year 10 while Figure 16 gives a schematic of the system showing contributing catchments. Appendix G Figures G6 to G9 provide catchment plans for years 5 to 18.

Separate rainfall periods of 18 years duration have commenced in 1900 with each subsequent period offset by 10 years. In this manner, the mine water system has been tested against 100 years of record for last century.

Initial storage conditions in all dams have been assigned at low to mid storage levels. A provision for pit groundwater seepage has been included with seepage assigned as a rising component from an initial rate of 0.64 ML/day (after evaporative losses) to a 2020 rate of 4.2 ML/day accumulated from all pits over the term.

Pumpage and usage has been adjusted for CPP operations at an average 9.5 Mtpa ROM with tailings delivered initially to Tailings Dam 2 and subsequently to Mt. Thorley Abbey Green Pit (3.4ML/day minimum loss rate). The remaining 5.5 Mtpa of a planned 15 Mtpa will be directed to the Mt. Thorley mine CPP where pit operations feeding that washery will have ceased at about year 10.

Other usage rates like dust suppression and truck wash down are assumed to be the same as the 'calibrated' model. All dam to dam transfer rates remain fixed during the 18 years term of modelling except when dam storage levels are below the assigned daily pumping rate – transfer rates are then adjusted downwards to remaining storage. If pumpage from one dam to another encounters a storage that is at capacity, then an overflow occurs to the next nominated storage with all surplus water accumulating in the 500ML Discharge dam. This dam is planned for commissioning in about 2005 when the existing 400ML dam is mined through. If the system is at capacity then water is retained in pit.

HRSTS discharges have been included by examining 100 years of synthesised river flow data and determining when discharge opportunities would have occurred (see Appendix G). HRSTS maximum discharge rate is the currently licensed rate of 100ML/day (adopted for flood discharges) while a maximum high flow discharge rate of 70 ML/day has been adopted based on the need to remove surplus water. This rate has been calculated as a proportion of the total allowable discharge (TAD) average for the HRSTS lower sector (from river flow and salinity records), and the current number of salinity credits retained by Coal and Allied.

Appendix G provides graphical output for a dominantly wet period from 1940 to 1958, a dry period from 1930 to 1948 and a relatively average period from 1970 to 1988 – Figures G10 to G15. Storage exceedance probability (percentile) plots have also been generated for all model simulations for the key storages including the mine pits and the main dams. These plots (Figure 17 a,b,c) illustrate the percentage of time a particular storage is equaled or exceeded over the 18 years term of modelling and provide a useful risk profile.

Model simulations indicate the following:

- North and West pits are maintained in a generally dewatered state 95% of the time for a modelled pit pumping capacity of 15 ML/day (170 L/s) continuous operation in each pit area (Figure 17a). During the remaining 5% of the time, storage could rise above 200 ML if the more extreme rainfall periods are encountered like the third quarters in 1930 and 1950. Increased pumping capacity would reduce the risk of impairing workability but additional storage would be required to contain pumped water.
- Total mine storage is mostly below 1000 ML as indicated on Figure 17b lower plot. For the remaining time the storage rises to a predicted maximum of between 1200 ML and 2500 ML depending upon the rainfall received. A median response of 1600 ML is shown.
- The 500 ML Discharge Dam (Figure 17b upper plot) is predicted to be less than half full for 50% of the time. This is attributed to an aggressive HRSTS discharge regime where all flood and high flow opportunities are utilised with high flow discharges ranging from zero to a maximum of 70 ML/day depending upon the available storage in the Discharge Dam.

- The Main Water Storage Dam is at capacity for 60 to 80% of the time (Figure 17c) with a possibility of storage exhaustion up to 7% of the time. Make up water would need to be drawn from the MTO, HVO during these times. A maximum rate of 5 ML/day is calculated.

While the above provides predicted outcomes based on model parameters, in reality it is likely that some HRSTS discharge events will not be utilised, pumps may fail or Discharge Dam water quality may rise and reduce the high flow discharge rate in terms of salt tonnes exported from site. As a result it is likely that pit water storage may rise and be retained for longer periods. Additional HRSTS salinity credits may then need to be obtained to boost high flow discharge rates and recover system balance. Since Coal and Allied retain more than 200 credits, sufficient flexibility should be available to counter imbalances.

7. POTENTIAL ENVIRONMENTAL IMPACTS

The proposed extension of mining at Warkworth Mine will continue to induce change to the local groundwater and surface water environments. Potential impacts arising from the development will include:

- Continuing loss of coal measures aquifer pressures
- Change in groundwater quality in coal measures and alluvial lands
- Leakage of shallow groundwater from the Hunter River and Wollombi Brook alluvium
- Change in runoff in local watersheds
- Change in surface water quality
- Salinisation in the final voids following cessation of mining

7.1 Loss of coal measures aquifer pressures

Future mining will continue to induce loss of aquifer pressures in the seams and in formations overlying the seams with pressure losses predicted to continue post mining for a period of more than 100 years. Coal measures pressures will never recover to pre mining levels since the area of mine development (including neighbouring mines), now retains different hydraulic properties with spoils permeability being 2 to 3 orders of magnitude higher than undisturbed coal measures. The net effect of changed properties will be a relatively flat water table over the mined area at a maximum elevation of about 45 mAHD. Since the area of extended mining is located at the headwaters of a number of catchments, the overall impact is not considered to be significant.

Depressurisation of the coal measures and depressurisation impacts are predicted to extend no further than about 2 to 3 kilometres from the proposed pit perimeters over the remaining mine life. This distance will extend to, and possibly beneath Wollombi Brook.

Loss of aquifer pressures is not predicted to impact any existing water supply bores or wells within the coal measures since most are located within shallow alluvium.

7.2 Change in groundwater quality

Groundwater within the coal measures west of the mine site is highly saline with salinity levels often observed to be above 15000EC. These elevated salinities are atypical for the upper Hunter and reflect discrete coal seams within which the monitoring piezometers have been located.

Pit water qualities reflect a lower range from less than 4000 to 6500 EC suggesting mixing of improved quality coal measures water and rainfall runoff. Continued mining will sustain regional depressurisation and may lead to aquifer/aquitard leakage with some change and possible improvement in groundwater quality. However it is highly improbable that coal measures groundwaters will exhibit a fall in salinity to the point where beneficial usage is increased.

7.3 Leakage from the alluvial lands

Coal measures pressure losses will migrate further westward towards Wollombi Brook leading to an increased hydraulic gradient between the brook an North pit. Leakage is predicted to have commenced in about 1997 from alluvial areas near and including Wollombi Brook. However the leakage rate is calculated to be very low and less than 0.015 ML/day over an area of more than 2.4 sq. km. (0.006 litres per sq.m. per day). This estimate is also subject to possible interference pressures generated by Wambo, HVO (South Lemington) and MTO mine. The leakage rate is predicted to increase to a maximum of about 0.24 ML/day assuming hydraulic connection between strata vertically beneath Wollombi Brook is present. The long term rate is likely to remain very low and when distributed over the approximate zone of depressurisation, calculates to 0.1 L per sq.m. per day.

Leakage from the area east of current mining is also predicted to increase from about year 10 of the extended mining period rising to 0.36 ML/day at the end of mining. This eastern region comprises a much larger area of alluvial lands than the western area. A leakage rate of about 0.037 L per sq.m. per day is calculated over an area of 9.9 sq.km.

7.4 Loss of catchment runoff

There will be a continuing loss of runoff in local catchments as they are consumed by the mine pit. The main drainages impacted include Sandy Hollow Creek, Dights Creek and Doctors Creek. However rehabilitation of areas in the eastern part of the mine site will re-instate runoff to these same drainages with a net increase in catchment runoff. A part of Longford Creek catchment (13.6%) and another un-named creek (4.6%) will also be consumed. Loss of runoff is considered unlikely to impact these catchments.

7.5 Change in runoff water quality

Runoff water quality in rehabilitated areas draining to Sandy Hollow, Dights and Doctors Creeks is likely to exhibit a reduced salt load in the longer term compared to other local drainages and historical measurements in Doctors Creek. This is mostly attributed to the removal of regional aquifer pressures within the coal measures. All areas planned to be returned to the natural catchment will need to be carefully monitored at the sedimentation dam exit points during early years of rehabilitation to ensure water qualities (suspended and dissolved constituents) are acceptable.

7.6 Final void

An open pit (free water) void will remain on completion of mining. Depending upon the final closure plan, the void will exhibit a salinity higher than existing pit water due to leaching of salts from spoils, and evaporative processes. Some cyclic variability is predicted as runoff from adjacent rehabilitated areas dilutes salinity and evaporation concentrates salinity. The extent to which catchment runoff is directed to the voids, will be determined through runoff monitoring during the last 7 years of the mine life and detailed design during closure planning.

For the current void design, the leachable salt load (over 100 years) is estimated at 8.4 x 10^5 tonnes generating a minimum void water quality of 4667 mg/l (7180EC) before any evaporative concentration is included. Inclusion of evaporation will significantly escalate the salinity of void water in the long term. The runoff area contributing to the void is calculated to be sufficiently small to ensure that evaporation dominates and the void remains as a long term groundwater sink thereby preventing advective dispersion of salinity back into the coal measures.

8. DLWC LICENSING REQUIREMENTS

Licensing of certain aspects of the mining operations is normally required under Part 2 and Part 5 of the Water Act, and the Water Management Act.

8.1 Part 2 (Water Act) Licensing – surface water facilities

The existing mine infrastructure will be used for future operations. Current infrastructure relating to management of surface water runoff, erosion and sedimentation controls is either licensed or does not require licensing. Since future operations do not provide for harvesting of runoff or conveyance of runoff between catchments beyond that already approved, licensing is not likely to be required. However should water management plans change in the future, then applications should be made where appropriate.

8.2 Part 5 (Water Act) Licensing – groundwater seepage

Licensing relating to groundwater seepage to the mine pit may be required under Part 5 of the Water Act if pumped water has a beneficial use. Separate borehole licenses will need to be sought/maintained for any future observation piezometers.

9. WATER RESOURCES MONITORING

Groundwaters and surface waters are currently monitored at Warkworth Mine by the Coal and Allied environmental services group or their appointed sub contractors. Monitoring sites include boreholes, dams, key surface drainages and elements of the mine water management system as shown on Figure 18. Additional piezometers are recommended for continued monitoring of depressurisation and water quality in areas west of the proposed extension. These locations are also indicated on Figure 18 as PZ1 to PZ6. They are preliminary and subject to more detailed ground survey and future verification of depressurisation at existing piezometers.

A comprehensive surface and groundwater monitoring programme must be maintained as part of the overall mine environmental monitoring. The programme should include current monitoring activities incorporating dams and drainages, groundwater monitoring bores and overall mine water management through real time monitoring. All data should be reviewed regularly as part of compliance procedures and alert protocols.

Water management monitoring should continue to include:

- weather monitoring - rainfall, evaporation, wind etc.

- measurement of water levels and water quality (EC, pH, ionic speciation and other parameters) within the existing network of monitoring bores and at additional monitoring bores that may be constructed in the future;
- measurement of water levels and water quality (EC, pH, TSS and other parameters) within the mine water system;
- maintenance of the transfer protocol to convey data from the mine to DLWC in compliance with the trading scheme;
- annual reporting as part of licensing conditions.

In addition to the above and as part of overall quality procedures, the monitoring programme will be subject to review annually by Warkworth Mine or Coal and Allied environmental services group and/or their appointed consultants.

10. CONCLUSIONS

Water management studies have been conducted for continued mining at Warkworth Mine. The studies have addressed groundwater and surface water issues together with an analysis of the mine water management. Within the constraints and limitations imposed by the available data base and analytical methods, the following conclusions can be drawn.

In respect of groundwater studies it is concluded that continued mining will result in ongoing groundwater seepage to the North and West pits with an increasing contribution occurring as leakage from the surrounding undisturbed coal measures. Leakage may also occur and increase from shallow alluvial areas associated with Wollombi Brook and the Hunter River providing joint connectivity prevails throughout the strata to facilitate such leakage.

Pit water seepage will increase from a current estimated rate of about 0.64 ML/day to a rate of about 4.2 ML/day after 18 years. The water quality will reflect a mixture of coal seams and interburden with a salinity most probably similar to that observed in the current mine water system and ranging from 4000 to more than 6500 EC. Potentially higher salinities will be evident when contributions from certain seams, are intercepted. Seams to the west of the present operations exhibit salinities as high as 18000 EC.

Loss of formation aquifer pressures will influence areas several kilometres from the mine pit and the final void. Existing water supply boreholes or wells have not been identified within the zone of significant depressurisation. Bores and wells located within the alluvial lands near Wollombi Brook and the Hunter River will not be affected.

Pit water will accumulate and water levels will recover in the final voids if mining ceases after year 18. A period of more than 100 years is predicted for an equilibrated system to re-establish based on groundwater seepage alone. However the period will be shortened by runoff contributions from surrounding landforms. Water levels will never fully recover due to changed conditions within the coal measures where relatively permeable spoils have replaced impermeable coal measures. Instead the recovered water table elevation will ultimately be governed by evaporative processes. Current estimates based on final void preliminary design support a sustained evaporative sink with an equilibrated level below 45 mAHD. Spoils re-saturation within the void will result in an initial void water quality estimated to range from 4667 to 7559 mg/l rising in the long term to high salinity through evaporative concentration. Because the void will act as a sink or groundwater attractor, advective dispersion of void salinity into regional areas is unlikely.

In respect of surface water, clean water runoff will continue to be segregated from mine water via the maintenance of contour drains, the diversion channel between Sandy Hollow and Longford creeks, sedimentation and mine water dams. Continued mining will have negligible impact on local and regional watersheds. Parts of Sandy Hollow, Dights and Doctors Ck catchments previously consumed by mining will be rehabilitated and natural runoff returned to these creeks in eastern and north eastern areas.

The continued mining to greater depths will attract more groundwater into the mine water system than is currently managed. This increase will be offset in part by a reduction in runoff from areas scheduled for rehabilitation. However system modelling indicates the likelihood of surplus water that will need to be removed from site. Testing of the mine water system against 100 years of daily rainfall records indicates surpluses can be managed providing most HRSTS high and flood flow discharge opportunities arising in the future, are utilised.

Water sharing between Warkworth Mine, MTO, HVO and Mount Thorley Coal Loader will maximise the potential for the use of recycled water.

Mackie Environmental Research
July 2002

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IMPORTANT INFORMATION ABOUT YOUR HYDROLOGICAL REPORT

Third party data

The science of hydrology including groundwater and surface water hydrology, is based upon analysis of historical data and prediction using various analytical tools. Often historical data is sought from various sources including clients of Mackie Environmental Research (MER), Government data repositories, public domain reports and various scientific and engineering journals. While these sources are generally acknowledged within the report, the overall accuracy of such data cannot be established. Indeed some Government agencies specifically require indemnification before providing data. MER conducts certain checks and balances and employs advanced data processing techniques to establish broad data integrity where uncertainty is suspected. However the application of these techniques does not negate the possibility that errors may be carried through the analytical process. MER does not accept responsibility for such errors.

Discrete sampling

It is important to note that in the earth sciences more so than most other sciences, conclusions are invariably drawn from limited sampling and testing eg. drilling of exploration and test boreholes, flow monitoring, water quality sampling and other types of data gathering. While conditions may be established at discrete locations, there is no guarantee that these conditions prevail over a wider area. Indeed it is not uncommon for some measured geo-hydrological properties to vary by orders of magnitude over relatively short distances. In order to utilize discrete data and render an opinion about the overall surface or subsurface conditions, it is necessary to apply certain statistical measures and other tools that support scientific inference like analytical or numerical computer modelling techniques. Since these methods require some simplification of the systems being studied, results should be viewed accordingly. Importantly, predictions made may exhibit increasing uncertainty with longer prediction intervals. Verification therefore becomes an important post analytical procedure.

0 1000 2000 3000 Metres

Scale 1:50000 Base map information from 1:25,000 topo series (Central Mapping)
Additional data supplied by Warkworth Mine

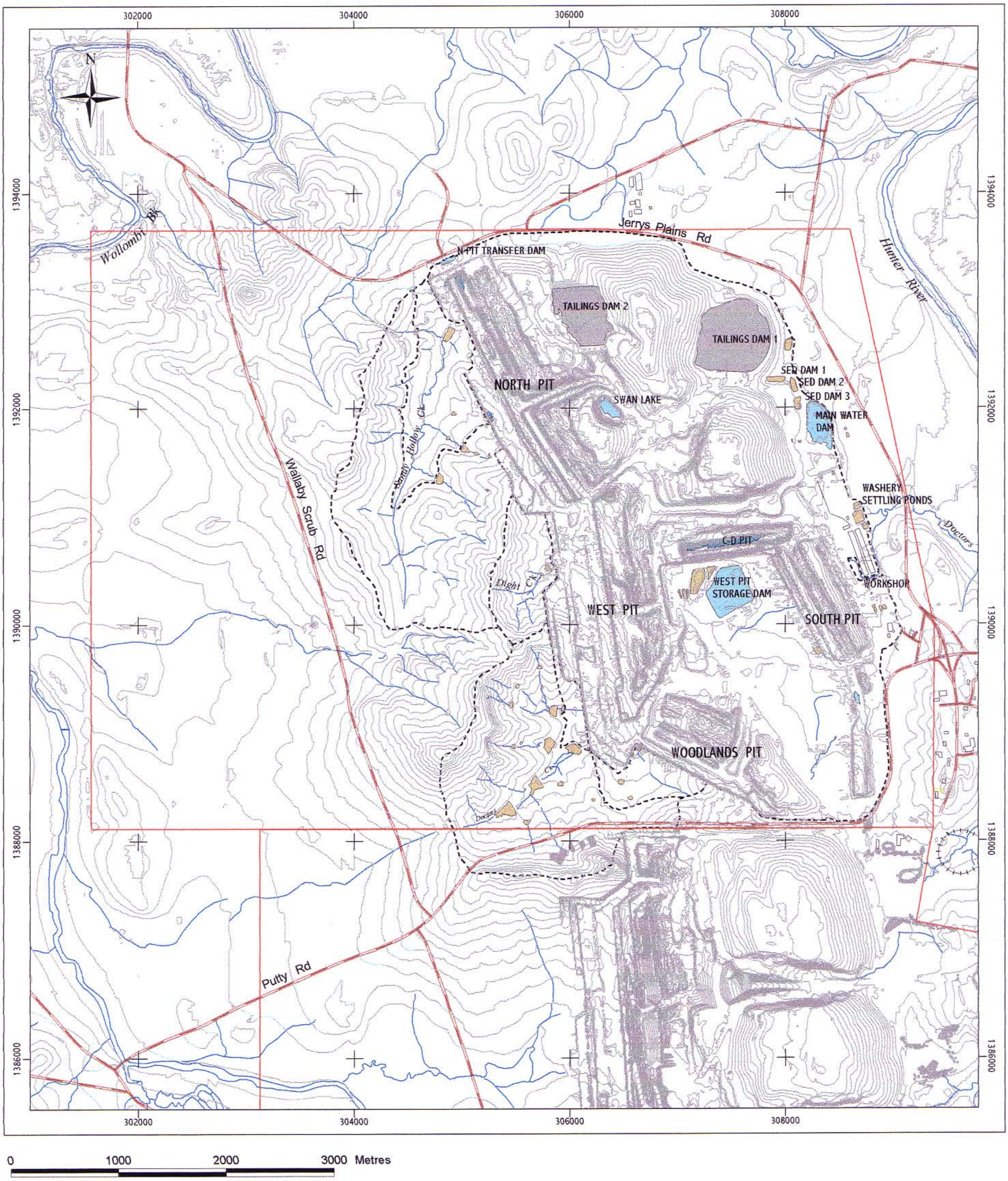
- creeks
- dirt roads
- sealed road
- main road
- railway
- mine lease
- main watersheds affected by mining

WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

General site layout and hydrological elements

Mackie Environmental Research

Figure 1



Scale 1:50000 Base map information from 1:25,000 topo series (Central Mapping)
Additional data supplied by Warkworth Mine

- creeks
- dirt roads
- sealed road
- main road
- railway
- mine lease
- main watersheds affected by mining

WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

Local topography and hydrological elements

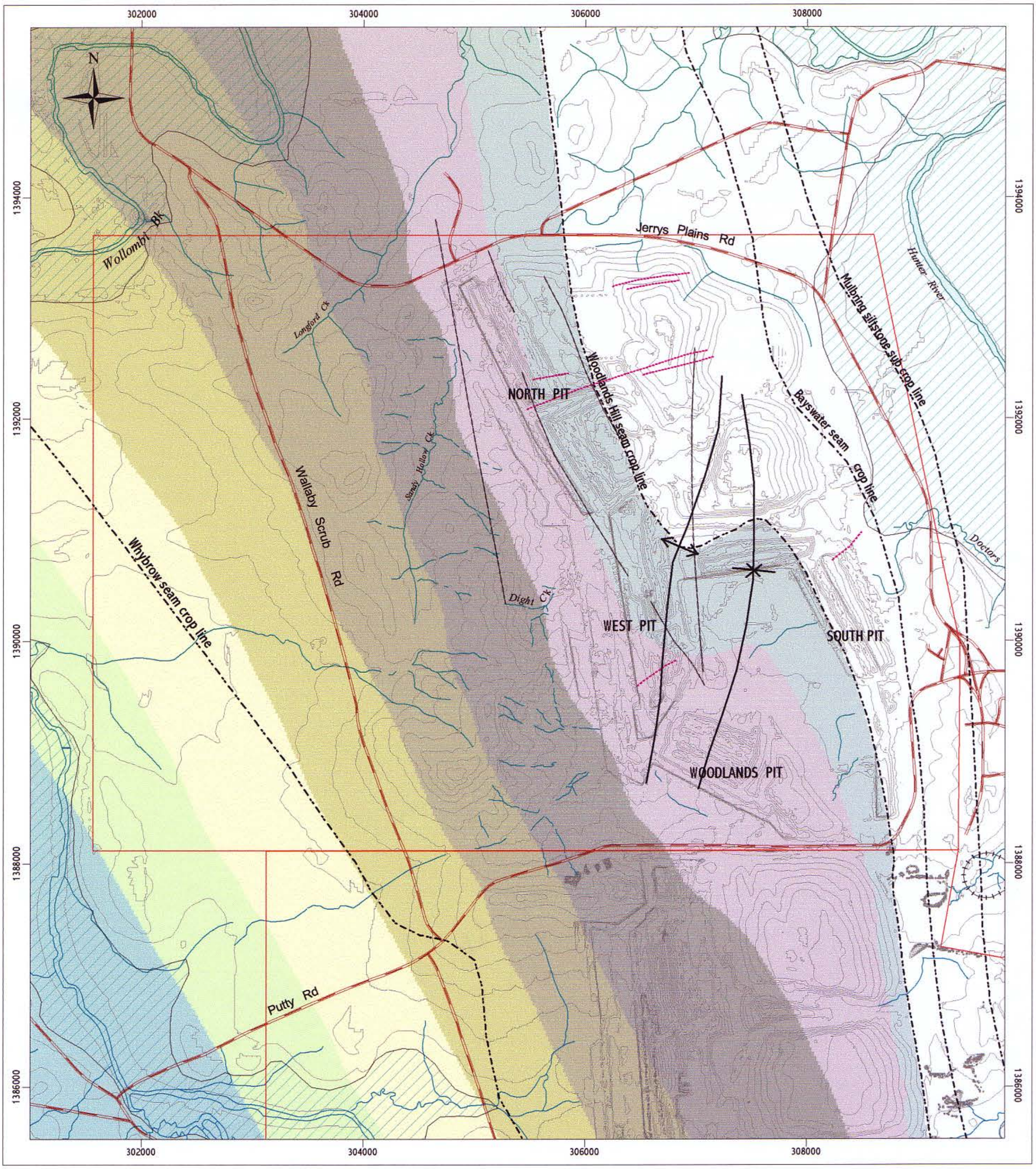
Mackie Environmental Research

Figure 2

STRATIGRAPHY OF THE SINGLETON SUPER GROUP

SINGLETON SUPER GROUP	WOLLOMBI COAL MEASURES		GRIEGS CREEK COAL	GRIEGS CREEK SEAM	coal
		GLEN GALLIC SUBGROUP	REDMANVALE CK FORMATION		conglomerate
			DIGHTS CREEK COAL	HILLSDALE COAL MBR	coal
				NALLEEN TUFF	tuffaceous sandstone
				HOBDEN GULLY COAL MBR	coal
		DOYLES CREEK SUBGROUP	WATERFALL GULLY FORMATION		sandstone, siltstone, claystone
			HAMBLETON HILL SANDSTONE		sandstone, siltstone
			PINEGROVE FORMATION	WYLIES FLAT COAL MBR	coal inc. splits
			GLENROWAN SHALE		shale, claystone
		HORSHOE CREEK SUBGROUP	LUCERNIA COAL	EYRIEBOWER COAL MBR	coal seams
				LONGFORD CREEK SILSTONE	siltstone
				ROMBO COAL MBR	coal seams
				HILLSDALE CLAYSTONE	claystone
				CARRAMERE COAL MBR	coal seams
			STRATHMORE FORMATION		predominantly siltstone
			ALCHERINGA COAL	ALCHERINGA SEAM	thin coal seams
			CLIFFORD FORMATION		sandstone, minor claystone
		APPLE TREE FLAT SUBGROUP	CHARLTON FORMATION	STAFFORD COAL MBR	coal inc. splits
			MONKEY PLACE CK TUFF		tuffaceous sandstone, siltstone
			ABBEY GREEN COAL	ABBEY GREEN SEAM	coal inc. splits
			WATTS SANDSTONE		sandstone, minor congl. marker
	WITTINGHAM COAL MEASURES		DENMAN FORMATION		sandstone, siltstone, laminite
		JERRYS PLAINS SUBGROUP	MOUNT LEONARD FORMATION	WHYBROW SEAM	coal inc. splits
			ALTHORP FORMATION		claystone
			MALABAR FORMATION	REDBANK CREEK SEAM	coal inc. splits
				WAMBO SEAM	coal inc. splits
				WHYNOT SEAM	coal inc. splits
				BLAKEFIELD SEAM	coal inc. splits
				SAXONVALE MBR	coal inc. splits
			MOUNT OGILVIE FORMATION	GLEN MUNRO SEAM	coal inc. splits
				WOODLANDS HILL SEAM	coal inc. splits
			MILBRODALE FORMATION		claystone
			MOUNT THORLEY FORMATION	ARROWFIELD SEAM	coal inc. splits
				BOWFIELD SEAM	coal inc. splits
				WARKWORTH SEAM	coal inc. splits
			FAIRFORD FORMATION		claystone
			BURNAMWOOD FORMATION	MT. ARTHUR SEAM	coal inc. splits
				PIERCEFIELD SEAM	coal inc. splits
				VAUX SEAM	coal inc. splits
				BROONIE SEAM	coal inc. splits
				BAYSWATER SEAM	marker seam
			ARCHERFIELD SANDSTONE		lithic sandstone – marker bed
		VANE SUBGROUP	BULGA FORMATION		sandstone, siltstone, laminite
			FOYBROOK FORMATION	LEMINGTON SEAM	coal inc. splits
				PIKES GULLY SEAM	coal inc. splits
				ARTIES SEAM	coal inc. splits
				LIDDELL SEAM	coal inc. splits
				BARRETT SEAM	coal inc. splits
				HEBDEN SEAM	coal inc. splits
			SALTWATER CREEK FORMATION		sandstone, siltstone, laminite
MAITLAND GROUP			MULBRING SILTSTONE		siltstone claystone
			MUREE SANDSTONE		sandstone, siltstone, congl.
			BRANXTON FORMATION		sandstone, siltstone, congl.

Figure 3



0 900 1800 2700 Metres

Scale 1:50000 Base map information from 1:25,000 topo series (Central Mapping)
Additional data supplied by Warkworth Mine

creeks	
dirt roads	
sealed road	
main road	
railway	
mine lease	
selected seam crop lines	
mapped faults	
mapped dykes	

Woodlands Hill floor (mAHD)

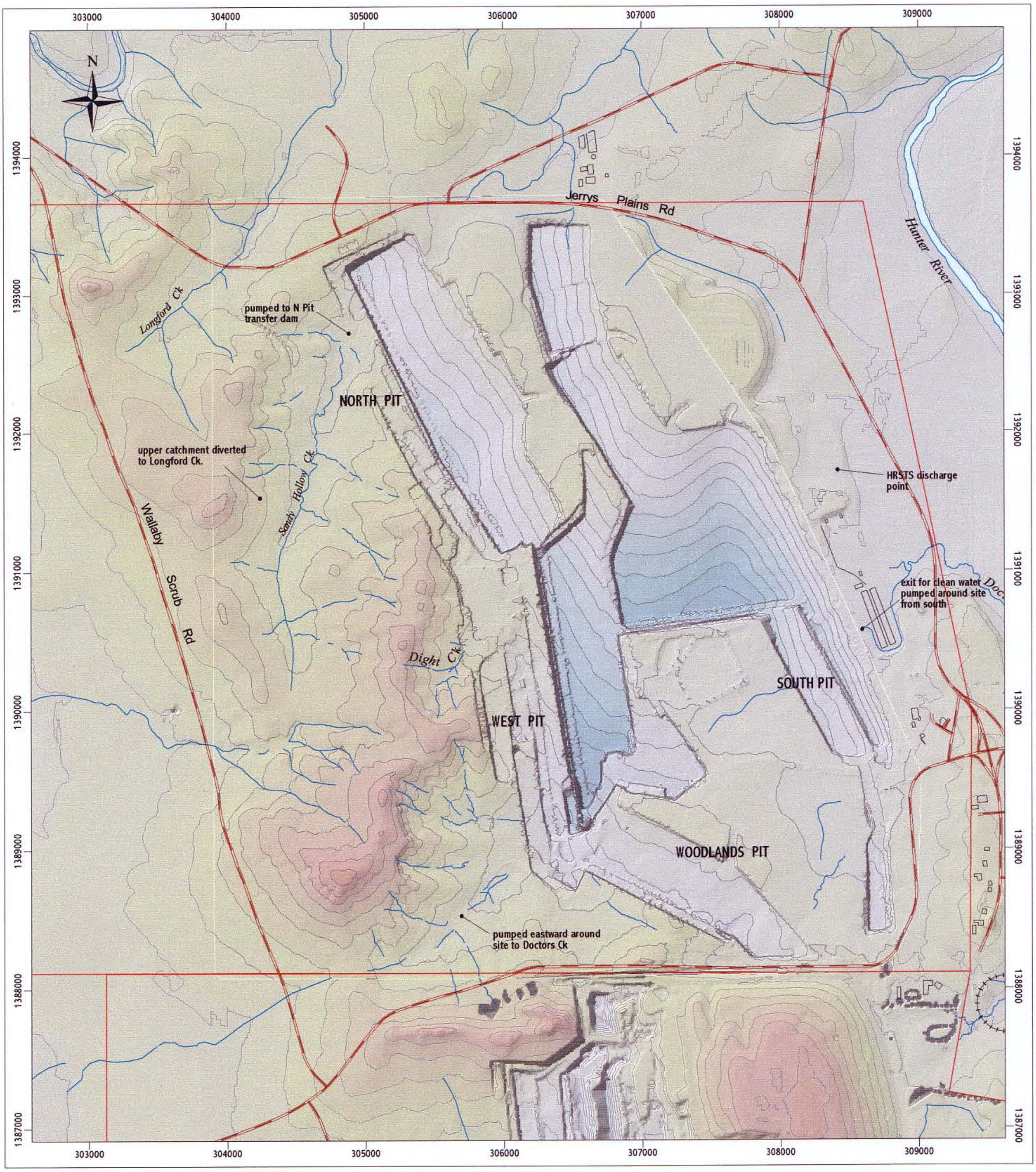
- -250- -200
- -200 - -150
- -150 - -100
- -100 - -50
- -50 - 0
- 0 - 50
- 50 - 100
- 100 - 150

WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

Regional geology

Mackie Environmental Research

Figure 4



see water management schematic for storage and pumping details

0 1000 2000 3000 Metres

Scale 1:40000 Base map information from 1:25,000 topo series (Central Mapping)
Additional data supplied by Warkworth Mine

-200 - -80	10 - 20	110 - 120
-80 - -70	20 - 30	120 - 130
-70 - -60	30 - 40	130 - 140
-60 - -50	40 - 50	140 - 150
-50 - -40	50 - 60	150 - 160
-40 - -30	60 - 70	160 - 170
-30 - -20	70 - 80	170 - 180
-20 - -10	80 - 90	180 - 190
-10 - 0	90 - 100	190 - 200
0 - 10	100 - 110	200 - 210

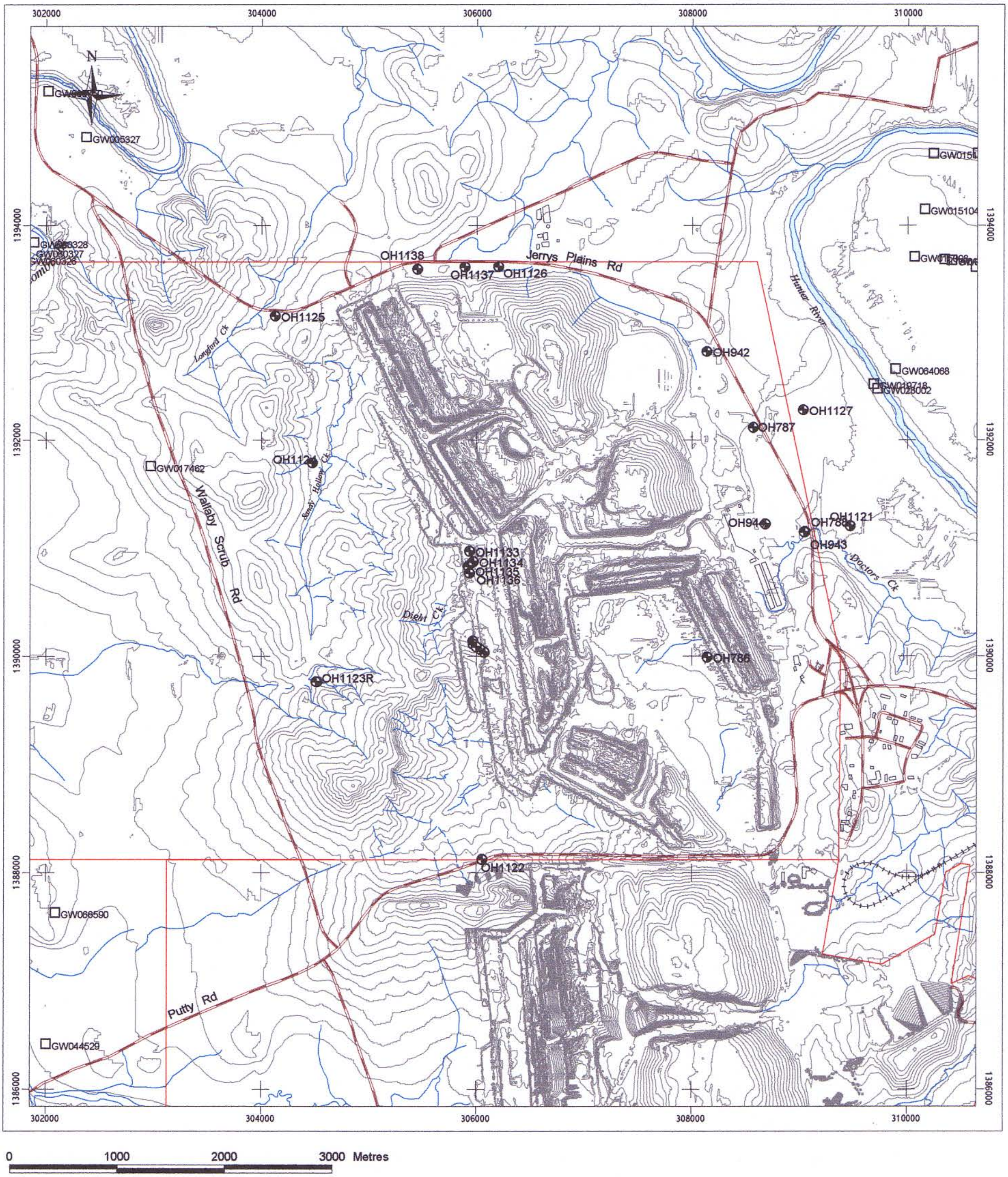
10m topo. contours
railway
major road
minor road
drainage

WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

Mine floor levels from commencement to 2002

Mackie Environmental Research

Figure 5



0 1000 2000 3000 Metres

Scale 1:50000 Base map information from 1:25,000 topo series (Central Mapping)
Additional data supplied by Warkworth Mine

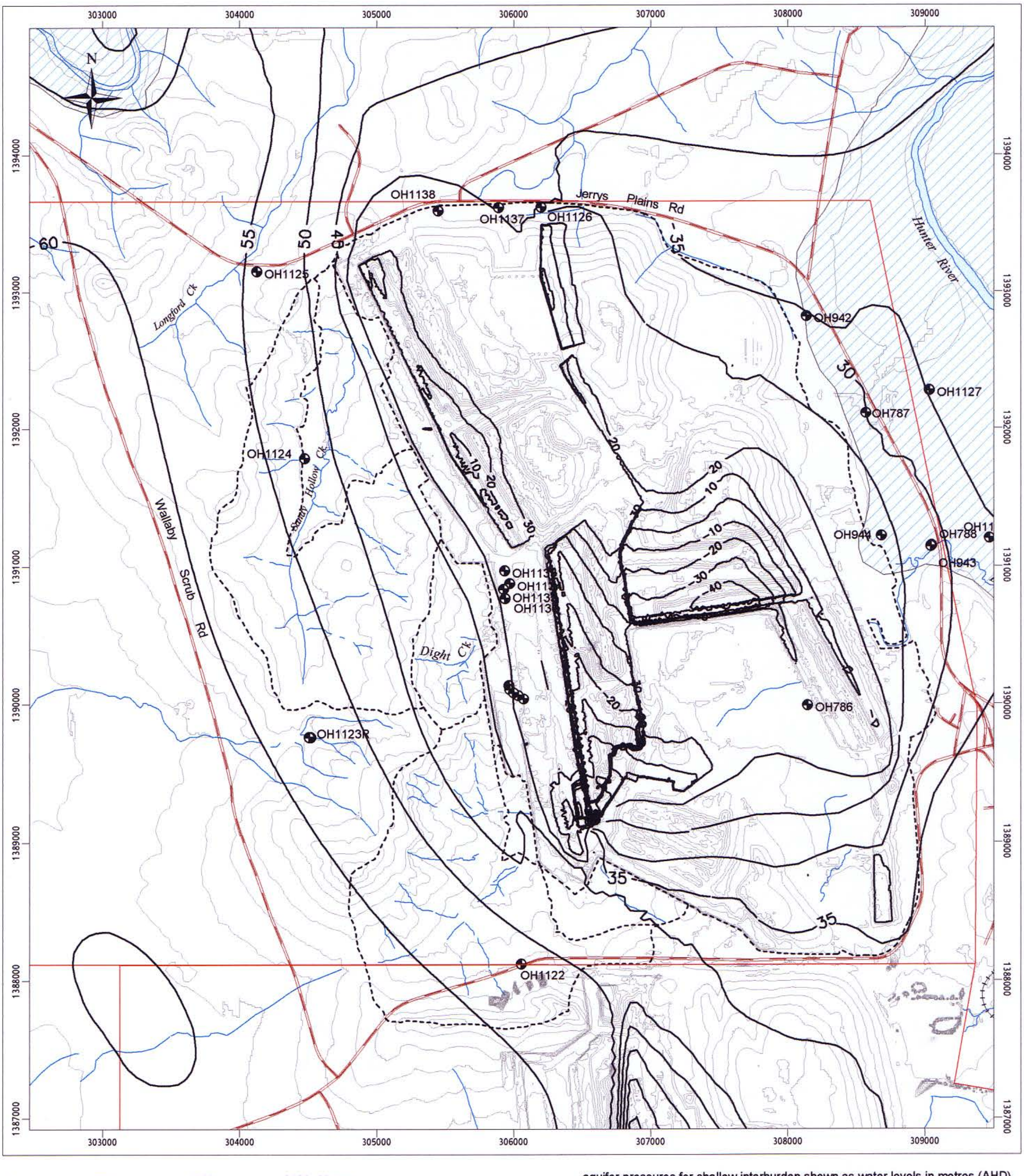
- creeks
- dirt roads
- sealed road
- main road
- railway
- mine lease
- DLWC registered well or bore
- mine piezometer locations

WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

Mine piezometer locations and DLWC registered wells/bores

Mackie Environmental Research

Figure 6



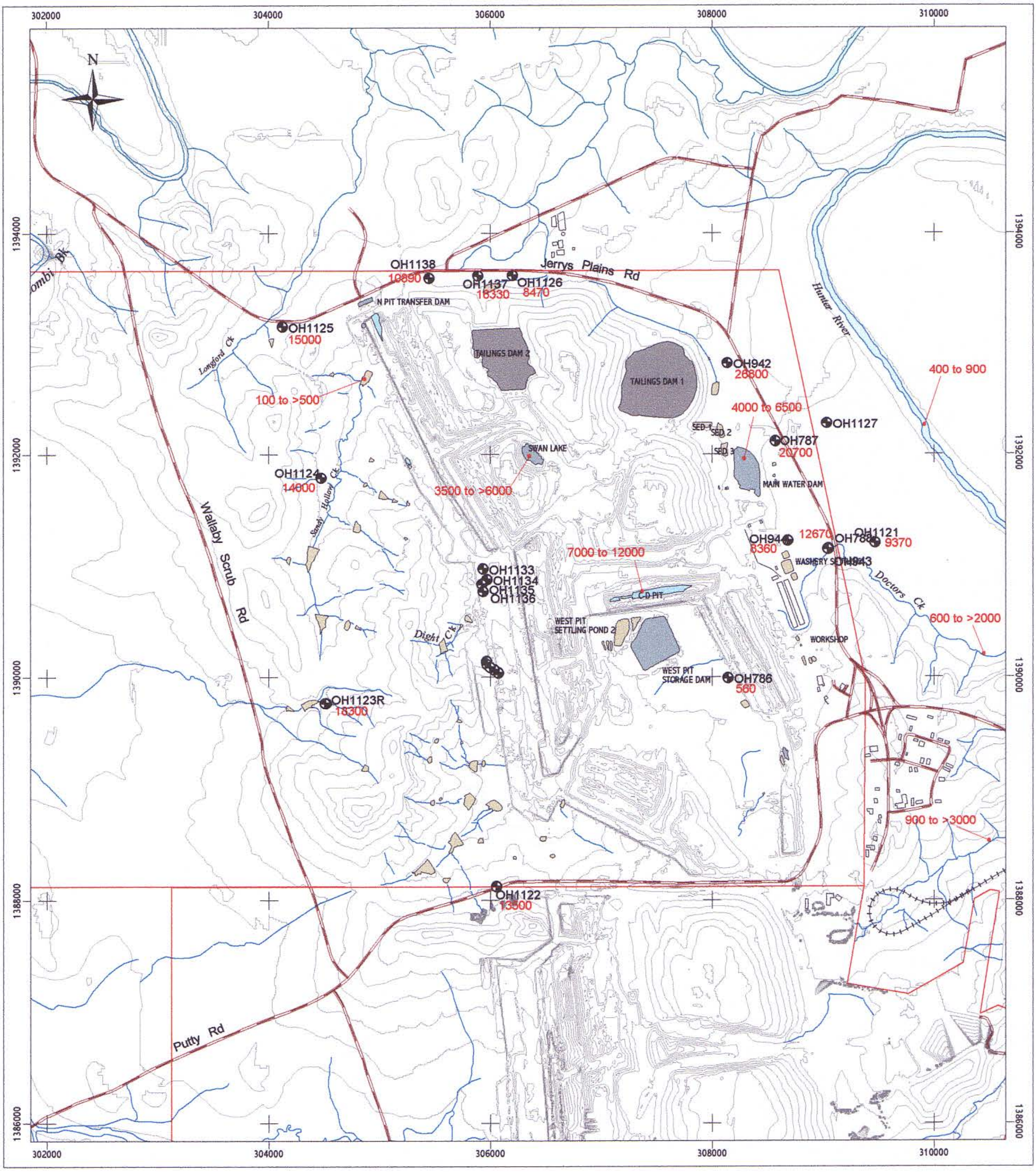
aquifer pressures for shallow interburden shown as water levels in metres (AHD)
(aquifer simulation model used to generate regional estimates)

Scale 1:40000 Base map information from 1:25,000 topo series (Central Mapping)
Additional data supplied by Warkworth Mine

- creeks
- dirt roads
- sealed road
- main road
- railway
- mine lease
- piezometer locations

WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

Regional aquifer pressures (shallow interburden)



0 1000 2000 3000 Metres

EC measurements from historical mine data

Scale 1:50000 Base map information from 1:25,000 topo series (Central Mapping)
Additional data supplied by Warkworth Mine

- creeks
- dirt roads
- sealed road
- main road
- railway
- mine lease
- mine piezometer locations (EC in uS/cm)

WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

Regional salinity (EC) measurements and provinces

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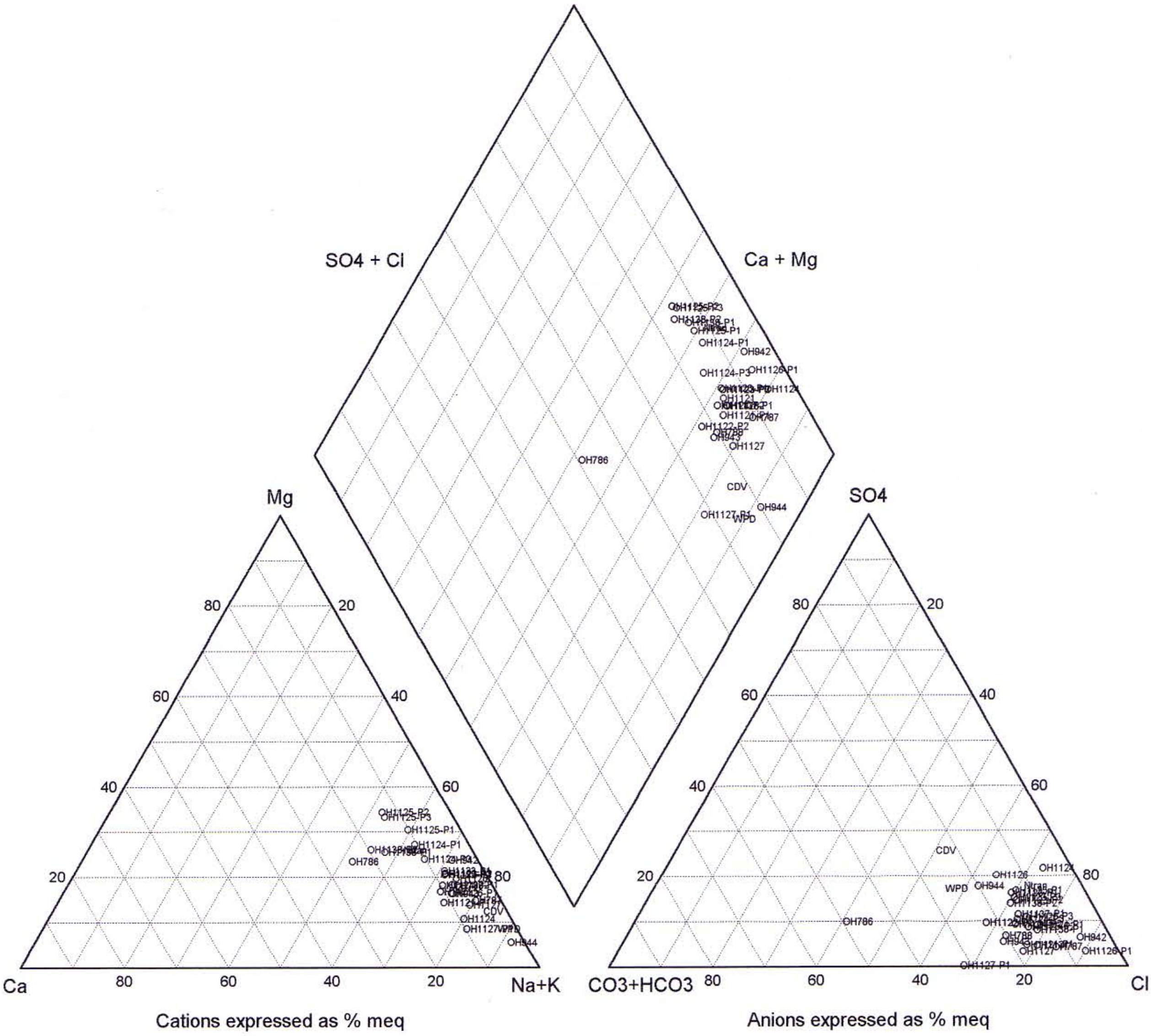
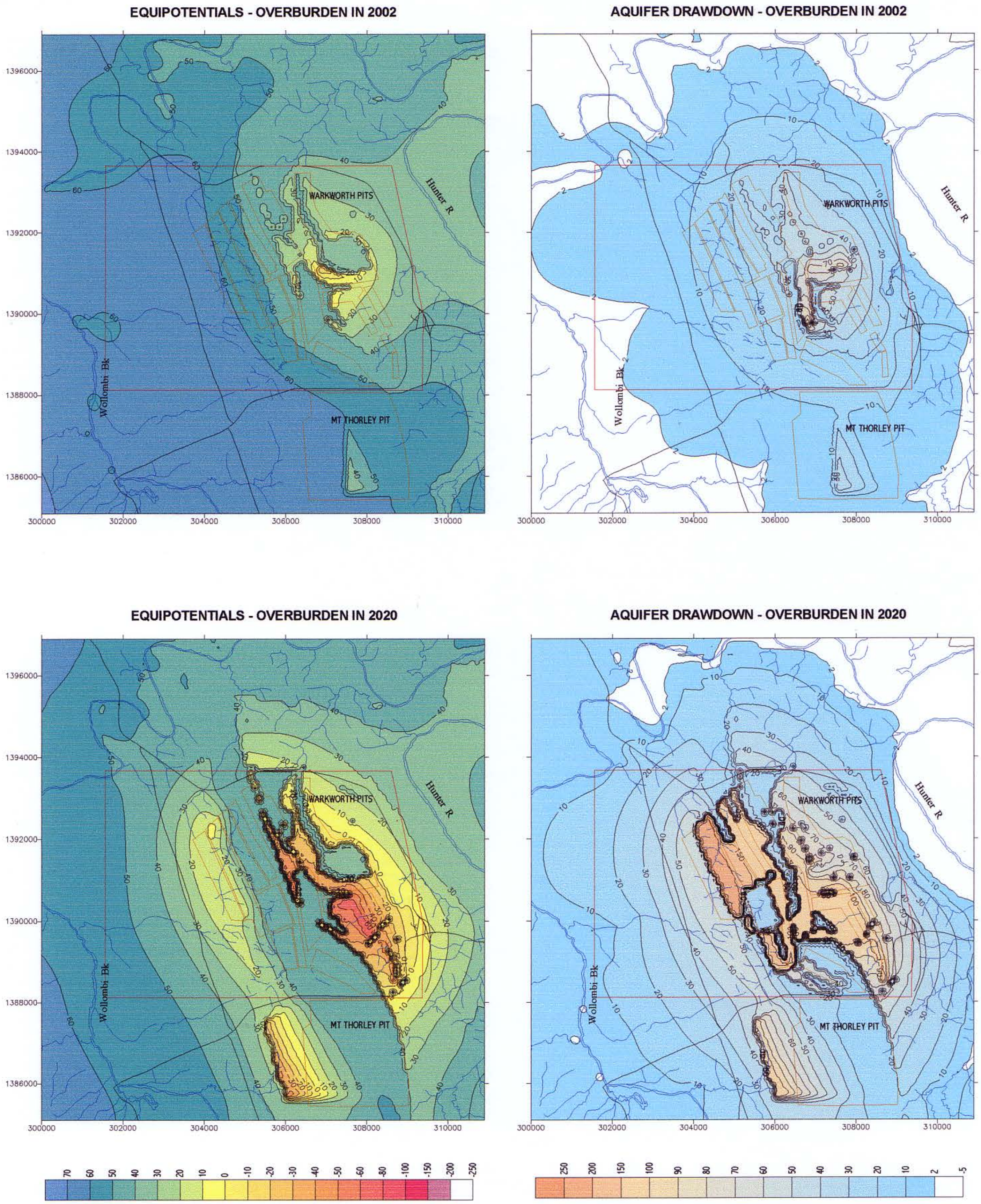
Figure 8



IONIC SPECIATION SUMMARY (milligrams per litre)

Sample	TDS	Ca	Mg	Na	K	CO3	HCO3	SO4	Cl
OH786	340	25	16	65	9		150	25	80
OH787	13810	110	360	3790	40		1230	440	6560
OH788	7900	120	280	2240	55		1410	420	3450
OH942	18590	170	860	5010	50		680	900	9350
OH943	4680	105	160	1430	20		840	190	1940
OH944	5130	7	60	1870	29		920	720	1940
OH1121	5620	150	190	1610	16		700	210	2720
OH1121-P1	5140	130	160	1650	17		670	200	2490
OH1122-P2	8410	110	350	2430	36		1570	650	3610
OH1123-P1	12050	150	560	3700	45		1270	1570	5300
OH1123-P2	12050	140	490	3360	38		1230	1400	5350
OH1123-P3	12050	150	520	3550	42		1265	1480	5400
OH1124	1550	25	25	360	9		50	300	770
OH1124-P1	11700	260	670	3080	55		1035	840	5640
OH1124-P2	8440	160	320	2540	31		1125	640	3950
OH1124-P3	8800	180	430	2360	28		1075	730	4050
OH1125-P1	12330	240	740	2910	32		1175	1710	5600
OH1125-P2	9520	270	620	1920	25		1035	670	4580
OH1125-P3	10535	300	660	2150	28		1070	930	4970
OH1126	6570	80	270	1980	38		840	1060	2620
OH1126-P1	4980	80	170	1540	25		780	900	18800

HYDROCHEMICAL FACIES DIAGRAM



Coal measures aquifer pressures (left hand plots) in metres (AHD)
Loss of pressure (right hand plots) in metres of water
Contouring based on 50 metre interpolation

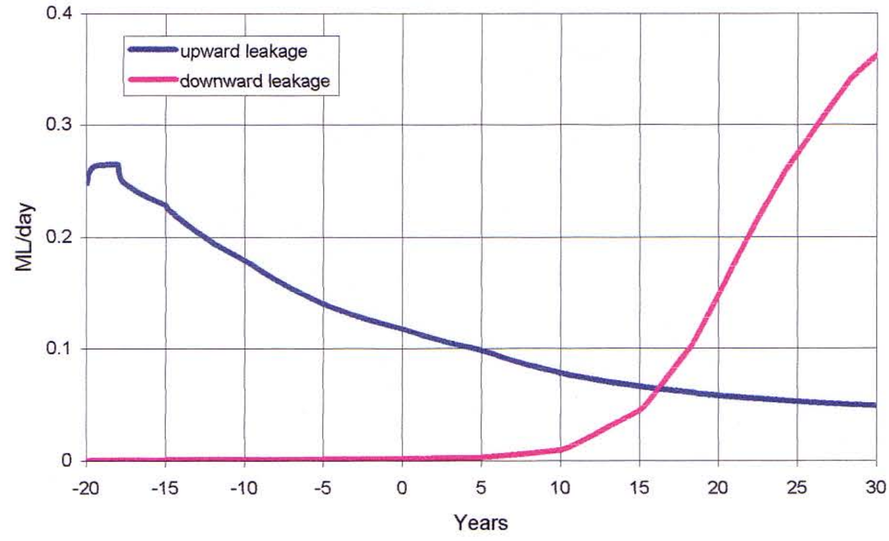
Scale 1:130,000

WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

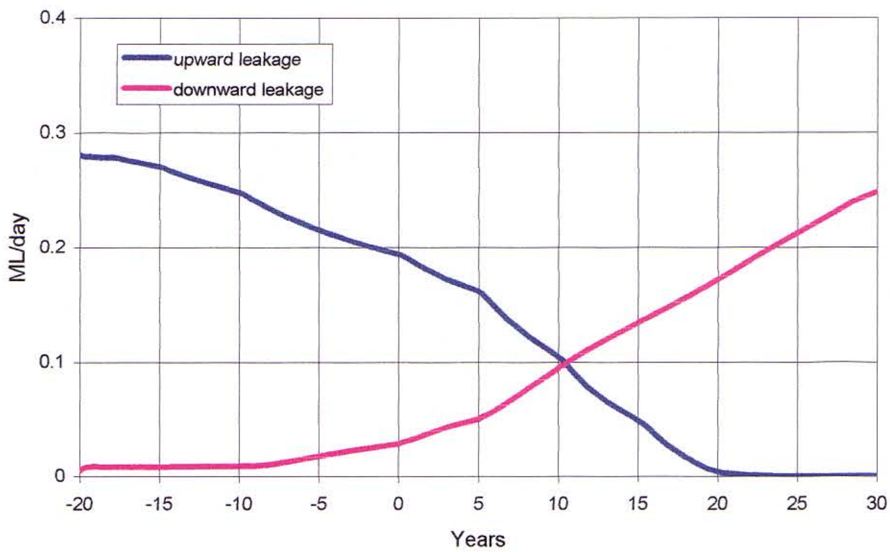
Coal measures depressurisation
Shallow overburden zone at 2002 and 2020

Figure 10

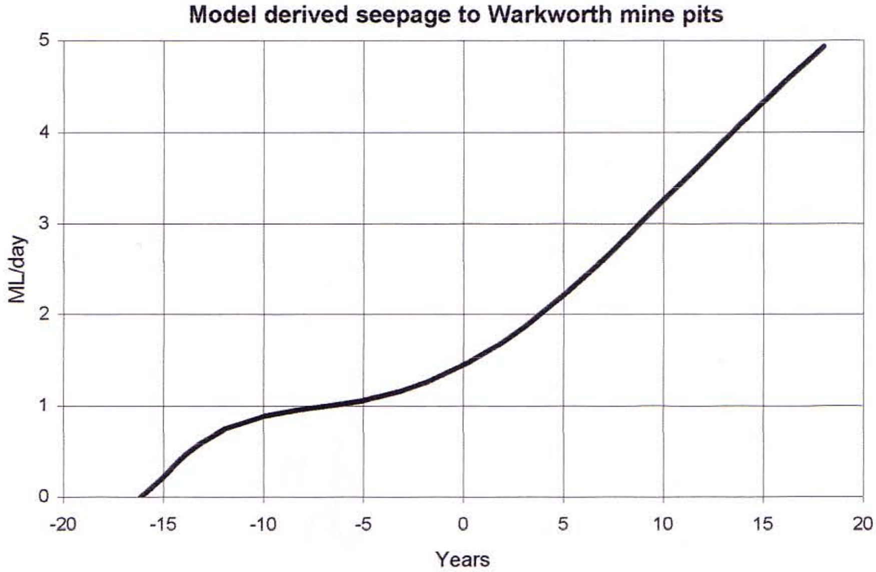
Model derived leakage to/from Hunter River alluvium



Model derived leakage to/from Wollombi Brook alluvium

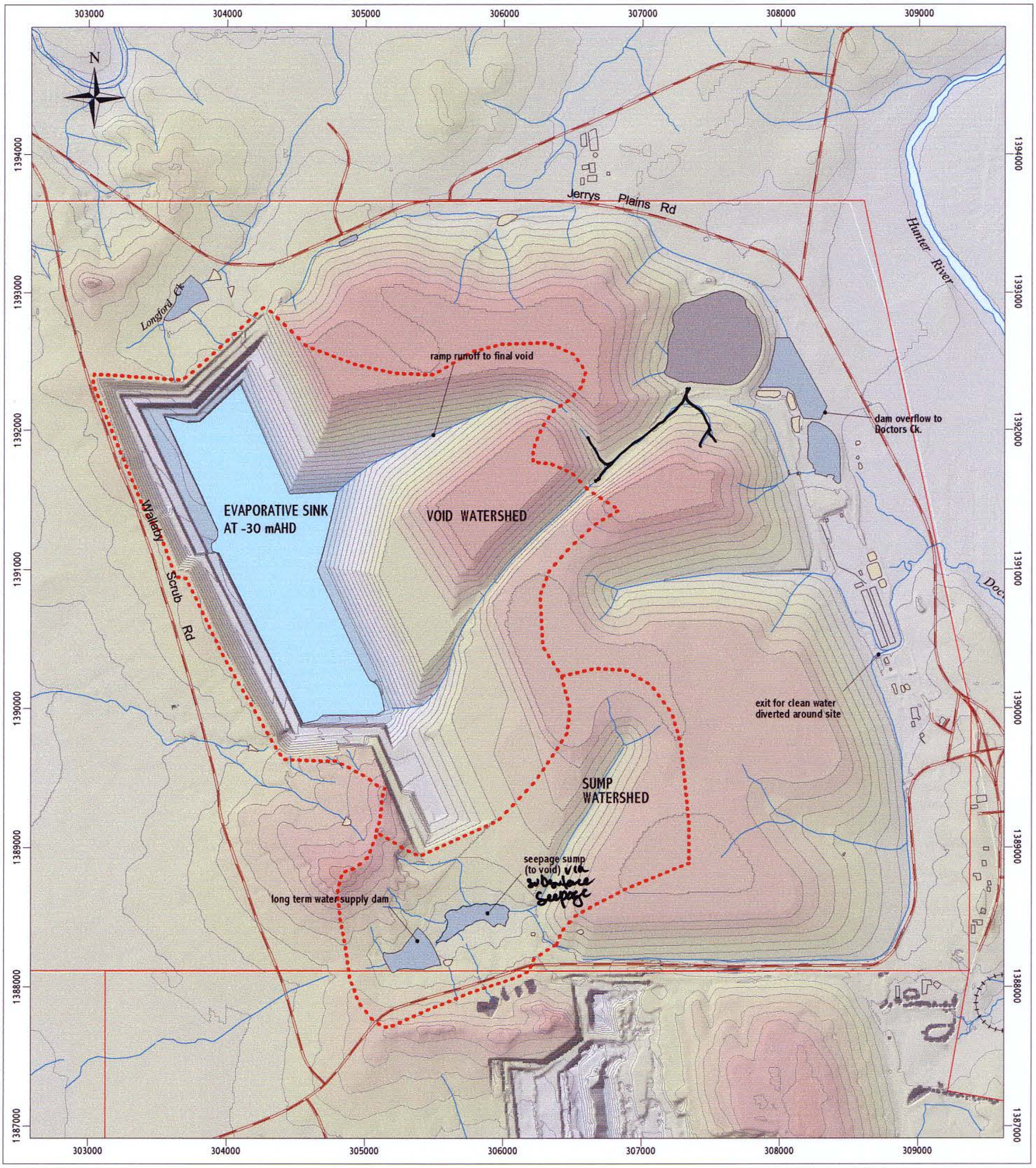


Model derived seepage to Warkworth mine pits



Leakage to/from alluvial lands and mine pit seepage generated by aquifer model

Figure 11



0 1000 2000 3000 Metres

see water management schematic for storage and pumping details

Scale 1:40000 Base map information from 1:25,000 topo series (Central Mapping)
Additional data supplied by Warkworth Mine

-200 - -80	10 - 20	110 - 120
-80 - -70	20 - 30	120 - 130
-70 - -60	30 - 40	130 - 140
-60 - -50	40 - 50	140 - 150
-50 - -40	50 - 60	150 - 160
-40 - -30	60 - 70	160 - 170
-30 - -20	70 - 80	170 - 180
-20 - -10	80 - 90	180 - 190
-10 - 0	90 - 100	190 - 200
0 - 10	100 - 110	200 - 210

- 10m topo. contours
- contour drain
- diversion drain
- railway
- major road
- minor road
- drainage
- pipeline
- watershed divide

- mine water
- sed. dam
- tailings
- void water

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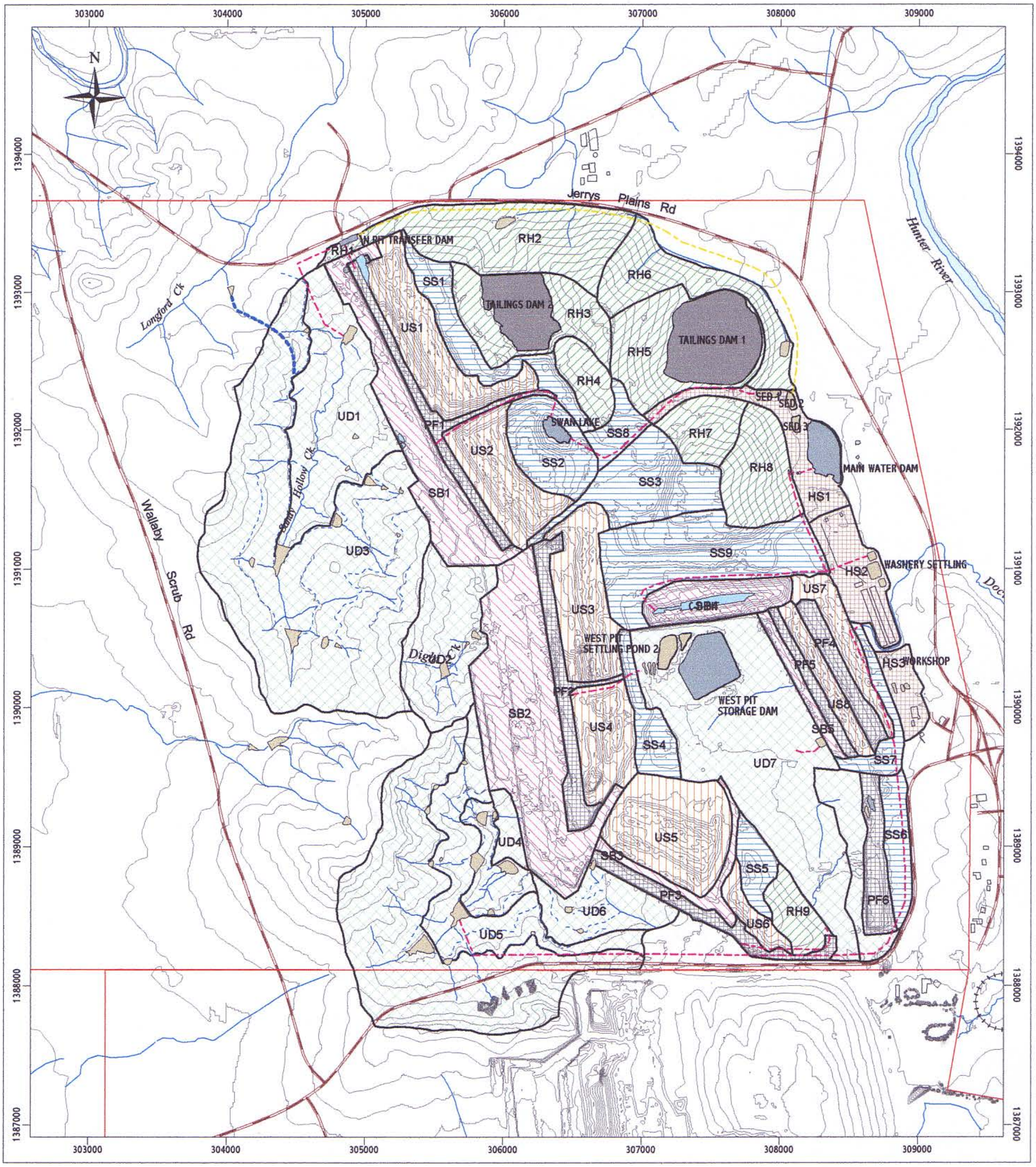
WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

Water management elements - final void

Figure 12



0 1000 2000 3000 Metres

Scale 1:40000 Base map information from 1:25,000 topo series (Central Mapping)
Additional data supplied by Warkworth Mine

see water management schematic for storage and pumping details

- 10m topo. contours
- contour drain
- diversion drain
- railway
- major road
- minor road
- drainage
- pipeline
- mine water
- sed. dam
- tailings
- void water
- hardstand
- pit floor
- rehabilitated
- strip and bench
- shaped spoils
- tailings
- undisturbed
- unshaped spoils

WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

Water management catchments at 0 years (2002)

Figure 13

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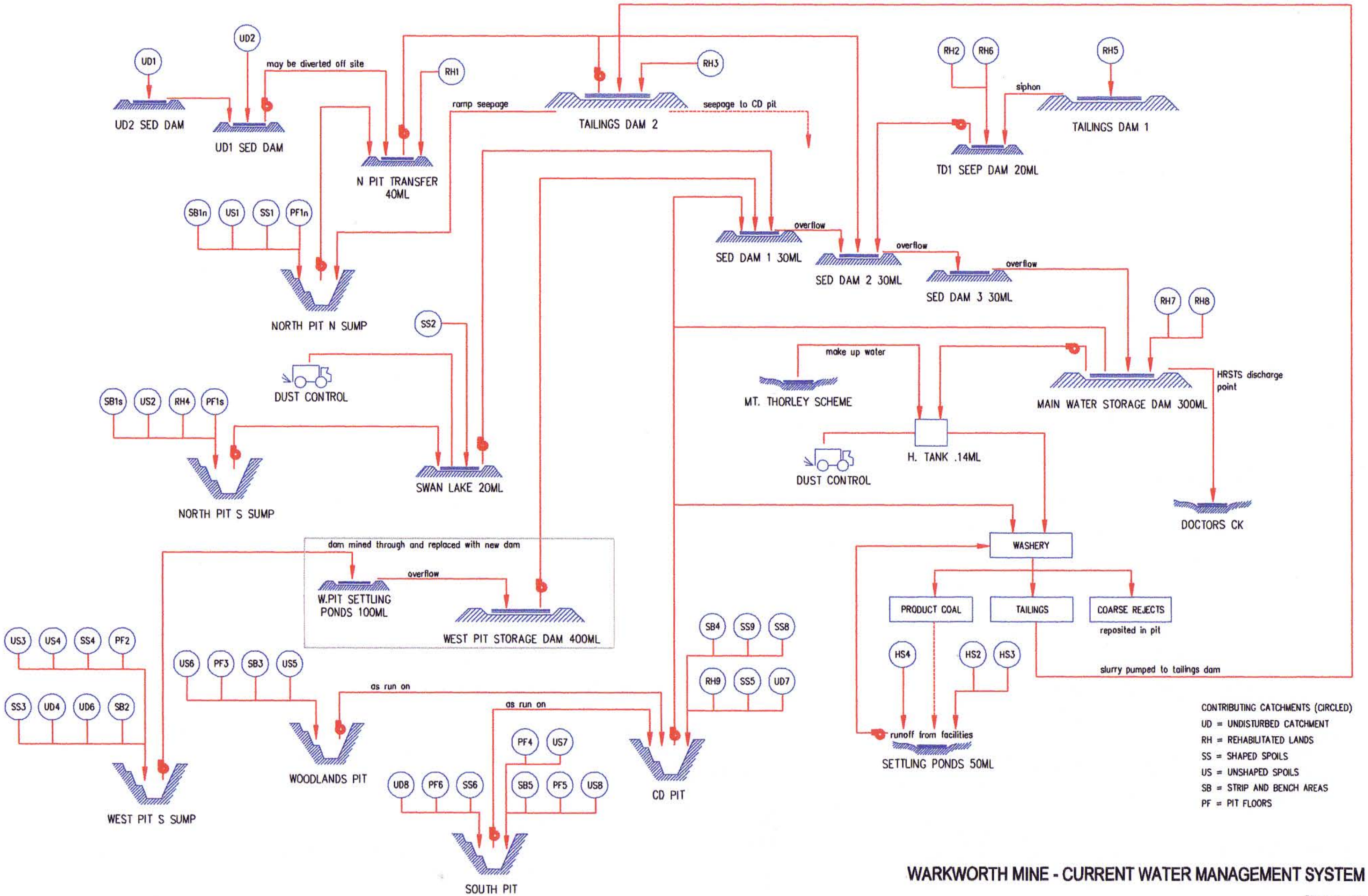
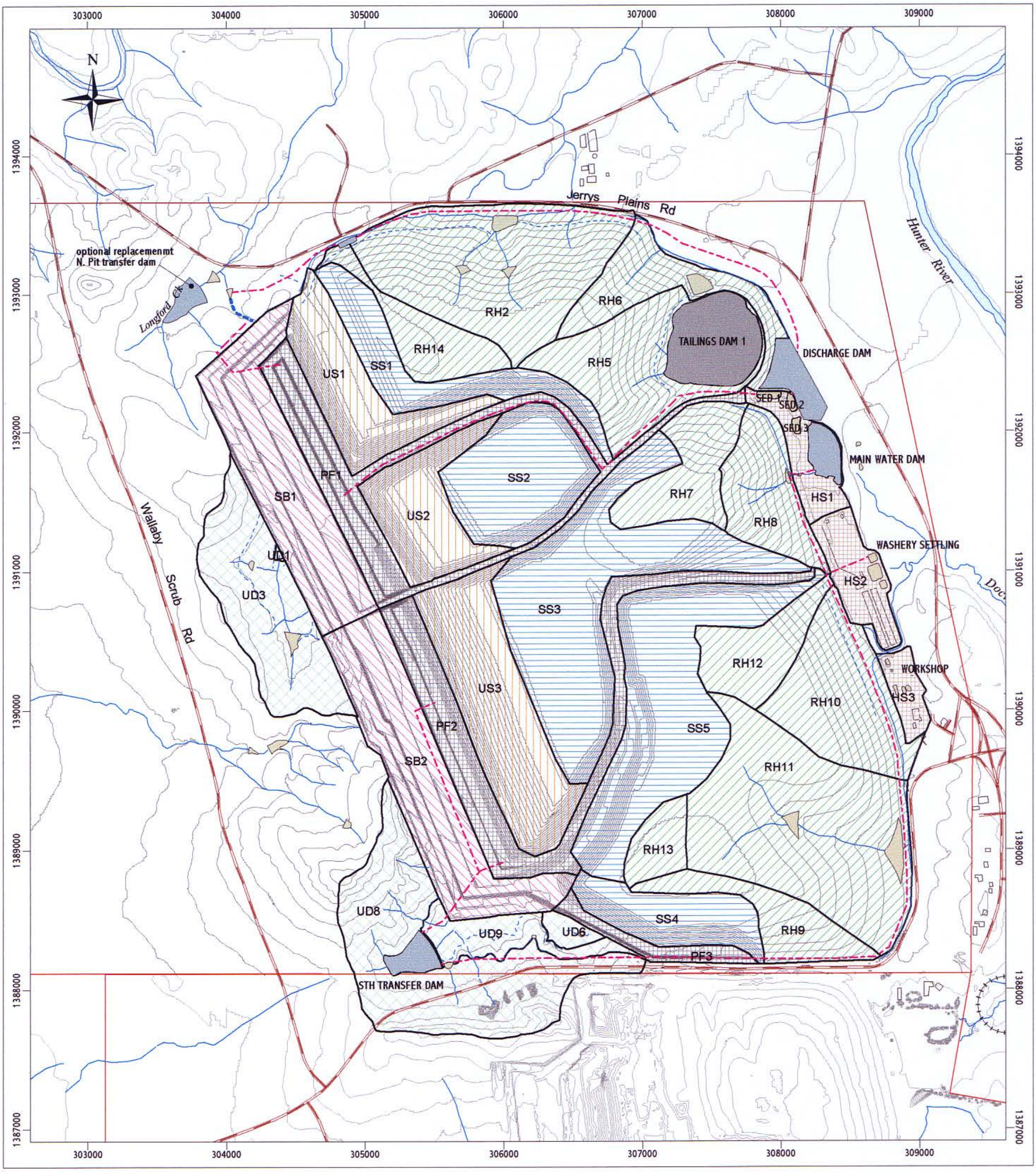


WARKWORTH MINE - CURRENT WATER MANAGEMENT SYSTEM

Figure 14

NOTE - WATER MANAGEMENT IN REHABILITATED AREAS NOT SHOWN



0 1000 2000 3000 Metres

see water management schematic for storage and pumping details

Scale 1:40000 Base map information from 1:25,000 topo series (Central Mapping)
Additional data supplied by Warkworth Mine

- 10m topo. contours
- contour drain
- diversion drain
- railway
- major road
- minor road
- drainage
- pipeline
- mine water
- sed. dam
- tailings
- void water
- hardstand
- pit floor
- rehabilitated
- strip and bench
- shaped spoils
- tailings
- undisturbed
- unshaped spoils

WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

Water management catchments after 10 years

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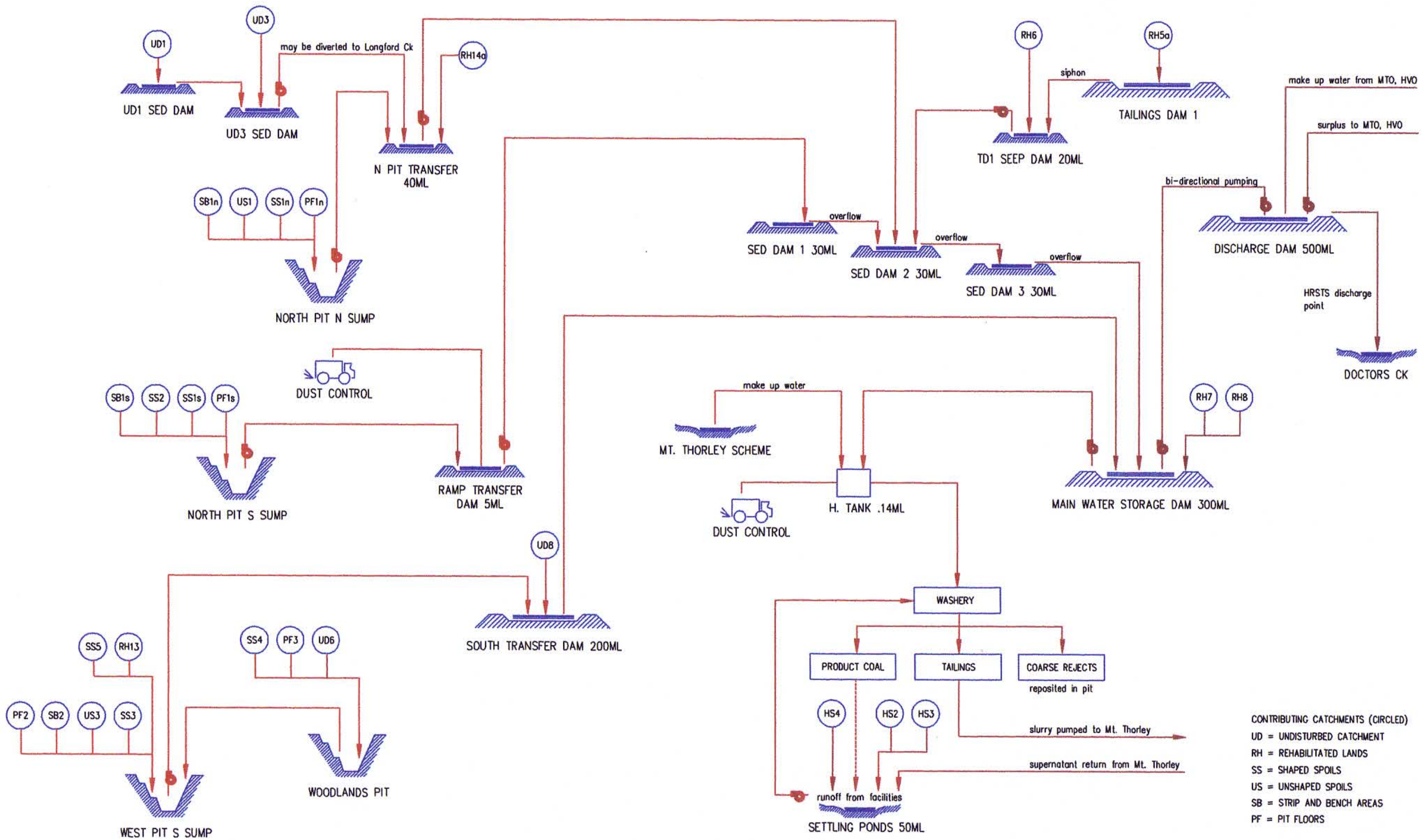
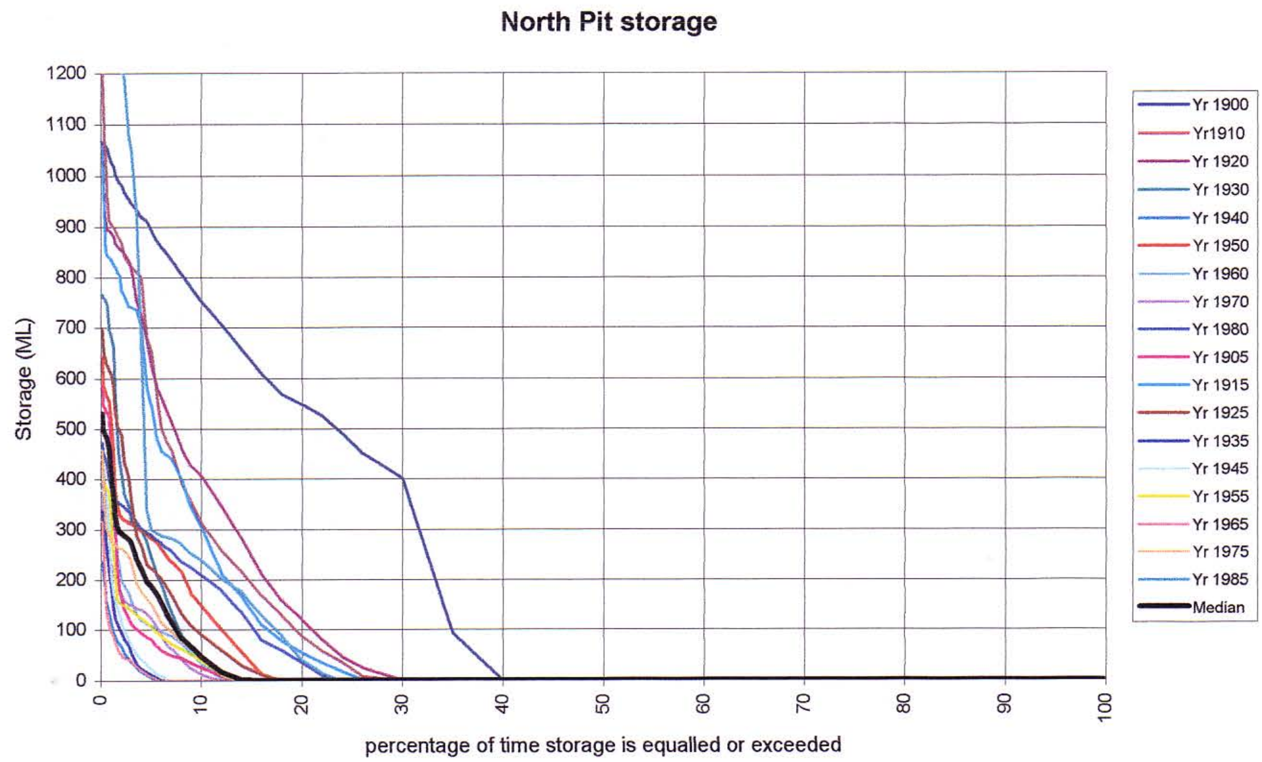
Figure 15

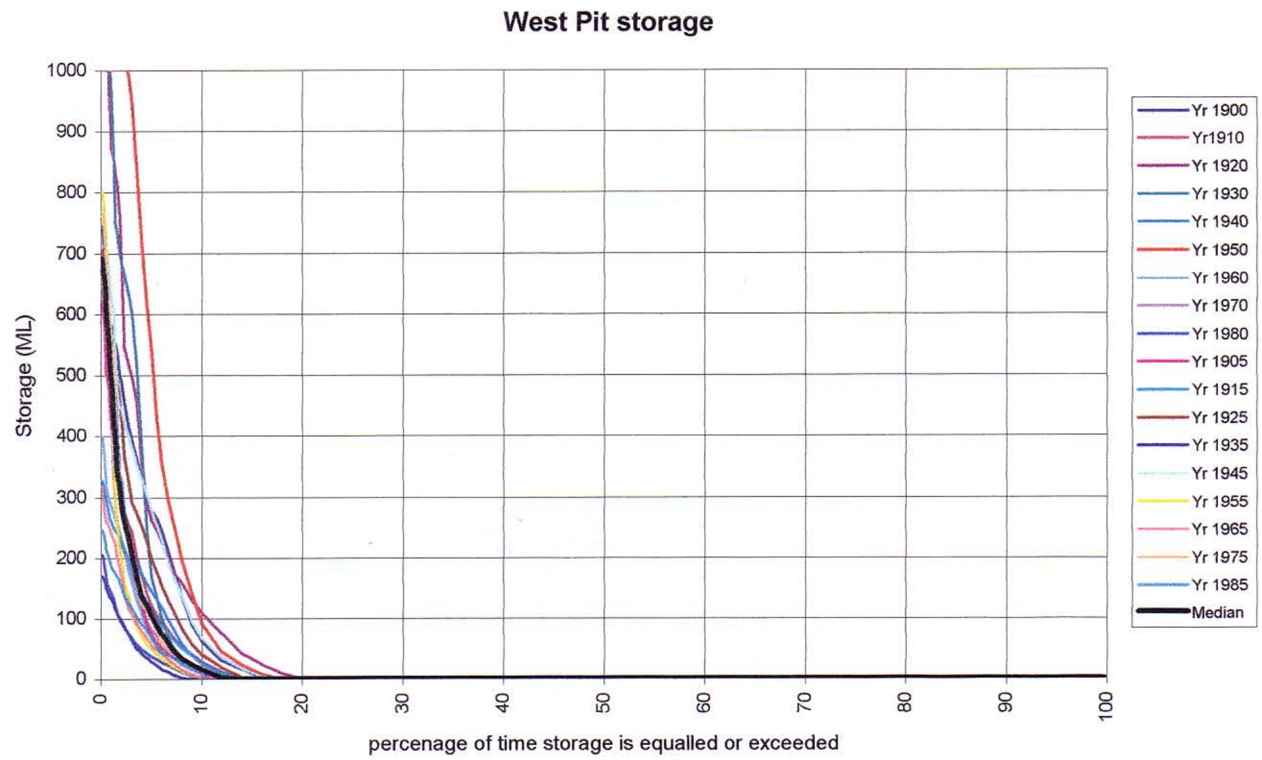


WARKWORTH MINE - 10 YEARS WATER MANAGEMENT SYSTEM

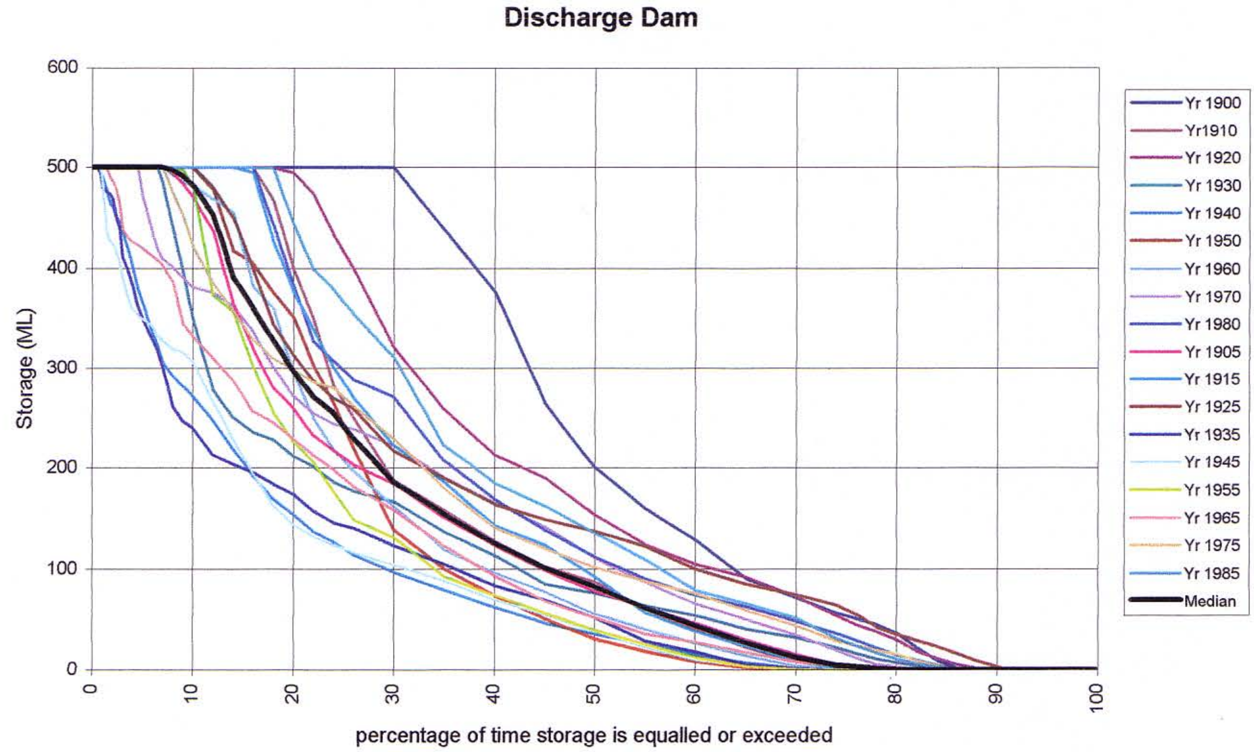
Figure 16

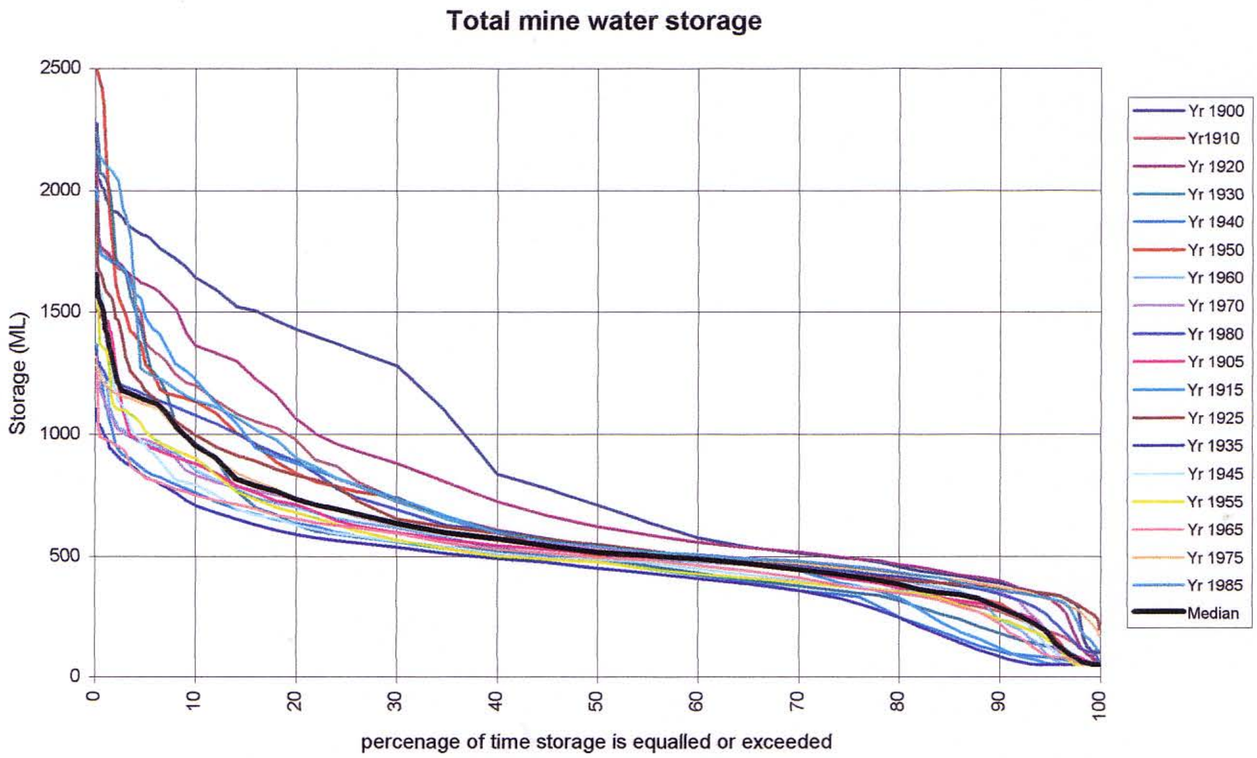
NOTE - WATER MANAGEMENT IN REHABILITATED AREAS NOT SHOWN



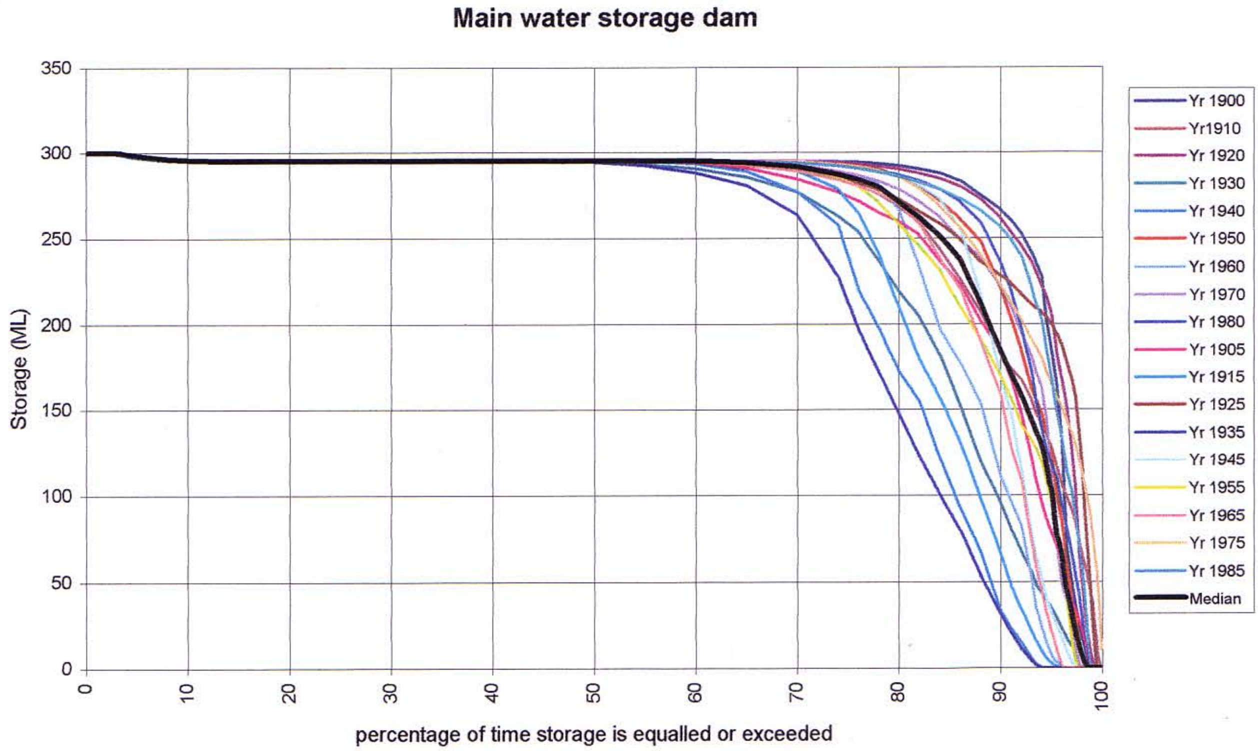


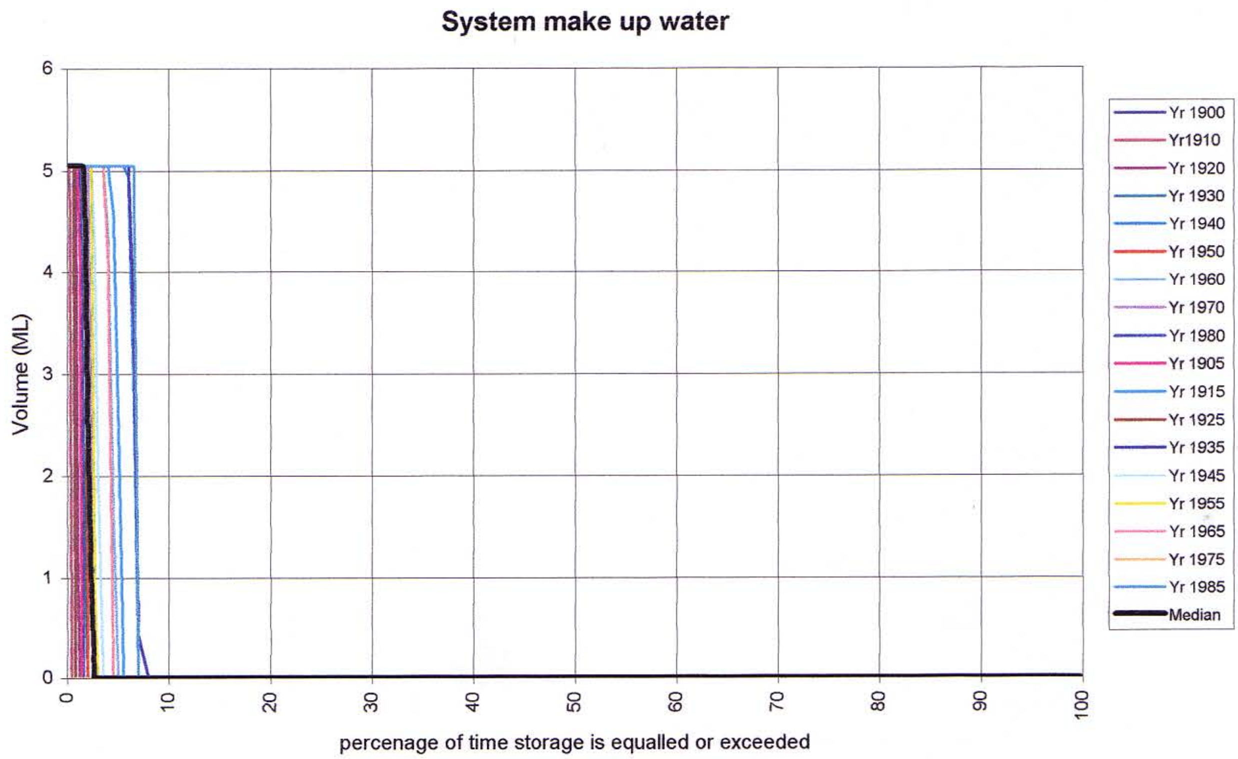
Warkworth Mine Extension - Water Managemenbt Study
Percentile plots: Base case with HRSTS discharges
North and West Pits



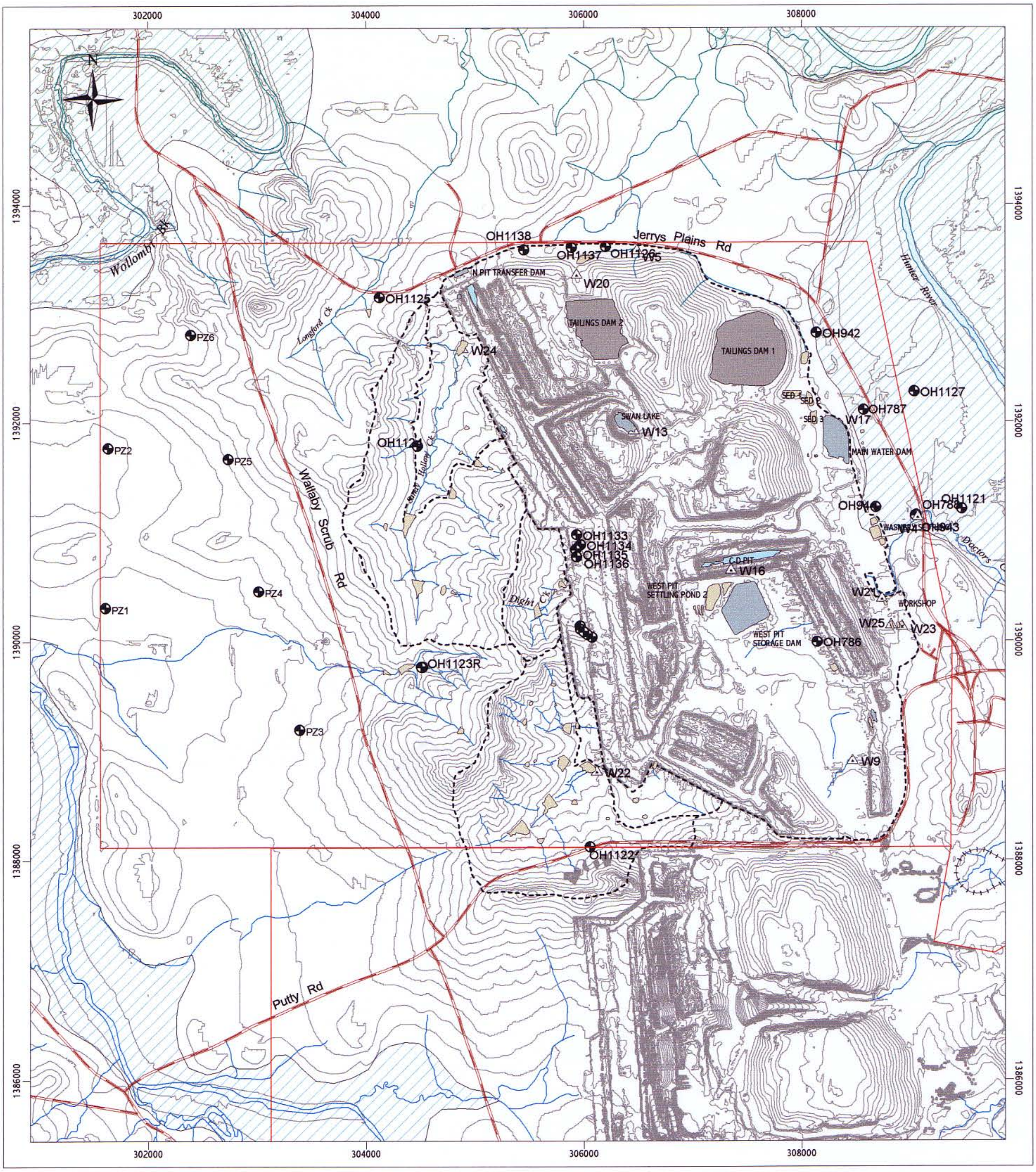


Warkworth Mine Extension - Water Managemenbt Study
Percentile plots: Base case with HRSTS discharges
Discharge Dam and total mine water storage





Warkworth Mine Extension - Water Managemenbt Study
Percentile plots: Base case with HRSTS discharges
Main water storage dam and make up water



0 1000 2000 3000 Metres

Scale 1:40000 Base map information from 1:25,000 topo series (Central Mapping)
Additional data supplied by Warkworth Mine

- creeks
- dirt roads
- sealed road
- main road
- railway
- mine lease
- △ surface water monitoring locations
- piezometer sampling locations

WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

Future surface and groundwater water monitoring locations

Figure 18

APPENDIX A

Rainfall histories and statistics

A1. CLIMATE DATA

Climate data has been sourced from the Bureau of Meteorology for use in mine water management system modelling. All data has been installed in MER database environment to facilitate processing and evaluation.

Long term data for Jerrys Plains, Singleton and Broke have been reviewed and compared to available local mine data. All stations exhibit reasonably close correlation in respect of key statistics like average monthly and annual rainfalls. Jerrys Plains rainfall has been used in water management simulations where testing has been conducted against the historical record. In addition, data for the more complete Jerrys Plains gauging station has been processed to generate recurrence intervals and average exceedance probabilities for specified rainfall durations up to 20 days. The following Table A1 provides a summary.

Table A1: Longer term intensity, frequency, duration statistics for 115 years of data.

ARI	AEP %	1 day	2 day	3 day	4 day	5 day	6 day	8 day	10 day	15 day	20 day
once in 1 years	63.2	48	65	72	78	82	87	93	99	115	126
once in 2 years	39.3	61	84	93	100	105	110	118	125	144	158
once in 5 years	18.1	79	109	121	131	136	141	152	160	182	199
once in 10 years	9.5	93	129	142	154	160	165	178	187	210	230
once in 20 years	4.9	107	148	164	178	185	189	203	214	239	261
once in 50 years	2.0	125	174	193	210	217	221	238	249	276	302
once in 100 years	1.0	140	195	216	235	243	246	264	277	306	333

Durations are based on screening of daily Jerrys Plains data within each year of available records from 1884 to 2000 - a log normal distribution is assumed.

ARI (Average Recurrence Interval) means – the average or expected value of the periods between exceedances of a given rainfall total accumulated over a given duration. For example, a rainfall total of 99mm over 10 days has an average recurrence interval of 1 year.

AEP (Average Exceedance Probability) means – the probability that a given rainfall total accumulated over a given duration will be exceeded in any one year. For example, a rainfall total of 99mm over 10 days has a 63.2% probability of being equaled or exceeded in any one year.

Evaporation data is summarised in the following Table A2.

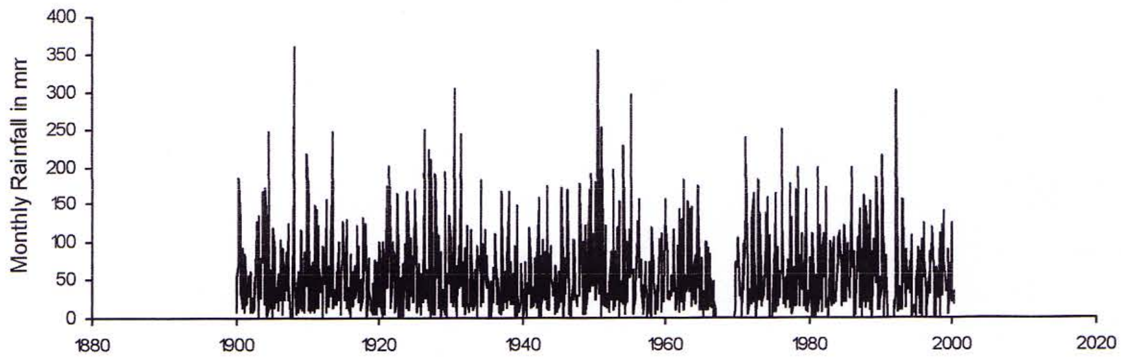
Table A2: Average potential daily evaporation (Pan A) in mm - Scone.

Jan	Feb	Mar	Apl	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec
8.8	7.2	5.5	4.3	2.8	2.1	2.5	3.2	4.2	5.4	7.6	9.2

Rainfall Statistics: Singleton PO + Army + Water Board

B.Met. No.: 61070

Period from 01/01/1900 to 31/03/2000



Annual average rainfall: 653 mm

Month	Average Rain (mm)	Average of raindays	Minimum (mm)	Maximum (mm)	Percentile10 (mm)	Median (mm)	Percentile90 (mm)
January	72.3	7.8	0.0	251.5	12.5	68.1	149.6
February	72.1	7.7	0.0	360.4	6.6	46.6	183.1
March	62.5	7.5	0.0	249.2	5.9	46.3	134.9
April	52.3	6.9	0.0	244.2	5.4	41.0	117.7
May	45.4	7.0	0.0	246.5	3.3	27.1	122.5
June	47.5	7.5	0.0	354.6	6.6	28.0	101.7
July	44.0	7.2	0.0	245.6	4.8	33.2	100.5
August	35.5	6.7	0.0	196.6	3.3	28.0	68.7
September	42.3	6.7	0.0	166.6	8.1	31.8	89.2
October	50.7	7.1	0.0	199.3	8.0	42.4	104.1
November	57.6	7.7	0.0	190.0	10.1	53.9	119.2
December	71.0	7.3	0.0	223.6	14.4	61.9	151.3

Period summary

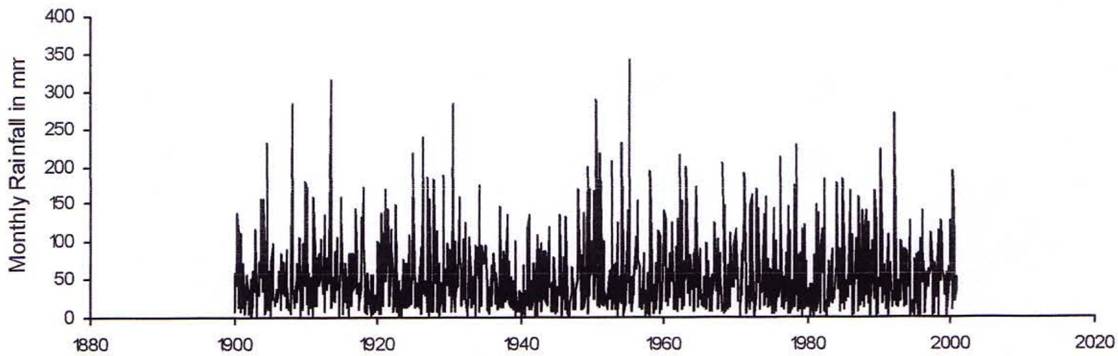
	Rainfall		Month	Year
Wettest month:	360.4	commencing	2	1908
Driest month (last):	0	commencing	4	1997
Wettest 3 months:	593.4	commencing	12	1970
Driest 3 months:	0	commencing	11	1966
Wettest 6 months:	814.7	commencing	6	1950
Driest 6 months:	0	commencing	11	1966
Wettest 12 months:	1402.5	commencing	2	1950
Driest 12 months:	0	commencing	11	1966
Wettest 36 months:	3115.6	commencing	2	1948
Driest 36 months:	80.89999	commencing	7	1966

all rainfall values in mm

Rainfall Statistics: Jerrys Plains

B.Met. No.: 61086

Period from 01/01/1900 to 30/09/2000



Annual average rainfall: 642 mm

Month	Average Rain (mm)	Average of raindays	Minimum (mm)	Maximum (mm)	Percentile10 (mm)	Median (mm)	Percentile90 (mm)
January	78.1	8.1	0.0	217.0	24.1	64.3	160.1
February	69.5	7.6	0.0	340.4	9.8	43.8	173.7
March	56.2	7.5	0.0	238.1	11.2	45.7	115.3
April	46.3	6.7	0.0	172.2	5.4	34.8	113.8
May	42.0	6.9	0.0	314.3	5.3	28.7	92.9
June	45.5	7.9	2.3	288.4	8.9	30.3	100.0
July	44.2	7.5	0.3	231.6	8.1	37.3	95.2
August	37.0	7.3	0.0	206.9	8.0	30.6	75.5
September	42.7	6.9	0.0	156.1	9.1	35.2	86.0
October	53.5	7.9	1.4	170.0	9.9	48.0	100.3
November	58.5	7.8	1.0	217.8	13.4	48.3	118.1
December	68.8	7.8	2.6	186.0	15.5	58.9	139.0

Period summary

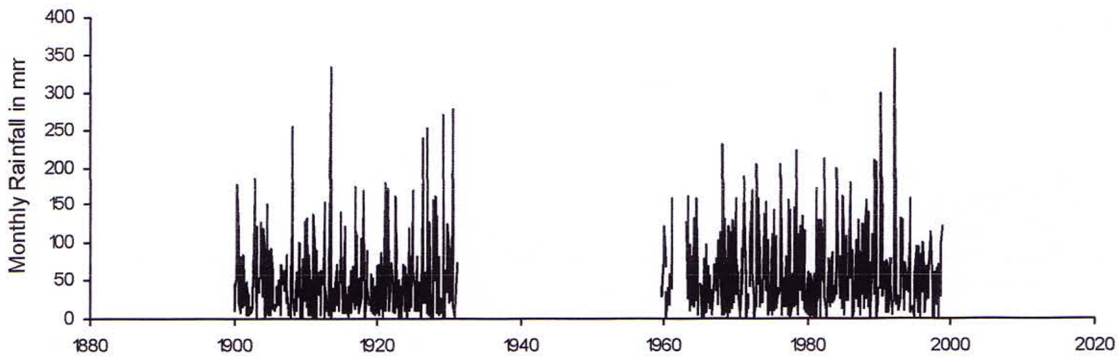
	Rainfall		Month	Year
Wettest month:	340.4	commencing	2	1955
Driest month (last):	0	commencing	8	1982
Wettest 3 months:	516.3	commencing	1	1908
Driest 3 months:	13.8	commencing	5	1940
Wettest 6 months:	760.9	commencing	2	1950
Driest 6 months:	63.2	commencing	5	1994
Wettest 12 months:	1298.3	commencing	2	1950
Driest 12 months:	246.5	commencing	4	1939
Wettest 36 months:	2966.4	commencing	9	1948
Driest 36 months:	1172.6	commencing	2	1939

all rainfall values in mm

Rainfall Statistics: Broke (Harrowby)

B.Met. No.: 61100

Period from 01/01/1900 to 30/09/1998



Annual average rainfall: 633 mm

Month	Average Rain (mm)	Average of raindays	Minimum (mm)	Maximum (mm)	Percentile10 (mm)	Median (mm)	Percentile90 (mm)
January	70.0	6.7	3.3	231.3	9.6	65.0	151.2
February	67.9	6.3	0.0	358.8	6.4	40.4	159.3
March	61.2	6.5	0.0	238.3	3.8	58.2	134.6
April	53.2	5.5	0.0	210.4	6.0	35.2	135.6
May	46.5	5.6	0.0	334.5	2.8	28.3	115.4
June	47.4	5.7	0.0	278.1	8.1	31.0	103.4
July	41.0	5.2	0.0	161.5	4.3	31.0	90.5
August	31.4	4.4	0.0	125.0	3.4	24.6	70.8
September	36.9	4.8	0.0	126.7	6.3	30.5	81.0
October	52.9	5.9	0.0	202.7	8.6	38.8	124.5
November	56.4	6.3	0.0	169.3	8.0	49.1	128.9
December	68.4	6.2	4.5	250.6	16.2	54.1	126.0

Period summary

	Rainfall		Month	Year
Wettest month:	358.8	commencing	2	1992
Driest month (last):	0	commencing	8	1995
Wettest 3 months:	532.2	commencing	12	1991
Driest 3 months:	9.6	commencing	5	1970
Wettest 6 months:	705.8	commencing	1	1989
Driest 6 months:	36.1	commencing	5	1927
Wettest 12 months:	1118.4	commencing	4	1989
Driest 12 months:	254.7	commencing	9	1901
Wettest 36 months:	2881	commencing	8	1987
Driest 36 months:	1195	commencing	12	1917

all rainfall values in mm

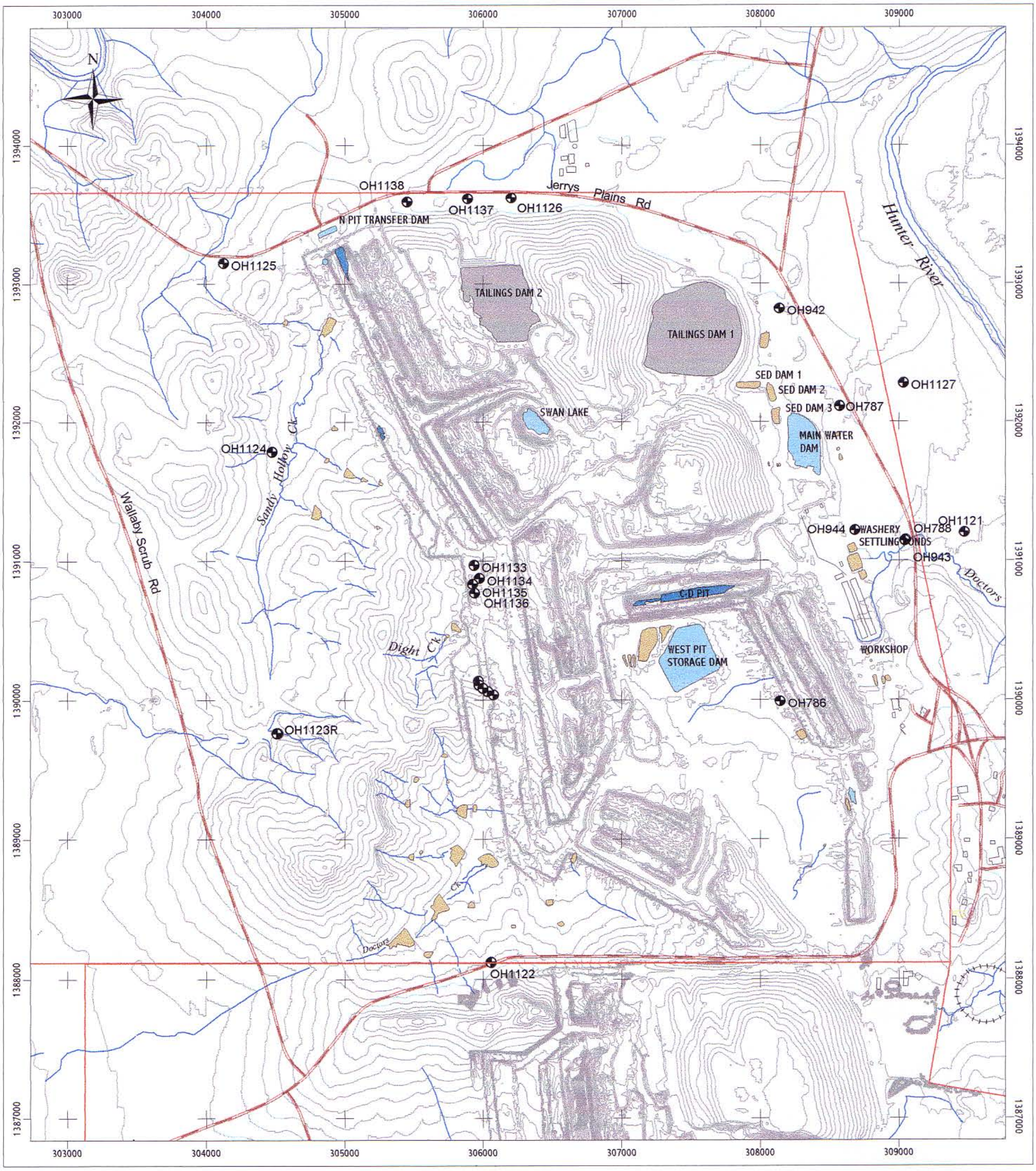
APPENDIX B
Groundwater monitoring data

B1. GROUNDWATER MONITORING BORES

B1.1 Water table monitoring

A number of piezometer locations were installed around the mine site in 1998 for the purpose of monitoring groundwater pressures within the coal measures to the west and the alluvial lands to the east of the site. Locations are shown on Figure B1. Historical water level monitoring data has been plotted as the hydrographs shown on Figures B2 and B3.

Reference to plots indicates water tables in the alluvial lands have been relatively stable in time while pressures recorded in piezometers to the west (multi level piezometers) exhibit loss of pressure ranging from zero to about 10 metres equivalent head of water.



0 1000 2000 3000 Metres

Scale 1:40000 Base map information from 1:25,000 topo series (Central Mapping)
Additional data supplied by Warkworth Mine

- creeks
- dirt roads
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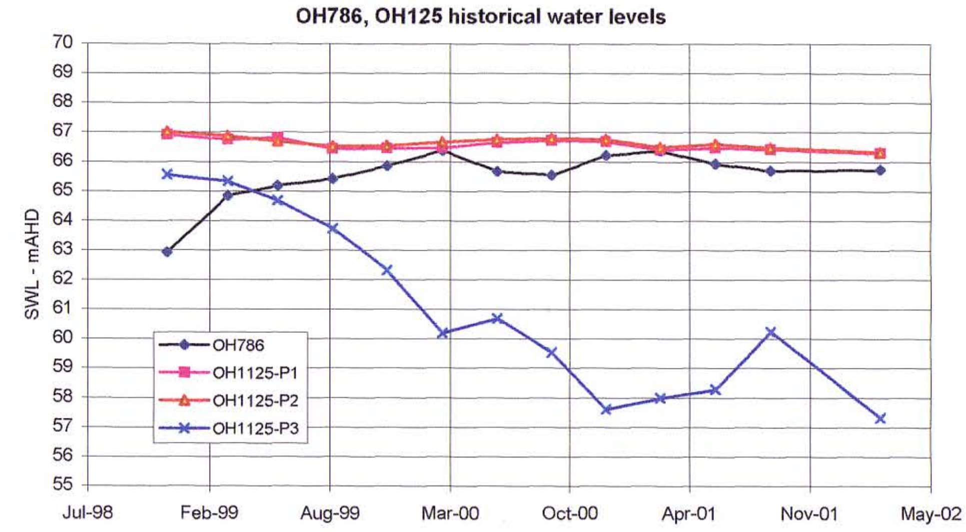
- main road
- railway
- mine lease
- piezometer locations

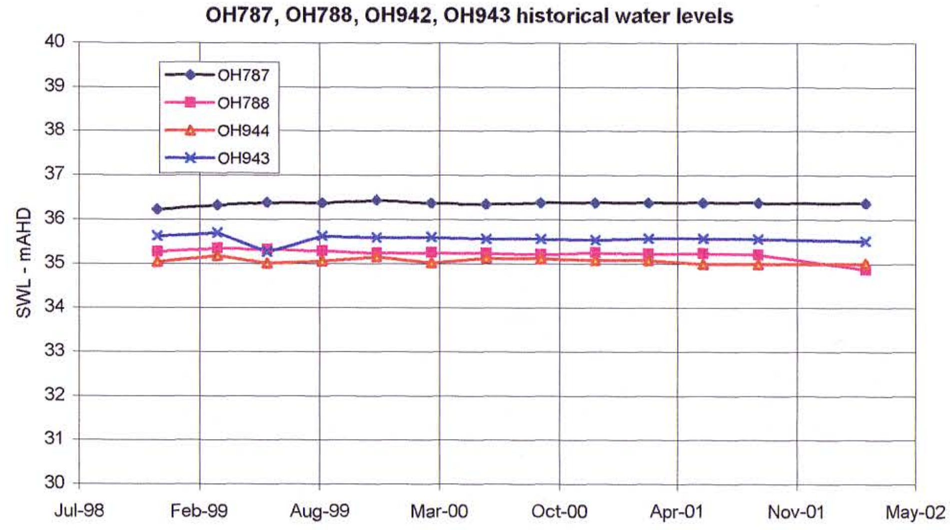
WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

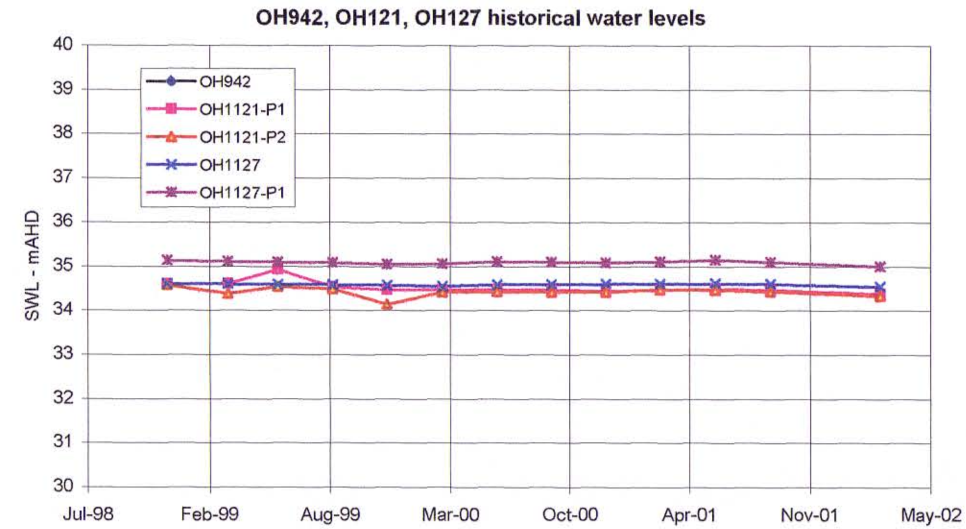
Monitoring piezometer locations

Mackie Environmental Research

Figure B1







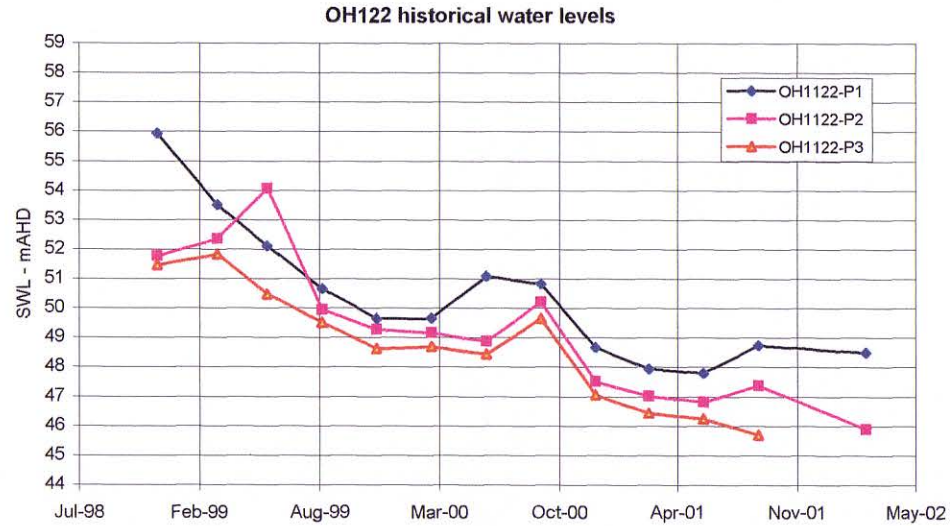
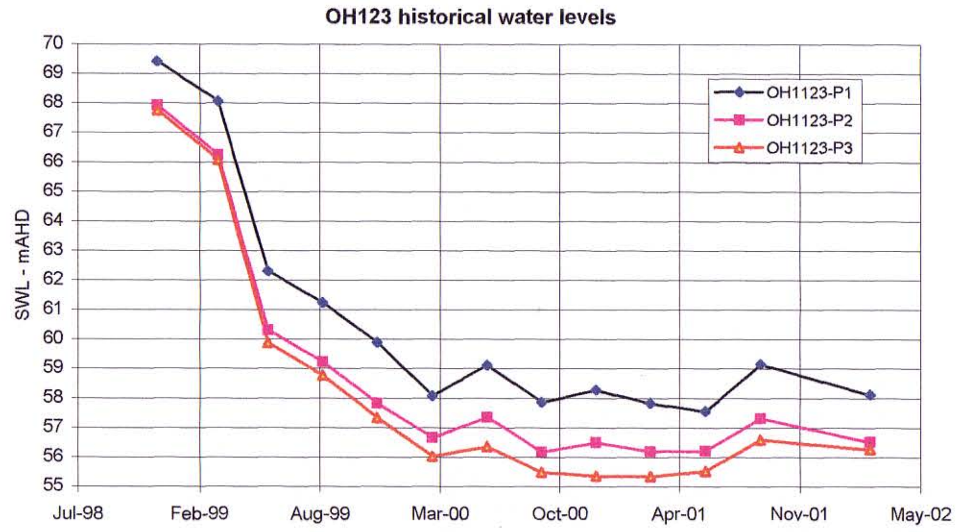
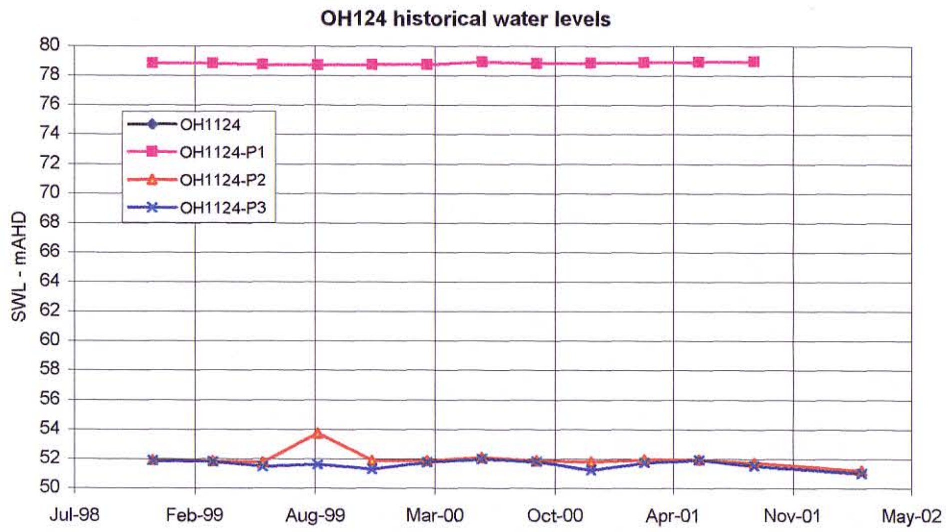
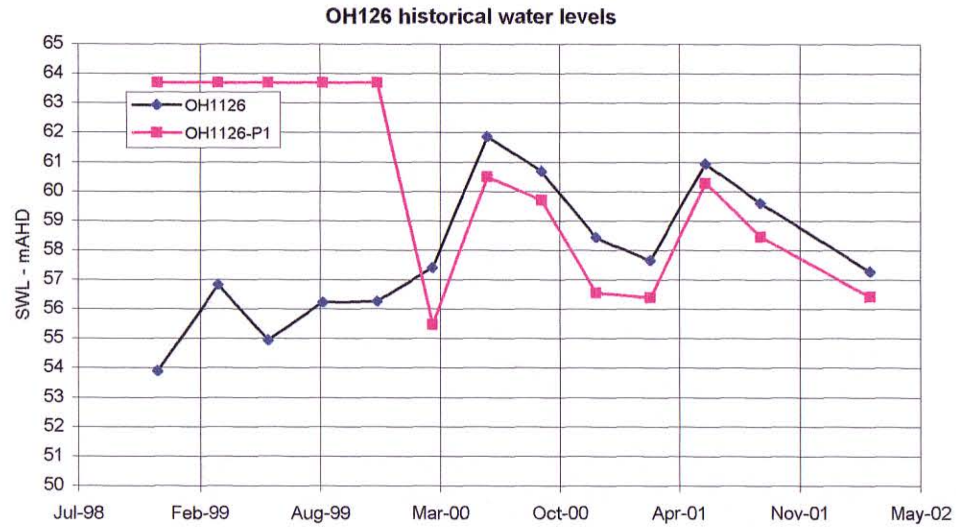


Figure B2

Piezometer monitoring data - July 1998 to March 2002







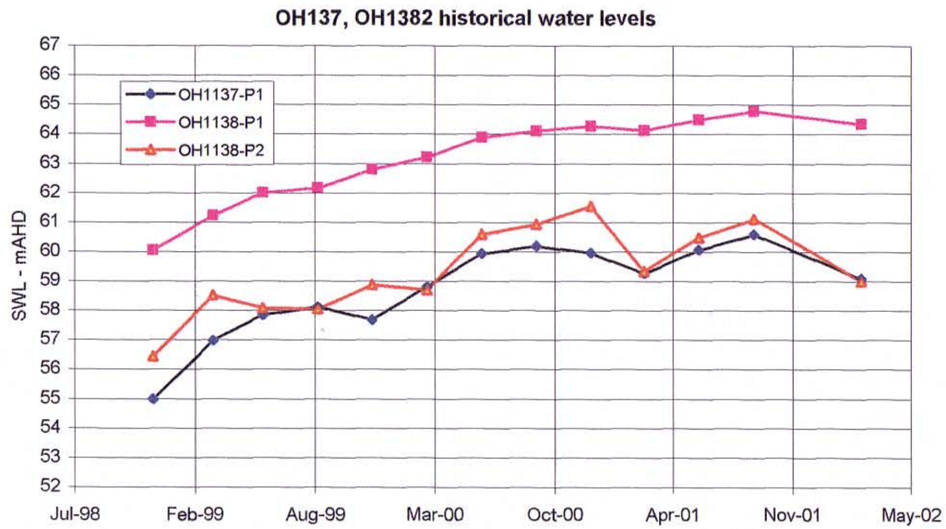


Figure B3

Piezometer monitoring data - July 1998 to March 2002

APPENDIX C

Hydraulic properties of aquifers

C1. AQUIFER HYDRAULIC PROPERTIES

Aquifer testing provides a means of estimating the groundwater transmission and storage characteristics of a geological formation. Various procedures can be employed depending upon the saturated aquifer thickness, regional extent, transmission properties and bore completions. Testing in the Warkworth area is limited to a dewatering trial in presplit overburden, packer and Horslev type testing in several piezoemetsr in the South Pit area, and airlift testing of piezometers prior to insertion of slim diameter casing.

Historical testing of seams and interburden has also been conducted in neighbouring areas and this information has been extracted from various sources. In addition, the analysis of regional drawdowns in monitoring piezometers (induced by pit depressurisation) and estimates of pit(s) groundwater seepage have provided supporting estimates of the 'bulk permeability' of the coal measures. These tests have been reviewed in order to develop regional estimates for aquifer modelling purposes.

C1.1 Piezometer airlift tests

Very few airlift measurements have been recorded during the history of mining due in part to the low emphasis given to groundwater impacts 20 years ago. However the few measurements provide at least an indication of the bulk permeability of coal measures strata

Table C1: Permeability estimates from piezometer airlift measurements

Location	Depth (m)	Bulk permeability - k (m/day)
OH786	7	$< 1 \times 10^{-4}$
OH787	18	$< 1 \times 10^{-4}$
OH1122	165	5×10^{-4}
OH1123R	210	$< 1 \times 10^{-4}$
OH1124	168	4×10^{-2}
OH1125	156	4.7×10^{-3}
OH1126	78	1×10^{-4}
OH1127	27	5×10^{-1}
OH1137	18	$< 1 \times 10^{-4}$

C1.2 Packer test in South Pit area

Packer and falling head tests were undertaken by D.J. Douglas & Partners (1991) along two transects aligned orthogonal to strike in the South Pit area. Seven HQ holes were drilled (DDH315 to DDH321) and geophysically logged. Results are represented in Table C2.

Table C2: Summary of South Pit hydraulic test data

Test sections – Southern line		K packer (m/day)	K Hvorselv (m/day)
Weathered zone			2.80E-1
interburden		7.00E-02	
Group 2 seams – Warkworth, Mt. Arthur		2.90E-01	3.30E-01
interburden		4.00E-02	
Seams 7/8 & 9/10 –Vaux, Piercefield		2.60E-01	1.00E-0`
interburden		3.00E-03	4.50E-02
Seam 6		6.00E-02	2.70E-01
interburden		9.00E-03	
Seam 5 & floor zone		9.00E-03	
Test sections – Northern line			
Weathered zone			9.20E-01
Group 2/3 seams – Warkworth, Mt. Arthur		2.80E-01	3.90E-00
Seams 9/10 – Piercefield		1.70E-01	2.54E-00
Seams 7/8 - Vaux		2.40E-01	

C1.3 Consolidation of data for aquifer modelling representation

Estimates of permeability have been consolidated to generate the following distribution used for aquifer simulations (Table C3). Aquifer modelling has represented numerous seams and interburden within a simplified layering (see Appendix E). Representative values have been generated by calculating the harmonic mean of separate lithologies. These are given in column 4 of the following table.

Table C3: Regionalised permeability values for aquifer modelling

Strata	Thickness (m)	K (m/day)	Total Kd (m^2/day)	Bulk K (m/day)
overburden inc Watts sandstone	50	1.00E-04		
Whybrow seam	5	2.50E-02		
sandstone-siltstone	20	1.00E-04		
Redbank seam	3	2.50E-02		
sandstone-siltstone	15	1.00E-04	2.09E-01	2.24E-03
Wambo seam	5	2.50E-02		
sandstone-siltstone	20	1.00E-04		
Whynot seam	5	4.40E-02		
sandstone-siltstone	20	1.00E-04		
Blakefield seam	4	1.00E-02		
sandstone-siltstone	20	1.00E-04		
Glen Munro seam	5	6.50E-03		

sandstone-siltstone	23	1.00E-04	4.26E-01	4.17E-03
Woodlands Hill (4) seam	4	1.20E-02		
sandstone-siltstone	25	1.00E-04		
Arrowfield seam	0	5.10E-02		
sandstone-siltstone	25	1.00E-04	5.30E-02	9.81E-04
Bowfield seam	6	5.00E-02		
sandstone-siltstone	5	1.00E-04		
Warkworth (1/2) seam	2	1.00E-02		
sandstone-siltstone-shale	30	1.00E-05		
Warkworth (4/5) seam	5	1.00E-02		
siltstone	20	1.00E-06		
Mt. Arthur seam	10	4.60E-04		
Piercefield seam	8	1.41E-01		
sandstone-siltstone	18	1.00E-04		
Vaux seam	6	1.48E-01	1.42E+00	1.29E-02
sandstone-siltstone	25	1.00E-04		
Broonie seam	6	3.70E-02		
sandstone-siltstone	25	1.00E-04		
Bayswater seam	5	2.30E-02	3.42E-01	5.61E-03
Archerfield sandstone	15	1.00E-05		
Bulga Fm	60	1.50E-02		
Foybrook Ck. Fm	60	1.50E-02		
Saltwater Ck. Fm	40	1.50E-02	2.40E+00	1.37E-02
Mulbring ss	300	1.00E-06	3.00E-04	1.00E-06

K = horizontal permeability, Kd = transmissivity

APPENDIX D
Surface and groundwater quality data

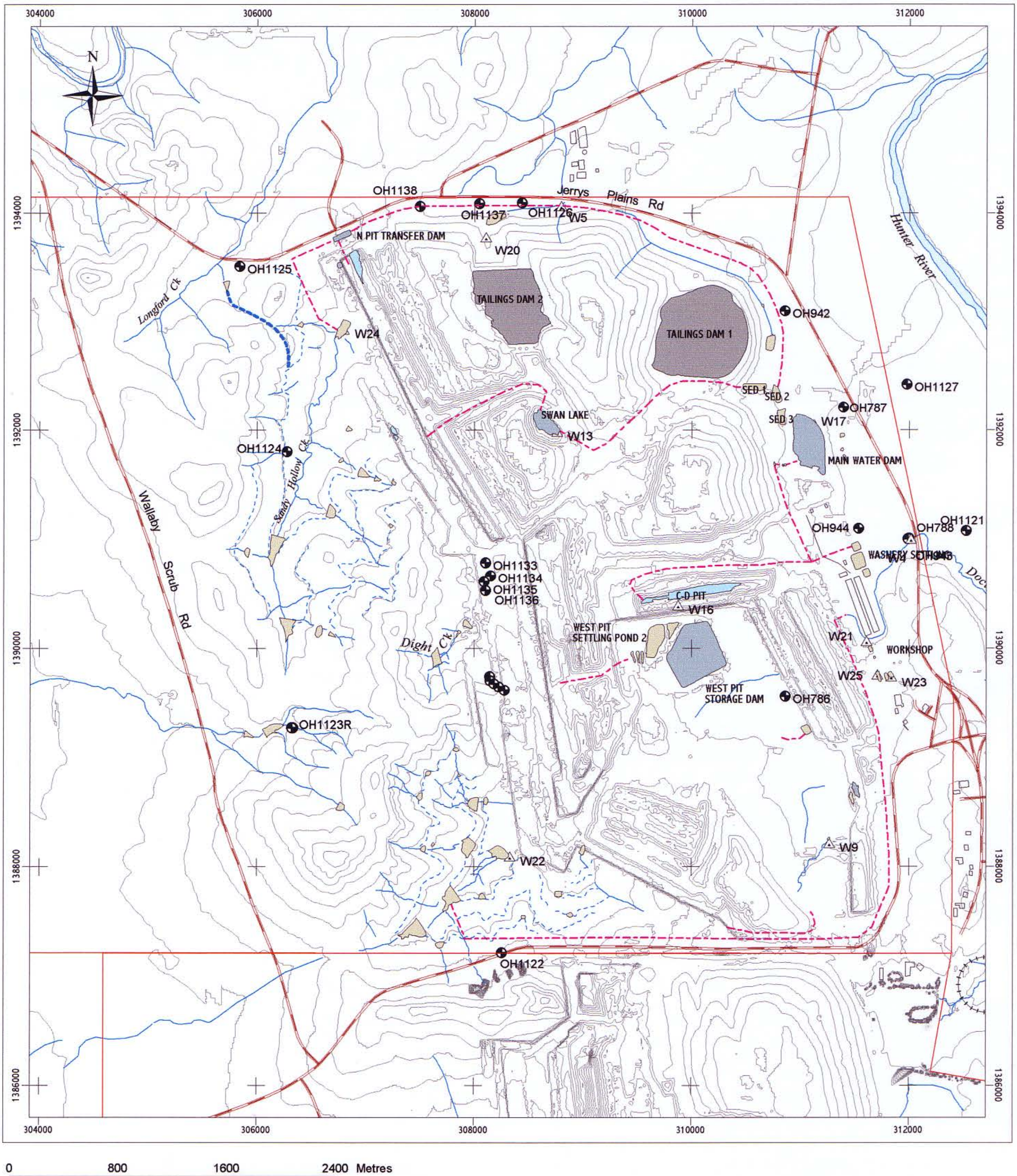
D1. HYDROCHEMISTRY

Groundwater in piezometers and surface water qualities in dams and sumps have been regularly sampled by Warkworth Mine. Parameters determined include pH, electrical conductivity (EC), total dissolved solids (TDS), non filterable residue (NFR) and basic cations and anions excluding carbonates and bicarbonates.

Figure D1 provides sampling locations while most recent data are given in the following Table D1.

Table D1: Hydrochemical data for to 2001-2002 (supplied by Warkworth Mine)

Location	pH	EC (uS/cm)	TDS (mg/L)	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	HCO3 (mg/L)	Cl (mg/L)	SO4 (mg/L)
OH786	6.7	560	340	65	8.7	25	16	150	80	25
OH787	7.5	20700	13810	3790	40	110	360	1230	6560	440
OH788	7.2	12670	7900	2240	55	120	280	1410	3450	420
OH942	6.6	26800	18590	5010	50	170	860	680	9350	900
OH943	7.7	8090	4680	1430	20	105	160	840	1940	190
OH944	7.7	8360	5130	1870	29	6.9	60	920	1940	720
OH1121	7.1	9370	5620	1610	16	150	190	700	2720	210
OH1121-P1	7.4	8640	5140	1650	17	130	160	670	2490	200
OH1122-P2	7.0	13340	8410	2430	36	110	350	1570	3610	650
OH1123-P1	6.8	18370	12050	3700	45	150	560	1270	5300	1570
OH1123-P2	7.0	18380	12050	3360	38	140	490	1230	5350	1400
OH1123-P3	7.0	18480	12050	3550	42	150	520	1265	5400	1480
OH1124	6.3	2910	1550	360	8.5	25	25	50	770	300
OH1124-P1	7.4	17950	11700	3080	55	260	670	1035	5640	840
OH1124-P2	7.2	13750	8440	2540	31	160	320	1125	3950	640
OH1124-P3	7.0	14200	8800	2360	28	180	430	1075	4050	730
OH1125-P1	6.9	18730	12330	2910	32	240	740	1175	5600	1710
OH1125-P2	6.9	14880	9520	1920	25	270	620	1035	4580	670
OH1125-P3	6.9	16290	10535	2150	28	300	660	1070	4970	930
OH1126	6.9	10960	6570	1980	38	80	270	840	2620	1060
OH1126-P1	7.0	8470	4980	1540	25	80	170	780	18800	900
OH1127	7.3	19520	12900	3683	29.9	150	325	2025	6030	335
OH1127-P1	7.1	11570	7000	2270	17.9	128	120	2015	3090	11.7
OH1137-P1	7.7	16330	10560	3220	39	130	400	1190	4770	960
OH1138-P1	7.0	13480	8330	1850	37	340	410	770	3990	530
OH1138-P2	6.9	10890	6520	1560	23	360	370	780	2930	740
N. Transfer dam	7.8	3495	2340	552	15	84	122	207	995	328
CD-void	7.9	8530	5460	1705	35	47	132	1244	1690	1125
400ML storage	7.6	4700	3280	1148	21	18	58	714	1170	465



Scale 1:40000 Base map information from 1:25,000 topo series (Central Mapping)
Additional data supplied by Warkworth Mine

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- piezometer sampling locations

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WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

Surface and groundwater water monitoring locations

Figure D1

APPENDIX E

Aquifer numerical model development

E1. MODEL DESIGN & CALIBRATION

The application of computer based numerical models to problem solving in groundwater engineering provides a powerful tool for the rationalization of spatially and temporally varying field conditions. The modelling process utilizes a system of mathematical equations for water flow through porous media subject to prescribed boundary conditions. The process requires definition of the aquifer system in respect of geometry, hydraulic properties and applied stresses including rainfall, pumpage, leakage and pit development.

In the present study, a finite difference approach (McDonald et.al. 1988) has been utilized. The method requires dividing the overall area of interest into rectangular cells or blocks defined by nodal points at individual block centres. The number of cells defined in the model grid has been determined by the spatial variations occurring in aquifer properties and the expected hydraulic gradients developed in the course of modelling. A variable cell size has been adopted whereby smaller cells have been located over existing and planned mine pit areas and larger cells have been adopted in more distant areas.

The model comprises 7 layers with cells arranged in 100 rows x 95 columns (9500 cells per layer). The overall model extents are indicated on Figure E1 which shows cell geometry. Smallest central cell dimensions are 100x100m.

The upper surface of layer 1 is set at 200 mAHD to ensure that water levels generated within the layer represent an unconfined aquifer system. The base of layers 1 is a surface that connects the estimated base of alluvial lands throughout the model including alluvium along Wollombi Brook and the Hunter River (see Figure E2 for east-west section). Along these drainages the alluvium geometry has been interpolated from a maximum saturated thickness of between about 15 and 20 metres located approximately along the drainage line, to a minimum saturated thickness determined by the model rainfall recharge and the rising bedrock surface away from the drainage.

Layer 2 represents coal measures and interburden to the base of the Woodlands Hill seam while remaining layers represent consolidated coal measures to horizons as specified in the following Table E1. Where possible these horizons have been interpolated and offset from the structure contours for the floor of the Vaux seam or the Woodland Hill seam. The grouping is based on identifiable low permeability strata like the Mulbring Siltstone, the Archerfield Sandstone or other more massive sandstones that are generally observed in the open pit walls to be relatively devoid of jointing.

Table E1: Model layer-stratigraphy and assigned permeability

Layer	Stratigraphy	Horizontal K (m/day)
1	arbitrary base including coal measures + alluvium	8.0×10^{-3} (alluv = 10.0)
2	arbitrary top to floor of Woodlands Hill seam	4.0×10^{-3}
3	floor of Woodlands Hill to top of Bowfield seam	1.0×10^{-3}
4	top of Bowfield to floor of Vaux seam	1.3×10^{-2}
5	floor of Vaux seam to top of Archerfield sandstone	5.6×10^{-3}
5	top of Archerfield sandstone to top of Mulbring siltstone	1.4×10^{-2}
7	Mulbring siltstone	1.0×10^{-3}

K = permeability

Hydraulic conductivties (permeabilities) assigned to each layer are prescribed in Table E1. Permeability values have been based upon a consolidation of available data (Appendix C), and back analysis of the area of influence and hydraulic gradients prevailing after 18 years of mining, A storativity value of 1 x 10^{-4} has been assigned to all hardrock strata as a reasonable upper limit for confined aquifer conditions while a value of 0.5 x 10^{-3} (0.5%) has been used for drainable porosity. A drainable porosity of 30% has been adopted for the alluvium assuming regional presence and continuity of a coarse basal gravel system with overlying clean sands.

Boundary conditions assigned to the model include head dependent 'river cells' for the Hunter River and Wollombi Brook. These cells either act as sinks if surrounding aquifer pressures are higher than the assigned elevations, or as sources if surrounding aquifer pressures are lower. River and brook bed elevations have been interpolated from sparse data at Bulga and Singleton flow gauging stations, available topographic data and limited mine survey data. Errors of several metres may be possible along some reaches. However these errors are considered to be acceptable within the scale of aquifer depressurisations predicted from mining.

Drainage cells have been assigned along the most of the creeks. These cells serve to 'fix' rising water tables to approximate creek bed elevations; if groundwater levels exceed the drainage cell elevations then the cells are activated and water is exported from the model at a rate governed by the prevailing groundwater pressures and creek bed conductance. Drain cells have also been assigned to existing and future pit excavations. The elevation of these cells has been determined from historical mine survey data (floor elevations represented on Figure 4 of the main text) and future mine planning. Cells are activated at specific times in the mining process that approximately represent the extraction of the floor seam. This simplification of 'immediate' extraction results in abrupt increases in the model predicted seepage rates to the mine pit(s) which have then been integrated with respect to time, to generate a more regular or 'smoothed' prediction of mine pit seepage.

Rainfall recharge has been applied to hardrock areas across the model at rates of 3 to 5 mm per annum or about 0.5 to 1% of annual rainfall. The rate is function of the adopted permeability – the lower the assigned permeability, the lower the recharge rate. A typical range used in previous studies is 0.5 to 2%. Recharge to the alluvium has been set at 60mm/year equivalent to about 10% of annual rainfall. Since recharge to this lithology is immediately 'sinked' to the major drainages via river cells, it is relatively insensitive for values of this magnitude or higher.

E1.1 Model limitations

Representation of the many seams and interburden lithologies by incorporating separate model layers, is considered impractical. The large number of 'dry cells' that would accumulate during simulation of open cut mining would result in significant instability in the solvers used to predict head distributions. For this reason the model has been simplified to a 7 layer case for the westerly dipping strata.

Model limitations include consolidation of many lithologies into single layers, simplified assignment of permeability based on consolidation of available data, generalisation of storativity, and uniform assignment of rainfall recharge.

E1.2 Model calibration

It has not been possible to closely calibrate the model to piezometric responses since coal measures piezometric data is of limited extent and derived from different seam horizons. A coarse history matching has however been undertaken by simulating mining from commencement in 1983 to the present time and comparing the regional depressurisation extent measured in 2001 with the model predicted extent, and comparing the estimated pit seepage with the model predicted seepage to the mine pit(s).

The simulated impact zone at 2002 has been defined by drawdowns greater than 2m this being the order of movement in piezometers that could be attributed to varying climatic conditions. Beyond this, falling water levels are most likely to reflect induced depressurisation. Simulated responses indicate a cumulative impact zone of approximately 1.5 kilometres to the west with no impact on the eastern alluvial lands due to the higher storage and recharge characteristics of these unconsolidated materials. Exceptions include piezometers located close to the northern perimeter of the pit but these are probably influenced by the shallow regolith groundwater system.

Best estimates for current pit seepage rates arising from groundwater are about 0.4 ML/day based on water balance calculations for the mine water system. This rate compares with modelled estimates of 1.4 ML/day after allowing for typical evaporative losses on the pit walls and floor areas of up to 1 ML/day based on an average annual evaporation rate of 1240 mm and an exposed loss area of more than 100 Ha.

E1.3 Simulation of mining

The progression of mining has been simulated from the beginning of 1983 (model start date) to the present time adopting a generalised representation of resource extraction. Future extraction has been simulated by assigning drain type cells to the deeper pit floors as depicted on the 0, 2, 5, 10, 15 and 18 years mine plans provided as Figures E3 to E5.

The initial 1983 pressure distribution cannot be determined from the available data. An estimate has therefore been generated using pre mining model constraints (steady state – Figure 4 of main text).

All model simulations have been checked for solution discrepancies by examining the overall mass balance for the modelling period. That is, all inflows, outflows and changes in groundwater storage have been consolidated and balanced at the end of each solution time step. Where significant discrepancies occurred, additional solution times were incorporated with a resulting convergence discrepancy generally less than 0.05%. Since the model is multi layered, representation of formation pressures within separate layers requires careful evaluation.

Figures E6 to E8 show predicted depressurisation and the predicted pressure differential or drawdown calculated as the difference from the initial pressure distribution in 1983 shown as the upper plot of Figure E6.

Mine pit seepage estimates have been prepared by summating pit seepages at floor/rain cells over the mine life. Since these estimates are at 2 to 5 yearly intervals, a continuous estimate has been prepared by integrating the piecewise response, accumulating and differentiating a suitable ‘fitting’ function. Figure E9 shows the time step response and the best estimate of seepage (fitted trend).

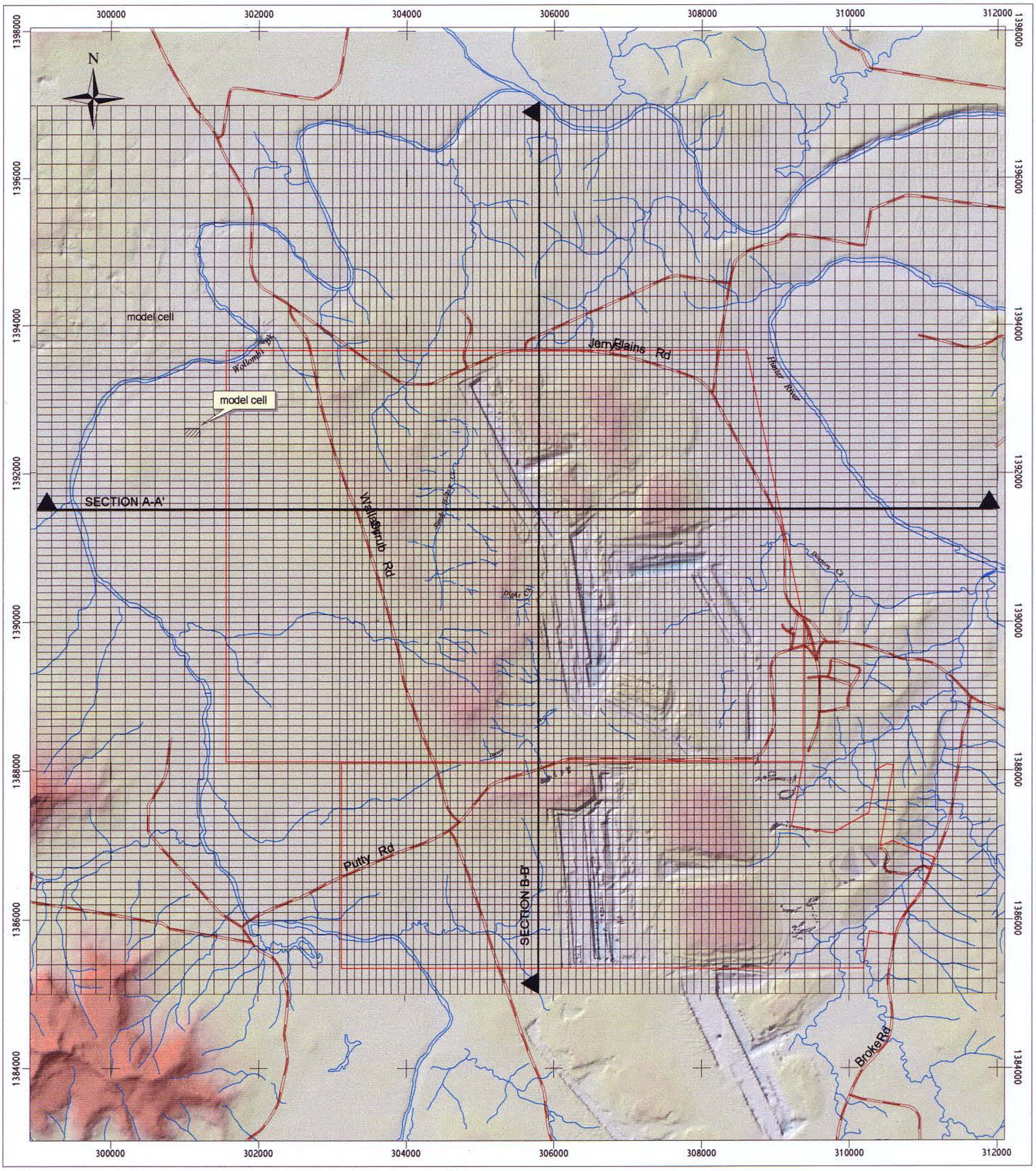
Since the pit is depressurising below the regional water table, the contribution to seepage arises from formation storage depletion (gravity drainage) and from leakage beneath the alluvial lands. In order to estimate leakage losses from the alluvial lands, specific cells were assigned to a zonal budget and the leakage term then extracted from the simulation output. Figure E10 shows the overall budget with inflow decreasing and outflow increasing. The net balance is also shown.

E2. RECOVERY OF AQUIFER PRESSURES POST MINING

On cessation of mining, the pit may re-saturate through natural groundwater seepage and rainfall runoff contributions. An estimate of the rate of recovery of void water levels attributed to formation seepage alone, has been made by assigning model water levels at the completion of mining in 2020 as an initial condition for recovery simulations. Hydraulic properties within the model have also been modified - permeability and storativity within the pit areas have been changed to 1m/day and 20% respectively for spoils. In open pit areas, 100% porosity has been assigned to represent air/void space. Rainfall recharge has been maintained at 11mm/annum for hardrock areas and increased to 30mm/annum over spoils areas to represent changed conditions in the root zone of rehabilitated areas. While this rate is fairly arbitrary higher rates will simply lead to an increased rate of recovery.

Due to the difficulty in achieving stable solutions when the re-wetting (cell recovery) function of Modflow is invoked (McDonald et.al., 1991), the solution process has been simplified by reducing the number of model layers and utilising coarse rewetting thresholds. Accordingly, recovery estimations should be considered as 'generalised' approximations.

The recovery of groundwater pressures will also depend upon the cumulative impacts arising from Mt. Thorley and any other mining operations in proximity. In order to establish a minimum time for recovery, Warkworth Mine has been simulated without cumulative impacts. That is, the water table at 2020 (including cumulative losses) has been allowed to recover through natural seepage without ongoing mining at surrounding mines. Figures E11 and E12 provide responses at 1, 10, 50 and 100 years after cessation. The mined area will not recover to the pre mining water table due to the replacement of large areas of low permeability and low storage hardrock with areas of high permeability and high storage spoils. A long term recovery level of about 45 mAHD is estimated.



0 2000 4000 6000 Metres

Scale 1:75000 Base map information from 1:25,000 topo series (Central Mapping)
Additional data supplied by Warkworth Mine

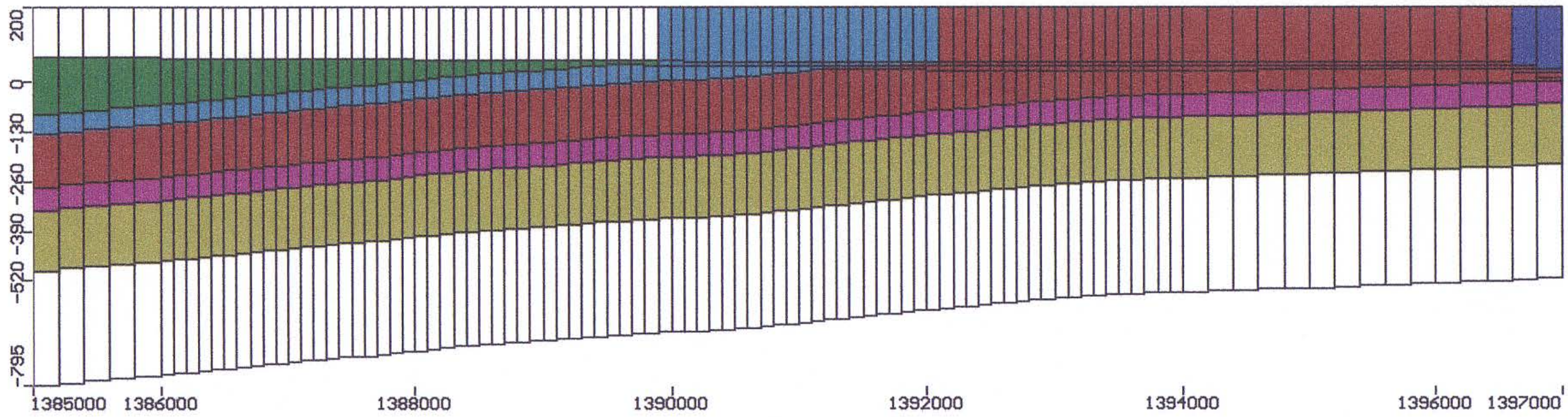
-20 - -10	50 - 60	120 - 130	190 - 200
-10 - 0	60 - 70	130 - 140	+200
0 - 10	70 - 80	140 - 150	creeks
10 - 20	80 - 90	150 - 160	dirt roads
20 - 30	90 - 100	160 - 170	sealed road
30 - 40	100 - 110	170 - 180	main road
40 - 50	110 - 120	180 - 190	mine lease

WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

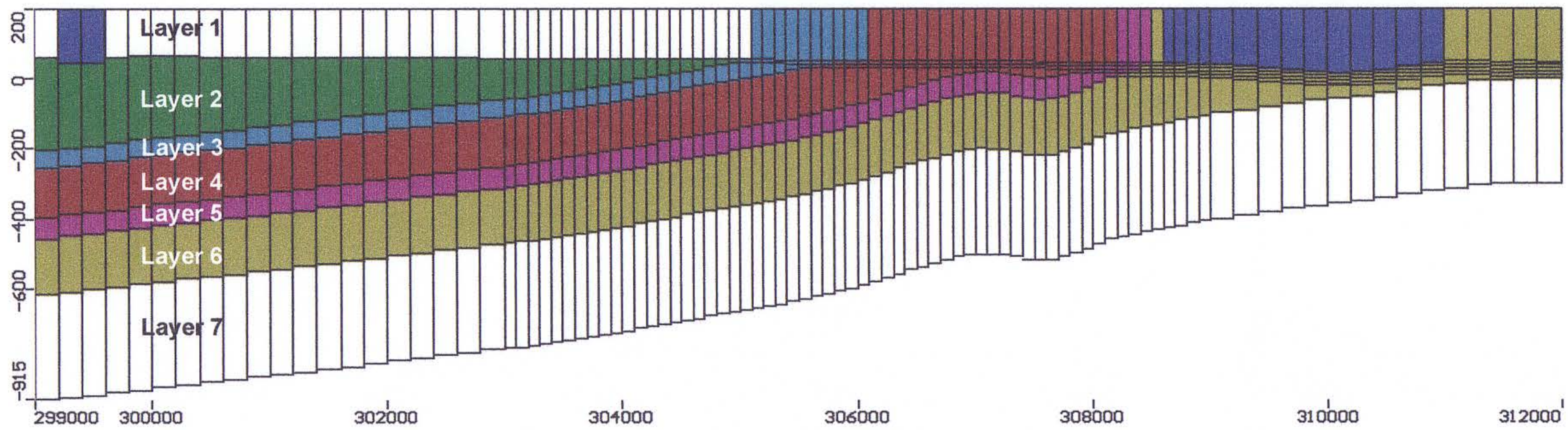
Aquifer model regional extents and cell geometry

Mackie Environmental Research

Figure E1

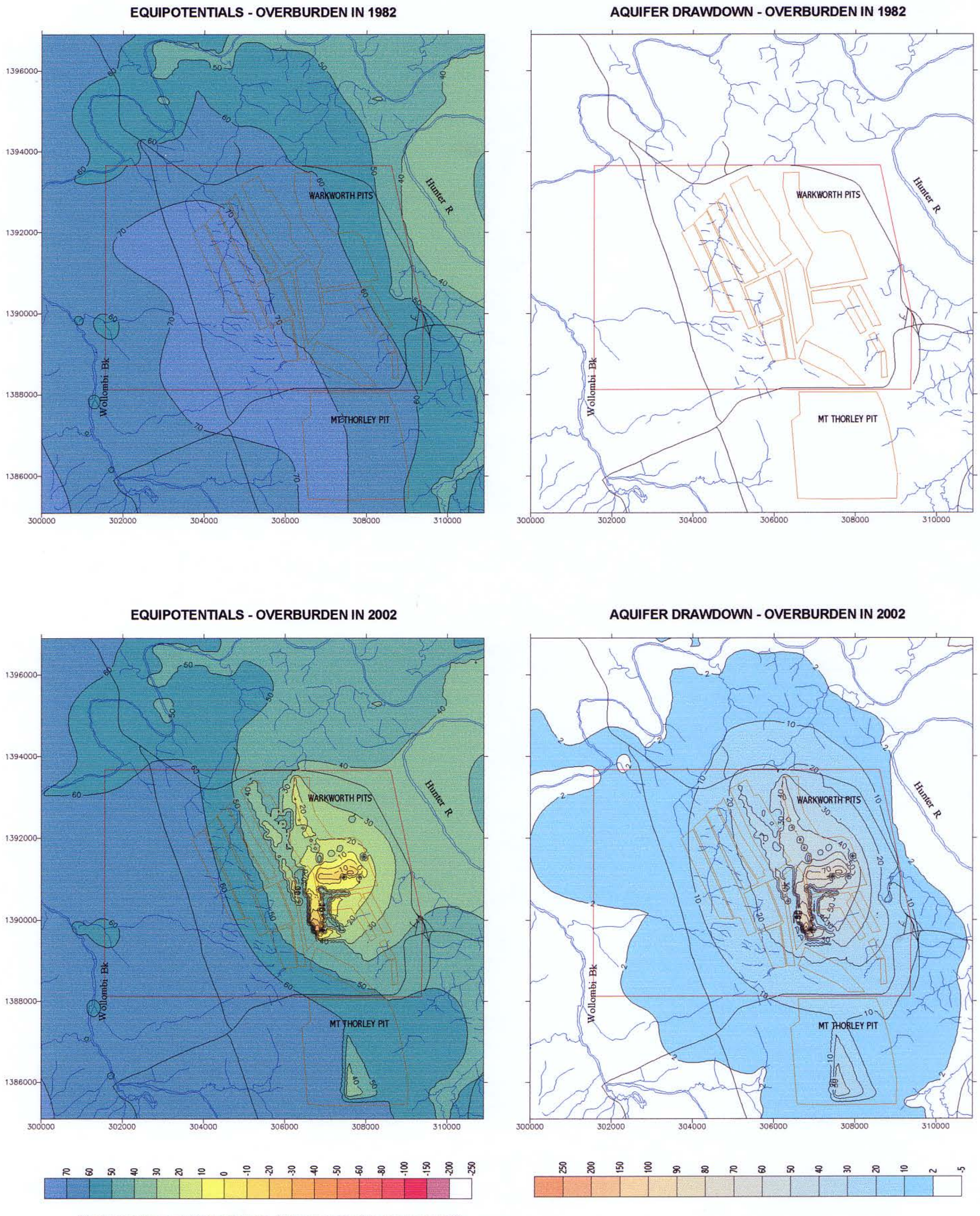


SOUTH TO NORTH SECTION B-B'



WEST TO EAST SECTION A-A'

Figure E2



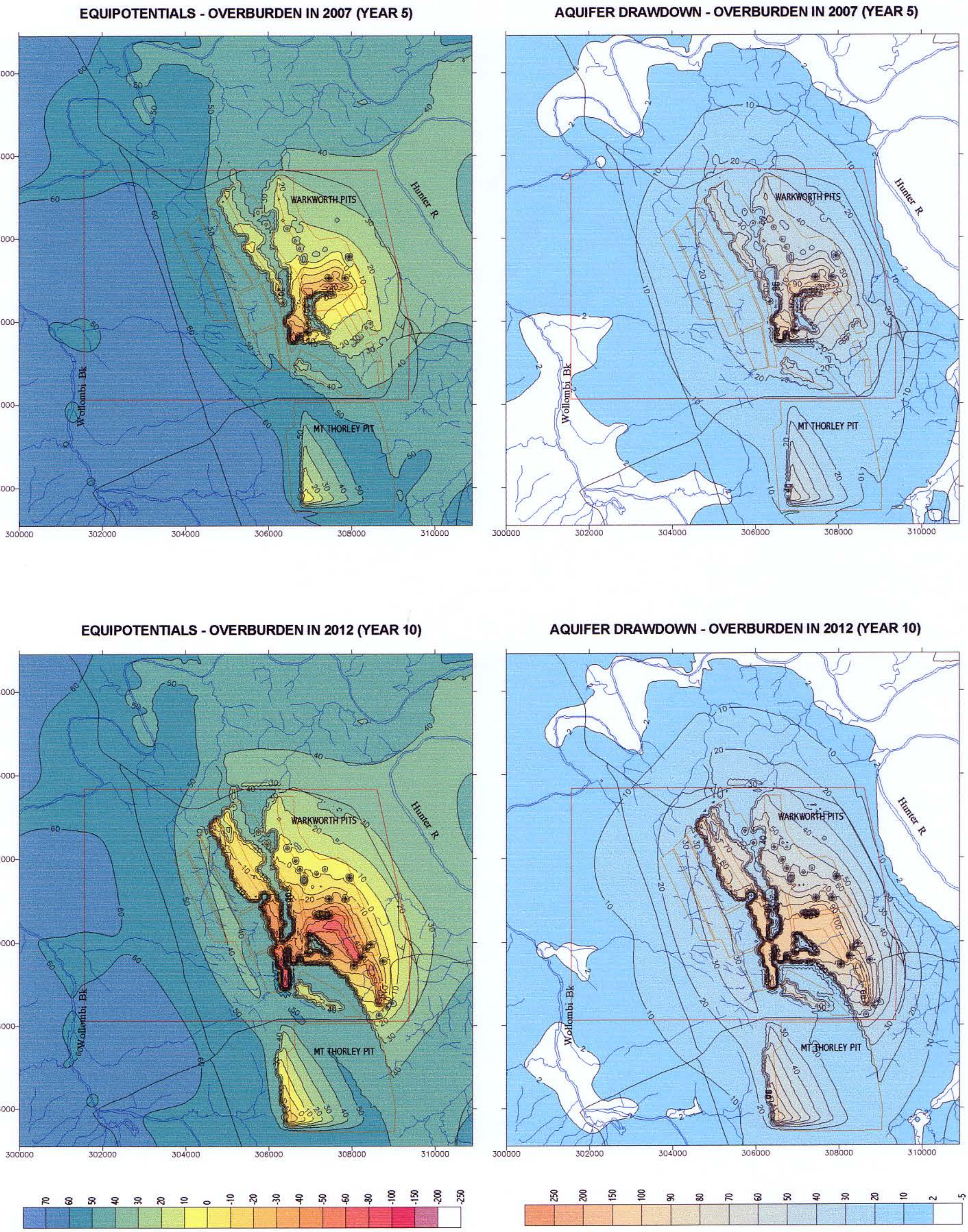
Coal measures aquifer pressures (left hand plots) in metres (AHD)
Loss of pressure (right hand plots) in metres of water
Contouring based on 50 metre interpolation

Scale 1:130,000

WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

Coal measures depressurisation
Shallow overburden zone at 1982 and 2002

Figure E3



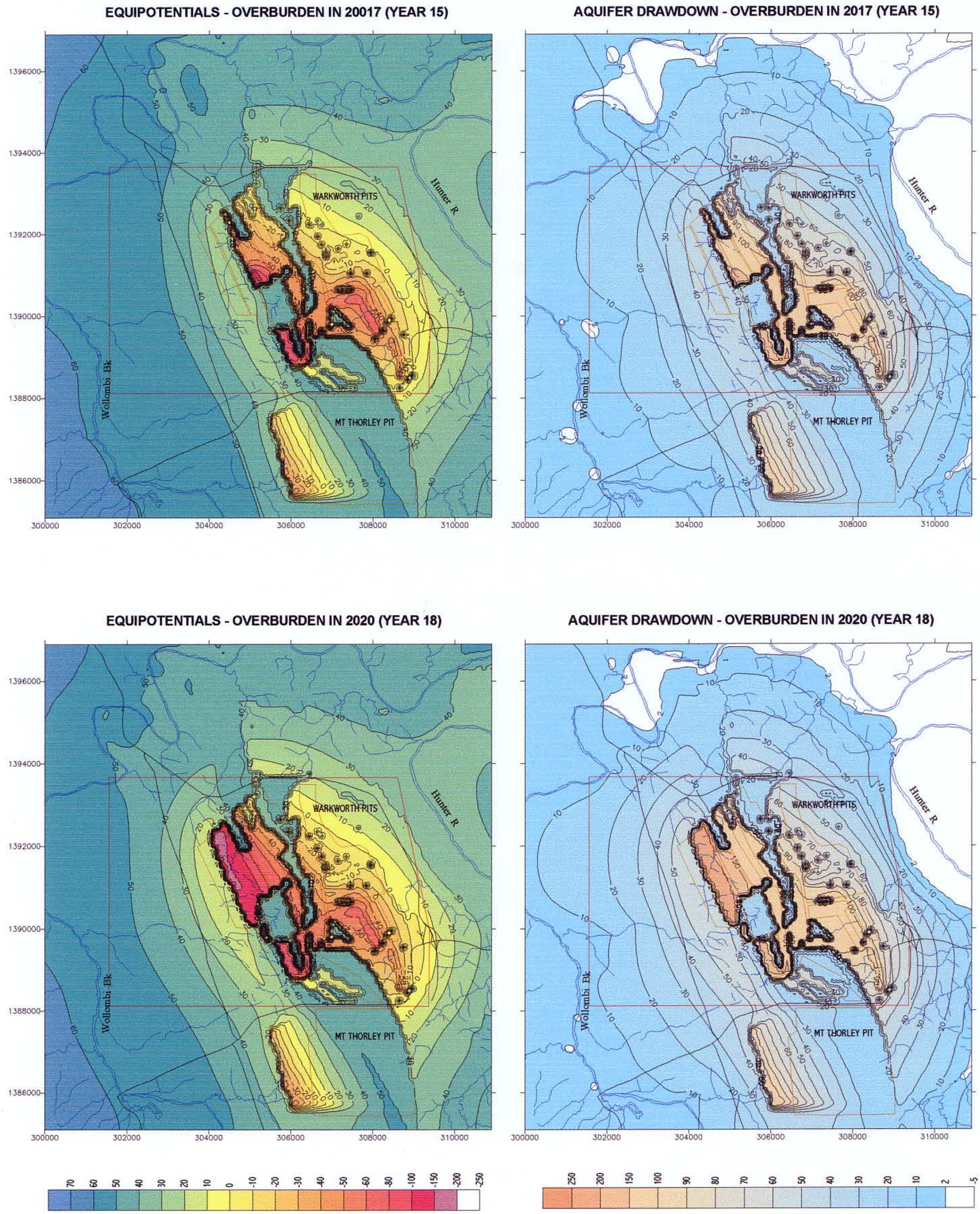
Coal measures aquifer pressures (left hand plots) in metres (AHD)
Loss of pressure (right hand plots) in metres of water
Contouring based on 50 metre interpolation

Scale 1:130,000

WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

Coal measures depressurisation
Shallow overburden zone after 5 and 10 years

Figure E4



Coal measures aquifer pressures (left hand plots) in metres (AHD)
Loss of pressure (right hand plots) in metres of water
Contouring based on 50 metre interpolation

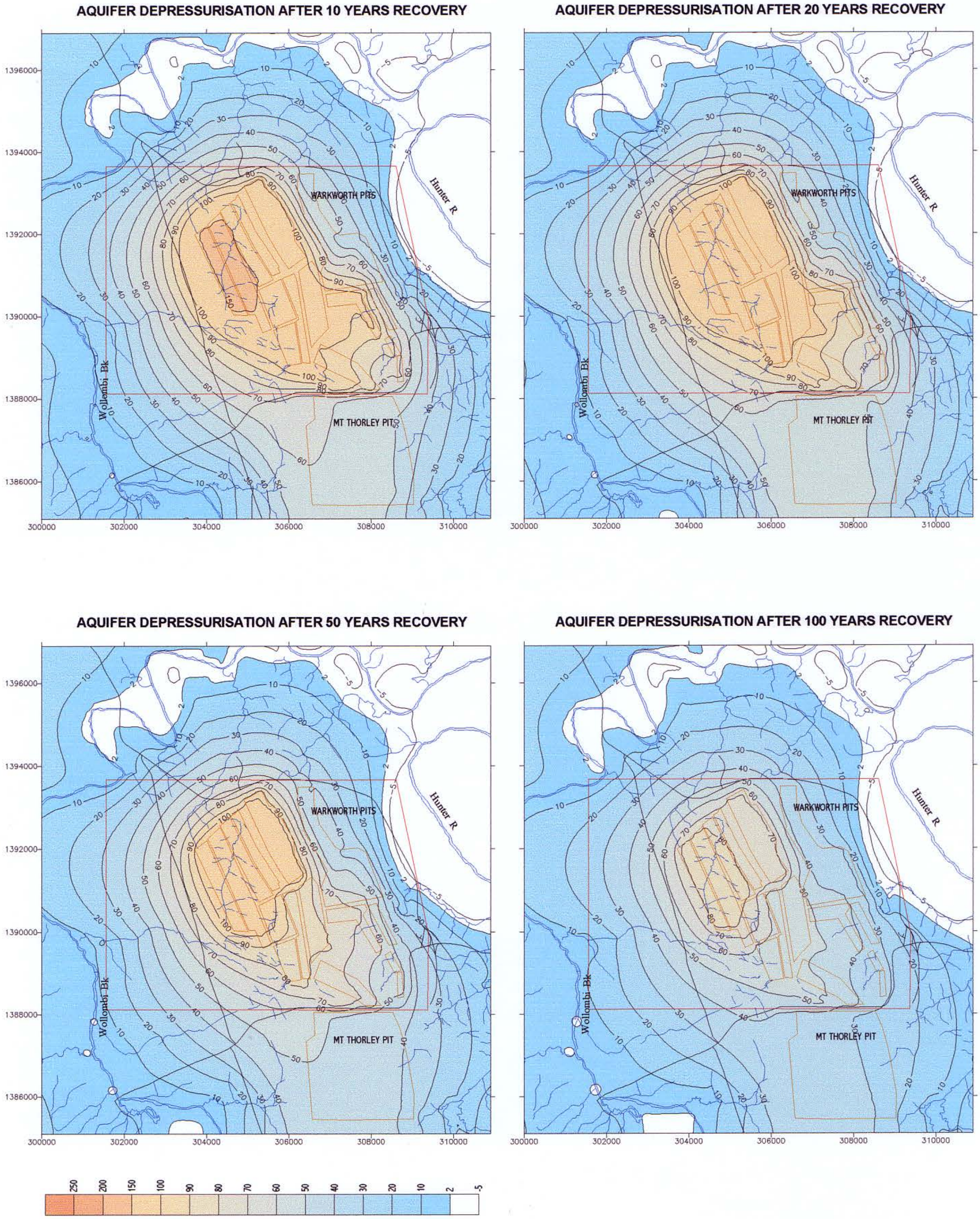
Scale 1:130,000

WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

Coal measures depressurisation
Shallow overburden zone after 15 and 18 years

Mackie Environmental Research

Figure E5



Coal measures aquifer pressures (left hand plots) in metres (AHD)
Loss of pressure (right hand plots) in metres of water
Contouring based on 50 metre interpolation

Scale 1:130,000

WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

Coal measures depressurisation (drawdown)
Shallow overburden recovery 10 to 100 years

APPENDIX F

Spoils leachate

F1. SPOILS LEACHATE

Interburden spoils have the potential to generate leachate in the long term. The process comprises two phases – leachate generation during mining, and leachate generation post mining.

During mining, rainfall percolates into mine spoils areas through unshaped, shaped and rehabilitated areas. The rate of infiltration/percolation varies significantly for the different catchment types. Percolating rainfall below about 5 metres depth (beyond evaporative and root zone influences), is most likely to remain as soil moisture and to migrate to the base of the spoils. The pathway adopted by infiltrating rainfall is preferential due to the nature of emplacement – highly variable grain sizes from less than 1mm to more than 2 metres diameter leave many open voids. Leaching of salts occurs along this pathway, the efficiency of the leaching process being governed by the grain size distribution. Large rocks remain essentially impermeable and have poor leaching characteristics while crushed rocks offer improved leaching characteristics due to the reduced grain size and increased surface area per unit volume.

Leachate generated during mining is retained within the mine water system since it generally emanates at the toe of the pit low wall and is subsequently used in coal washing, dust suppression and other activities. When mine pit operations cease and rainfall, runoff or groundwater begins to accumulate in the final void and beneath the shaped spoils profile, the groundwater quality will reflect a mixture of rainfall, percolating rainfall/leachate and regional groundwater. The process is quite complex and poorly researched. An approach has been adopted whereby an average spoils fragment size distribution is assumed and the leachable salt load calculated on the basis that relatively short term release (ie. not geologic time) is governed by surface area. Two distributions adopted for the current analyses are considered to generally represent limits of blast fragmentation. These distributions include an 'optimal' with a larger fragmentation, and a distribution with increased fines that may be attributed to increased lithic material or increased handling.

When mine pit operations cease and rainfall or groundwater begins to accumulate in the final void and beneath the shaped spoils profile, the groundwater quality will reflect a mixture of rainfall, percolating rainfall/leachate and regional groundwater. Based on computer simulations of the recovery process and estimation of percolation components, more than 60% of void water is expected to be sourced from rainfall derived/runoff while the remainder will be sourced from coal measures seepage.

Since void water level recovery will mass saturate the spoils, the salt contribution can be estimated by conducting leachate trials on rock samples having a similar grain size distribution to spoils emplaced. However, the practical limit to fragment size for laboratory trials in the current study has been restricted to a range from less than 0.18 mm (sieve size) to a maximum of 20 mm.

F2. SAMPLE PREPARATION

In order to undertake leachate trials, eight core samples were selected from exploration bore DDH305 shown on Figure F1 at increasing depths. This bore location provides good intersections of interburden zones.

The leachate technique adopted was a simple closed system comprising submergence of samples in de-ionised water and subsequent monitoring of pH and electrical conductivity (EC) over the following weeks.

Based upon current research, this closed system approach is considered to provide a reasonable representation of anoxic conditions prevailing in spoils at depth. Since pH reflects hydrochemical activity and EC is a good indicator of dissolved salts, monitoring of both parameters over time permits extrapolation to limiting values.

Prior to commencement of the trials, samples were sieved and different fractions separated. By undertaking trials on sieved samples, it was possible to re-constitute different distributions and determine with improved accuracy, the leachable salt load (LSL) for any distribution. Sieved samples included the following fractions +0.18, +0.9, +4.5 and +12.5mm. Samples were photographed and measured for elongation and distribution checks. Sample weights ranged from 50 to 120grams. All samples were maintained in the temperature range 19.0 to 20 degrees during the trials.

Measurement procedure comprised decanting approximately 50ml of leachate. A TPS MC84 meter was used for all EC measurements while a Lutron pH-206 meter was used for all pH measurements. Instruments were calibrated prior to commencement and following completion of measurements. Drift was noted to be insignificant on all occasions.

EC measurements were converted to represent milligrams dissolved salts (using a conversion factor of 0.65) per gram of spoils and then extrapolated to an end point at 100 years for subsequent calculation of mobilisable salt load. Data used for extrapolation of results for +0.9mm sieve are shown on Figure 2. End point LSL determinations were conducted by fitting an equation of the following form (coefficients listed in Table F1):

$$LSL = (a + b * \ln(t))^2$$

where: LSL = end point (g/kg)
a = coefficient
b = coefficient
t = time in days

Table F1: Summary of leachate samples (+0. 9mm fraction)

Sample	lithology	depth (m)	Coeff a	Coeff b	r^2	End point load (gm/kg)
305/54.5	coarse to fine grained white/grey quartzose sandstone with occasional carb fleks	54.5	0.80443	0.05136	0.961	1.82
305/91.5	coarse to medium white /grey grained quartzose sandstone with rare carb fleks	91.5	0.59144	0.06775	0.981	1.70
305/108	shale - grey to dark grey with minor laminite	108	0.43037	0.15529	0.980	4.25
305/125	sandstone - medium grained white/grey with minor carbonaceous fleks	125	0.67938	0.10855	0.980	3.31
305/140	sandstone - medium grained white with numerous carbonaceous streaks	140	0.38989	0.17600	0.993	5.01
305/170	sandstone fine grained grey white with carb fleks	170	0.42775	0.10872	0.992	2.46
305/198.5	siltstone and fg sandstone with carb streak layers throughout	198.5	0.28165	0.24451	0.994	8.12
305/226	claystone (Fairford) white to cream	226	0.28647	0.19583	0.987	5.49
					average	4.02

After 12 weeks, 8 samples (-0.18mm sieve) were dispatched for laboratory determination of major ions and selected rare elements (Genalysis Laboratory Services). Results are provided as the laboratory data sheets.

Laboratory data has been used to generate a tri-linear speciation Figure F3 for the purpose of classing the leachate and understanding the relationship between leachate chemistry and regional water sampling. Cations and anions are plotted in the lower left and lower right triangular fields respectively and these points have been projected into the central diamond field. Nearly all samples plot in an area dominated by sodium with minor contributions from calcium and magnesium. Bicarbonate is the dominant anion with subordinate chloride and sulphate contributions. No sample exhibits a strong primary salinity (NaCl). The strong sodium bicarbonate 'characterisation' is thought to reflect the dissolution of dawsonite, a mineral known to be prevalent throughout the Permian coal measures.

F3. SALT REMOBILISATION ANALYSIS

End point LSL calculations for all sieved fractions have been used to generate an estimate of the long term LSL per cubic metre of spoils. The estimation adopts an equation that reflects a falling LSL for increasing fragment size. While this does not include reactive or weathering components, there is increasing evidence to suggest the assumption is reasonable; most interburden units comprise clastic sediments with quartzose granular structure resulting from the depositional environment, and most spoils are emplaced and covered fairly rapidly.

F3.1 Salt load estimation

Blasting operations aim to optimise fragmentation towards the larger rock mass. The resulting distribution can be approximated by the Rozin Rammler formula shown on Figure F4. Two limiting plots are indicated – the optimal or maximum sizing assumes efficient blasting and blocking with reduced handling, while the reduced sizing assumes much lower efficiency in basting and handling resulting in a consequential increase in the smaller diameter rocks and fragments. The intermediate sizing is considered to represent the likely distribution at Warkworth Mine – a combination of drag line and truck and shovel operations.

Laboratory analyses and end point estimates for the very small particle sizes (less than 20mm) have been extrapolated to the full particle size using an equation that reflects a reducing LSL with increasing particle size. The equation is of the form:

$RR_{100} = a + b*\ln(\text{size})$ where: RR_{100} = salt release at 100 years (gm/kg of sample)

$a = 3.90$

$b = -.51$

size = average (retained sieve) particle size

Tables F2 and F3 provide summaries of theoretical particle distributions for a 10 tonne sample together with the calculated salt load based on measured release rates and the above equation, and an estimated cumulative (total) salt load for each of the limiting distributions shown on Figure 4. Assuming a spoils average emplaced density of about 1.9 t/m^3, the equivalent mobilisable salt loads per cubic metre of spoils for the optimal and reduced size distributions are 0.96 kg and 2.36 kg respectively.

Table F2: Calculated mobilisable salt (10t spoils) – maximum sizing distribution

Screen size (mm)	weight passing (%)	weight retained (mg)	Projected dia. (mm)	calc. salt load (gm/gm)	cum. salt load (gm)
<0.18	3.24E-08	0.3	0.09	0.002	0.002
0.18 to 0.4	160E-07	1.6	0.29	0.006	0.007
0.4 to 0.9	8.10E-07	8.1	0.65	0.027	0.034
0.9 to 2.1	4.41E-06	44.1	1.5	0.133	0.167
2.1 to 5	2.50E-05	250	3.5	0.670	0.837
5 to 10	1.00E-04	1000	7.5	2.2	3.0
10 to 20	4.00E-04	3999	20	7.1	10.1
20 to 50	2.50E-03	24969	35	43.8	53.9
50 to 100	9.95E-03	99502	75	126.6	180.4
100 to 200	3.92E-02	392110	150	393.4	573.9
200 to 500	2.21E-01	2212000	350	1660.6	2234.4
500 to 1000	6.32E-01	6321200	750	2152.3	4386.7
1000 to 2000	9.82E-01	9816800	1500	595.4	4982.1

Table F3: Calculated mobilisable salt (10t spoils) – minimum sizing distribution

Screen size (mm)	weight passing (%)	weight retained (mg)	Projected dia. (mm)	calc. salt load (gm/gm)	cum. salt load (gm)
<0.18	0.0006	5998	0.09	30.7	30.7
0.18 to 0.4	0.0013	7322	0.29	33.2	63.9
0.4 to 0.9	0.0030	16580	0.65	68.3	132.2
0.9 to 2.1	0.0070	39800	1.5	147.0	279.2
2.1 to 5	0.0165	95300	3.5	310.1	589.3
5 to 10	0.0327	162000	7.5	165.3	1054.7
10 to 20	0.0645	318000	20	754.4	1809.0
20 to 50	0.1530	885000	35	1846.8	3655.8
50 to 100	0.2830	1300000	75	2207.5	5863.3
100 to 200	0.4860	2030000	150	2729.5	8592.8
200 to 500	0.8111	3251000	350	2966.4	11559.2
500 to 1000	0.9640	1529000	750	800.8	12360.0
1000 to 2000	0.9987	347000	1500	59.1	12419.5

F3.2 Void water quality

The volume of interburden spoils emplaced during the mining process below the long term recovered water table of approximately 45 mAHD (and ultimately re-saturated), is estimated to total 8.8 x 10^8 m^3 as indicated on Figure F5. The void air space that will also fill from rainfall runoff and coal measures seepage is estimated to total 2.5 x 10^8 m^3.

Void water quality at the recovery of water levels has been estimated by calculating the 'instantaneous', salt load base upon projected LSL from spoils (Section F3.1) and dilutions derived from open void storage. A consolidated bulk porosity of 20% is assumed in spoils. The following Table F4 provides results of calculations based on leachable salt loads determined for each of the fragmentation distributions given in Tables F2 and F3 and not accounting for evaporative concentration in the void. Estimates assume about 70% of void/spoils water derives from rainfall (runoff modelling) while 30% derives from coal measures groundwater seepage with a total dissolved salts content averaging 8673 mg/L (approximately 13343 uS/cm EC).

Table F4: Summary of leachable load for different fragmentation regimes

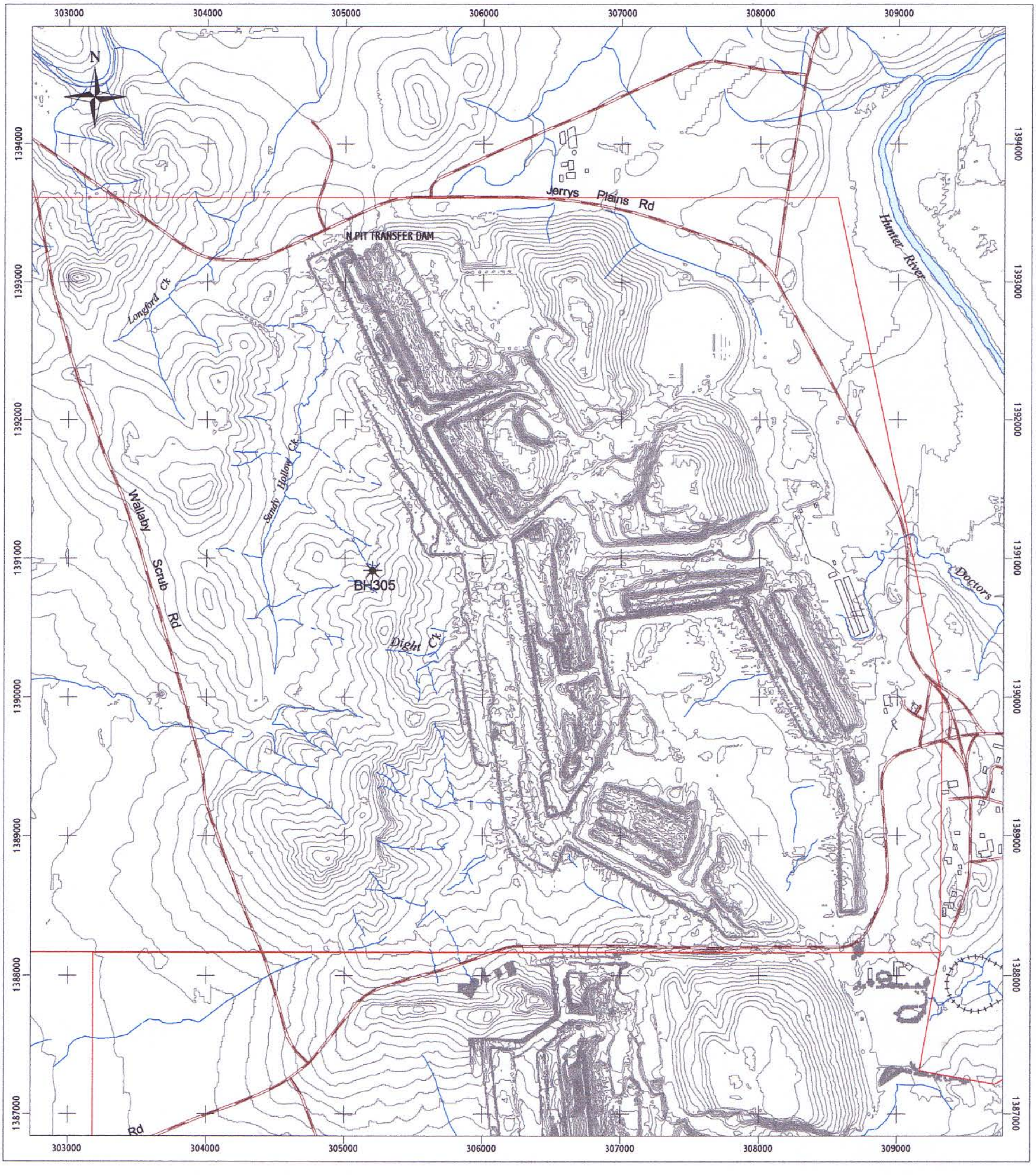
	units	Optimal fragmentation	Reduced size fragmentation
Leachable salt load	kg/m^3	0.96	2.36
Mixed water quality in spoils	mg/l	7542	14542
Final void mixed water quality	mg/l	4667	4559

F3.3 Void runoff - evaporation

Long term water levels in all voids will be governed by the balance between rainfall, runoff and evaporation assuming groundwater seepages are in an equilibrated state. It can be shown (MER 2001) that for an open water condition without contributing catchment runoff, water losses will accrue at a rate of about 1.3 mm per day based on the local rainfall record and Scone Research Station evaporation data (Appendix A) adjusted for open water potential evaporation.

Hence in the absence of inputs like runoff and groundwater seepage, an evaporative sink would be maintained in the final void. Increasing the runoff area to about 8.3 times the free water surface (83 ha for each 10 ha water surface) leads to a balanced state while larger runoff areas would lead to a surplus condition and higher void water levels than the equilibrated regional water table.

A final void water surface at 45 mAHD would have a surface area of approximately 281 ha while the contributing catchment based on preliminary final void design is estimated at 1058 ha. The ration of these areas is 2.76 and as such, an evaporative sink is predicted – the final void water level is likely to remain below 45 mAHD. The void will act as a sustained attractor and will increase in salinity through evaporative losses.



0 1000 2000 3000 Metres

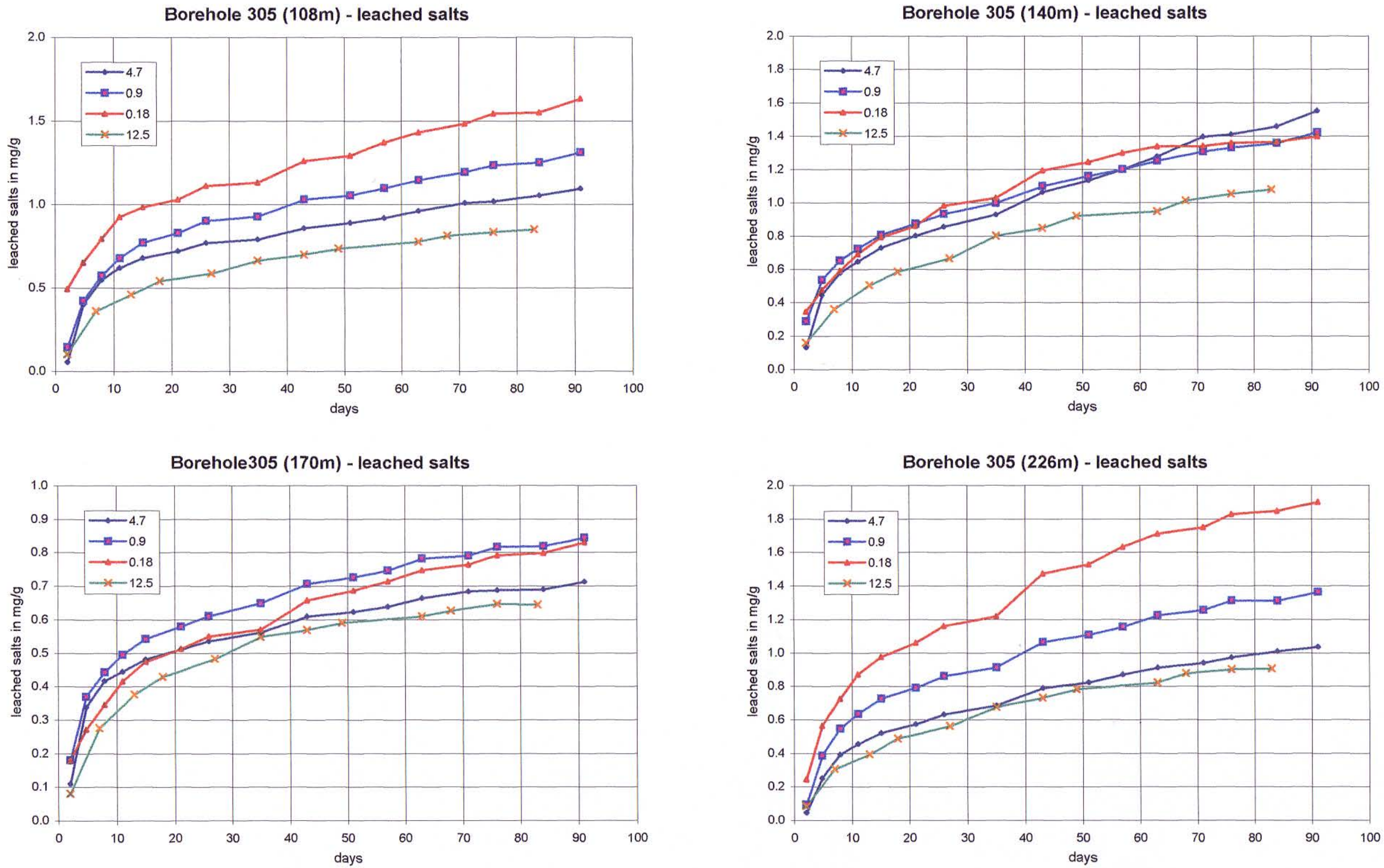
Scale 1:40000 Base map information from 1:25,000 topo series (Central Mapping)
Additional data supplied by Warkworth Mine

- creeks
- dirt roads
- sealed road
- main road
- railway
- mine lease
- piezometer locations

WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

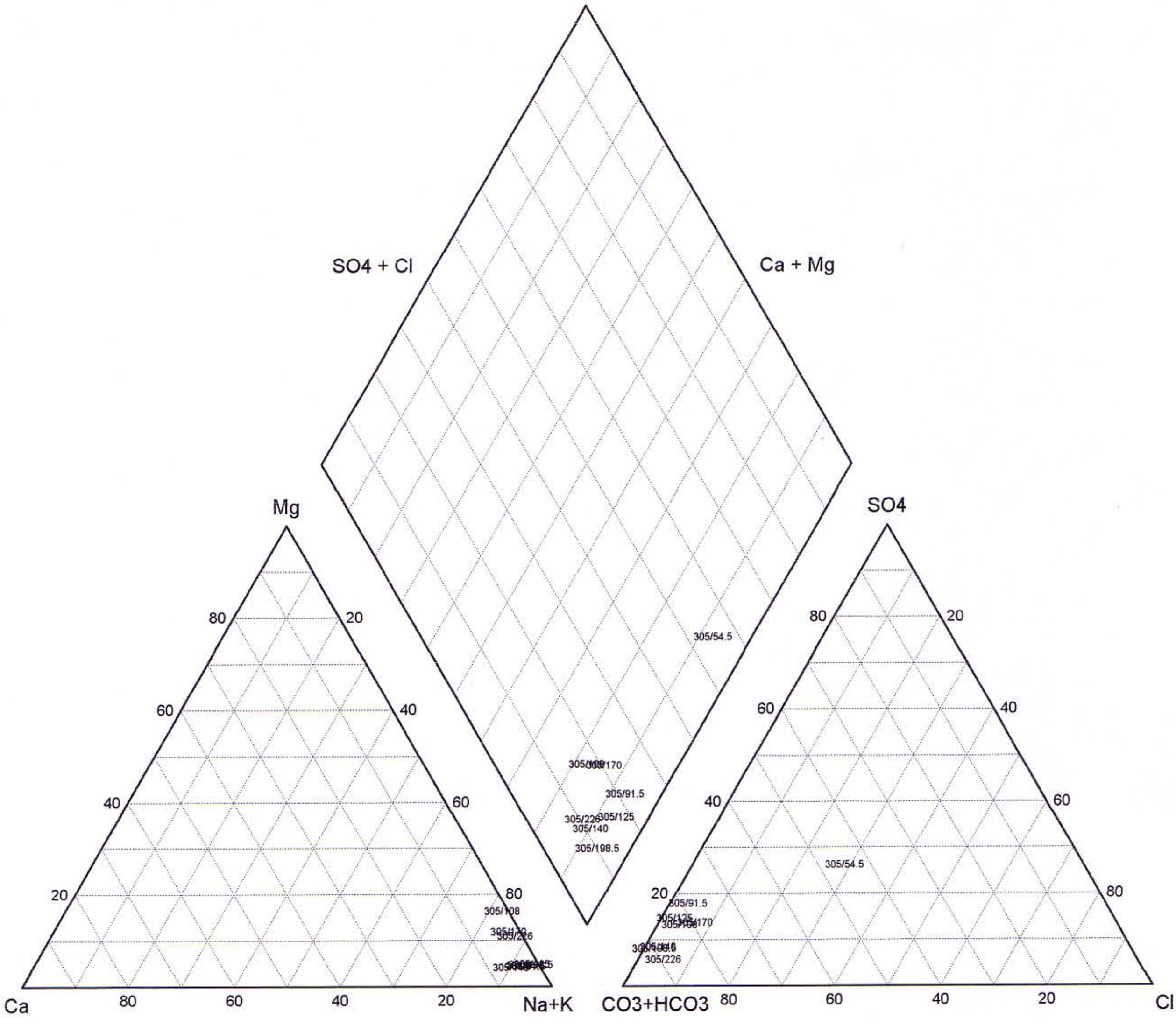
Location of bore for core leachate trials

Figure F1



Leachable salt trials on core - typical response plots

Figure F2



Cations expressed as % meq

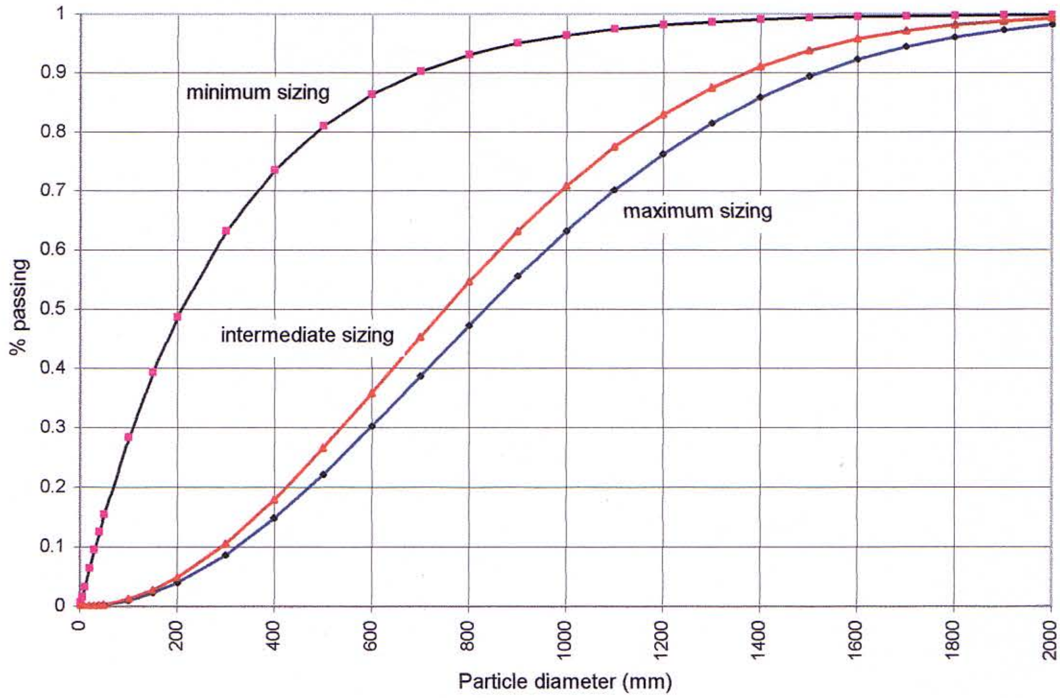
Anions expressed as % meq

IONIC SPECIATION SUMMARY (milligrams per litre)

Sample	TDS	Ca	Mg	Na	K	CO3	HCO3	SO4	Cl
305/54.5	320	3	3	104	6	6	122	62	50
305/91.5	280	2	2	85	10	21	153	35	5
305/108	2520	3	21	152	77	30	281	43	10
305/125	820	2	4	122	19	47	183	39	5
305/140	240	7	3	117	9		305	23	5
305/170	1300	3	9	96	49	21	159	27	10
305/198.5	1060	2	5	159	25	18	354	28	5
305/226	2900	3	12	154	37	56	207	16	10

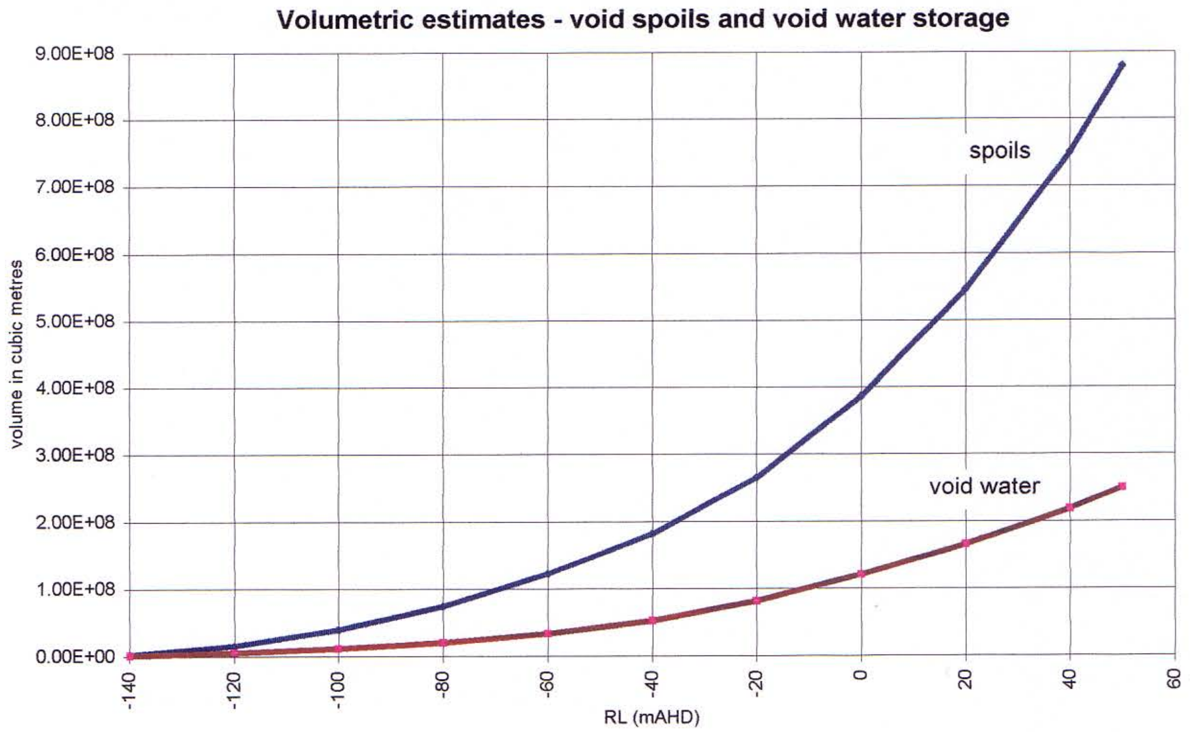
HYDROCHEMICAL FACIES DIAGRAM

Optimal blast fragmentation distribution



Fragment size distribtions assume Rozin - Rammler equation for blast fragmentation. Minimum sizing (increased contribution from fines) represents estimated minimum distribution and maximum leachable salt load. Maximum sizing represents the best estimate for mostly dragline operations and generates a lower overall leachable load. Warkworth distribution may be nearer intermediate sizing.

Assumed spoils fragmentation distribution



Spoils estimates based on void space in all pits since commencement of mining. Void water estimates based on final void only.

Spoils and void water volumes for final pit shell

APPENDIX G

Mine water management system

G1. MINE WATER MANAGEMENT MODEL

The WaterLog-5 dynamic catchment simulation and water balance model is a computer based scheme that has been designed and tested over a number of years. The model was developed in recognition of the need to understand mine water management system responses to rainfall and to establish storage capacities to meet most mine site operational conditions.

The proprietary computer model (written in Fortran 90) incorporates a number of published algorithms and estimation techniques, and includes rainfall and runoff from both undisturbed and disturbed catchments with provision for changing catchment areas, percolation to groundwater, pit seepage, accumulation of runoff in designated storage dams, siltation of dams, pumpage (transfer) between dams and pumpage from dams for mine site usage. The model also includes a module for discharge of surplus water from a system at nominated rates and at specified times to facilitate review of system response to external constraints such as the Hunter River Salinity Trading Scheme (HRSTS).

Fundamentally the model calculates and accumulates runoff from any number of specified catchment types based on daily rainfall and evaporation, and balances the water budget on a daily basis. The model is broadly subdivided into catchment contributions and storage management.

Like many soil moisture accounting techniques, the catchment runoff modules are based on a lumped parameter design utilising daily rainfall records and monthly evaporation potentials. The following schematic shows the general design of the runoff analytical process while the following provides an overview of components.

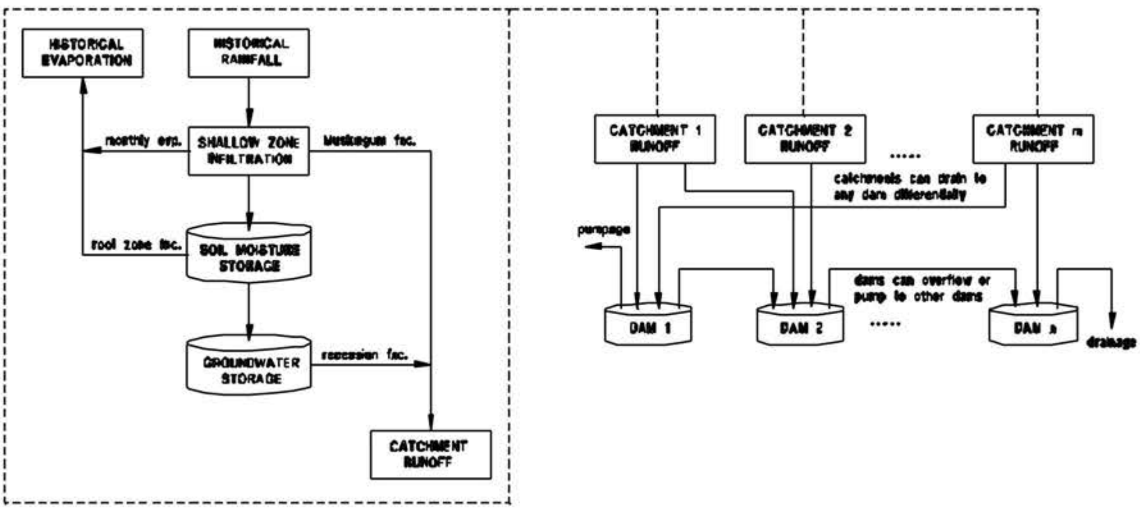


Fig G1: Generalised layout of water management model

Catchment areas: Catchment areas (including underground operations) are assigned but may be varied during the course of a model simulation. Variable catchment areas are particularly useful for generating simulations of mine and other developments where for example, strip and bench, pit, spoils and rehabilitated areas are steadily expanding during development. The smallest incremental change in a catchment area is monthly.

Rainfall: Daily rainfall data is used for all simulations. However to account for variability in rainfall and variability in infiltration, the model disaggregates daily receipts into a sequence of hourly receipts based upon a generalised relationship between absolute rainfall received, and event duration (Pitman, 1973). Once the duration of rainfall (less than 1 day) is established, the rate of fall is then adjusted to reflect a steady increase in intensity followed by a steady decrease in intensity over the period, the total mass received being equivalent to the recorded daily rainfall. Model time stepping is then adjusted accordingly. In this manner a more realistic accounting of evaporation and infiltration is implied but the procedure also constrains rainfall to the daily measurement period. Continuous rainfall over a number of days is treated as separate 24hr events for each day.

Evaporation: Evaporation is assigned as monthly mean Pan A adjusted by an open water or crop/tree loss factor etc. and is calculated and applied daily to both catchment soils and water bodies. Evaporation may also be estimated using the Penman-Thornwaite equations.

Interception storage: Initial losses from any rainfall event are incurred by interception within the canopy or grass cover, or by wetting of the soil surface before any infiltration can occur. Normally this amounts to only 1 or 2 mm of rainfall and is removed from the model accounting process at the average potential evaporation rate.

Surface runoff: This component is comprised of runoff from impervious areas and runoff attributed to surplus rainfall not able to infiltrate the soil zone when soil moisture is at a maximum or when rainfall intensity is higher than the soil infiltration capacity. Runoff from impervious rock outcrop is calculated by simply assigning a percentage of a catchment adjacent to drainage. Impervious areas can be estimated by geological inspections or air photo analysis. Runoff arising from surplus soil moisture is calculated by first accounting for a number of subsurface processes described below and including infiltration and percolation.

Infiltration: Soil seepage throughout a catchment is unlikely to be uniform. In order to address possible variance a symmetrical triangular frequency distribution (Pitman, 1973) may be utilised whereby minimum and maximum expected infiltration rates are assigned and the mass infiltration is then calculated. Other distributions may also be adopted. Infiltrated rainfall enters a nominated soil storage zone from which losses are then incurred via evaporative root zone uptake or downward percolation to a deeper aquifer. Surplus rainfall not able to be infiltrated at the specified rate, is assigned to surface runoff. Soil infiltrometer testing or experience at other locations can provide estimates of parameters governing infiltration. A number of measurements have been conducted in the Upper Hunter region to improve parameter selection.

Evapotranspiration: Loss from the soil storage zone is calculated by a pre-determined relationship between storage and evaporation. Pitman (1973) adopts two loss functions based on a linear relationship between potential evaporation and soil moisture. Additional routines provide options for the root zone (inc. rehabilitated areas).

Groundwater percolation: Downward migration of soil moisture is governed by a simple power relationship with the maximum percolation occurring when soil moisture storage (assigned as mm of water storage) is at a maximum. Once moisture has departed the shallow storage zone, evaporative processes no longer apply and the infiltrated volume is then assigned to shallow groundwater storage. Shallow groundwater storage is regarded as that component providing base flow to runoff in drainages or via the regolith to mine pits.

Groundwater seepage: Migration of shallow groundwater within the catchment normally results in bank seepage along drainage lines or seepage from the toe of spoils in mine areas. This process is simulated by a relationship where the rate of seepage is proportional to the square root of groundwater storage. As storage falls, seepage declines exponentially. Introducing an integer number of days before seepage emanates at the catchment exit accommodates lagging along this flow pathway. Lag may be extended from days to months to account for situations like mine spoils where rapid infiltration may occur but migration to the toe of spoils (in pit) may take a considerable time depending upon pit floor geometry and the emplaced spoils characteristics. An additional direct component of seepage calculated from alternative aquifer modelling techniques (analytical or numerical modelling) may be applied to a specific catchment to replicate mine pit or underground seepage contributions from floor and highwall or longwall areas.

Runoff: Surface runoff is attenuated by application of the well known Muskingum equation with a weighting factor set to zero for reservoir type storage attenuation.

Storages: Runoff from any number of catchments (each with differing properties) can be directed into storages. Runoff may also be split proportionally and assigned to different storages. The storages are assigned a maximum and minimum operating level together with a siltation rate designed to reduce storage in time. Rainfall and evaporation processes apply to each storage. Since evaporative losses depend upon surface water area, each water surface may also be adjusted on a prescribed volume/area relationship derived from a stage relationship and calculated daily. Storage can overflow by gravity drainage to another storage, or be depleted or replenished by pumping. Response plots for a mine site can then be generated for any part of the rainfall history. A storage may also be triggered to discharge at a prescribed time and rate (extremely useful for HRSTS compliant discharge assessments).

Pumping: Any number of pumps may be assigned to transfer water between storages or to pump water to a particular usage. Pumping rates can only be defined on a long-term average daily basis.

G2. MODEL SIMULATIONS

G2.1 Model calibration

The water management model has been previously calibrated in a coarse manner based on the system shown on Figure 15 (main text) and utilising pumping data, measured water levels in storages and anecdotal information. A history matching was generated for the period from 1995 to 2000 (MER, 2000). Model response plots indicated the system had very low storage over a number of periods, the most extreme being the first quarter of 1998. Make up water from the Mt. Thorley Scheme was required during these periods.

Qualifications applying to the model included the following:

- Catchments were assigned uniform infiltration parameters (for each catchment type) and changing areas during the mine life. This generalisation could result in extended lag times between rainfall receipts and runoff entering the mine water system. The loss to evaporation and to groundwater infiltration resulting from the lagging could introduce errors. It was not possible to address these errors globally without conducting extensive runoff measurements across the entire mine site.
- Mine usage rates for coal production (CPP) were average rates. These rates could vary significantly depending upon the quality of ROM being washed, the yield and the prevailing climatic conditions. This variability could introduce short term departures between observed and predicted stored water volumes;

- Accurate apportioning of dust suppression water usage was not possible as climatic and seasonal conditions may have lead to wide variance. Assigned values in the model were therefore based on average conditions;
- Pumping between storages and pumping for different usages was maintained constant during the simulation period. Hence some storages may have reflected higher simulated levels than measured levels at certain times. However higher levels in one storage would have been offset by lower levels in other storages.

These same qualifications apply to modelling of the future system response.

G2.2 Salinity trading scheme

Only a few discharges were incorporated in the calibrated model period. However future water management will rely upon HRSTS discharges. This scheme provides opportunity for release of impaired quality mine water to the Hunter River at times when the river can best accommodate elevated salt levels. The scheme operates through the provision of salt credits (first issued January 1996) and advice from DLWC regarding times of release. Discharge opportunities are governed entirely by flow and salinity conditions within the river and all releases occur into specified blocks of 24 hours duration.

A block is identified through careful evaluation of catchment rainfall distributions and responding river levels/flows. If river flow observations confirm a block will meet specified HRSTS criteria, then appropriate notification is given (by DLWC) and participants may then release mine water to the river.

Table G1 provides a summary of impending constraints on releases to the river. Three flow regimes are prescribed with discharges only permissible during ‘high’ or ‘flood’ flows. High flows require a calculation of the absolute salt load transferred to the river, the maximum load (and hence discharge) being determined by the number of salt credits held. Coal and Allied currently retain more than 200 credits.

During high flows, the discharge limit imposed on the Main Water Storage dam is based upon a percentage of the total allowable discharge (TAD) and is calculated by dividing the assigned salt credits by the total of salt credits (1000). The TAD is determined during a high flow by the difference between the measured river salinity, which is usually between 600 and 1000EC, and the sector assigned salinity (900EC) calculated in equivalent tonnes of salt. If the measured river salinity is below 900EC then mine water may be discharged. In this manner a percentage of the TAD is allocated to Warkworth Mine.

In order to determine an average TAD for the lower sector, river flow and salinity data for Singleton gauge has been processed over the period 1995 to 2002. By extracting high flow days and their equivalent salinity, it has been determined that an average TAD is about 1024 t. Hence the average discharge limit could exceed 205 t or about 70ML/day based upon an average long term discharge dam salinity of 4500 uS/cm (range 3000 to 6000 uS/cm).

Table G1: Hunter Salinity Trading Scheme definitions

River sector	Gauge	High flow salinity (EC - uS/cm)	Low flow (ML/day)	High flow (ML/day)	Flood flow (ML/day)
Upper	Denman	600	<1000	1000 to 4000	>4000
Middle	Glennies Ck	900	<1800	1800 to 6000	>6000
Lower	Singleton	900	<2000	2000 to 10000	>10000

all flood flow salinities are 900EC

G2.3 Calculation of HRSTS release opportunities

In order to determine historical HRSTS release opportunities applicable to historical rainfalls (for mine water system modelling), synthesized river flow data generated by DLWC has been processed assuming a minimum 2 days lead time for high and flood flow events in the upper sector and 1 day in the middle sector. If flood flows enter the middle sector above Denman but reduce to high flows, then a high flow is assumed to occur in the middle sector rather than a flood flow. High flows must satisfy salinity constraints on all sectors to carry through to the lowest scheme gauge at Singleton.

G2.4 Model simulations

The mine water management model has been used to assess system response to changing catchment areas and variable climatic conditions over the remaining mine life. Figures G2 to G6 show pit development and the main water management elements while Figures G7 to G11 show catchments contributing in full (or in part with diversions) to the mine water system. The following Table G2 provides a schedule of main catchment parameters adopted in the model.

Table G2 Summary catchment infiltration/runoff control parameters

Catchment	Pow	Smin (mm)	Smax (mm)	Sseep (mm/day)	Kmin (mm/hr)	Kmax (mm/hr)	Int. (mm)	Lag days
undisturbed	2	0	50	0.05	0	30	2	0
strip-bench	2	0	20	0.5	0	80	2	0
pit floor	2	0	10	0.1	0	50	2	0
unshaped spoils	2	0	400	5	0	200	2	10
shaped spoils	2	0	250	2	0	100	2	10
rehabilitated area	2	0	150	0.5	0	30	2	10
hard stand	2	0	1	0.01	0	0.1	2	0

Where:

Pow is a power exponent for the seepage equation
Smin is the minimum soil moisture storage capacity
Smax is the maximum soil moisture storage capacity before runoff is initiated
Sseep is the rate of percolation to the shallow (regolith) aquifer
Kmin is the minimum surface infiltration rate
Kmax is the maximum surface infiltration rate
Int is the interception storage (does not enter the soil store)
Lag is the travel time in days for percolation seepage emanating at wall toe

Runoff from each catchment has been accumulated in specific storages noted in Table G3 below and shown on Figures 15 and 17 (main text).

The remaining 18 years of pit life has been tested against historical rainfall periods of equivalent length (daily rainfalls). Selected periods have commenced in 1900 and have been offset by 5 years thereby overlapping model responses.

The 18 years period of mining includes the following constraints and controls:

- CPP usage (as a loss rate for 9.5 Mtpa) – 3.4ML/day
- Dust suppression as water cart usage at an average rate of 1.4 ML/day
- stockpile dust control at a rate of 0.12 ML/day
- variable catchment areas with South, Woodlands and West pits progressively closed;
- rainfall entering the pit(s) is pumped rapidly to nominated dams in order to maintain pit/seam workability;
- increasing groundwater seepage to the North and West pits at rates determined from aquifer numerical modelling;
- redirection of runoff from rehabilitated areas out of the mine water system and back to the regional catchments.

Table G3: Mine water system – main storages

Title	Area (m^2)	Capacity (ML)	Name & characteristics
Main Water Storage Dam	4530	300	The main water storage dam supplying the washery. Licensed HRSTS discharge to Doctors Creek – Discharge point will be relocated to the new 500ML Discharge Dam.
West Pit Storage Dam (400ML Dam)	43270	400	Accepts water pumped from northern part of the West Pit via the West Pit Settling Ponds – mined through in 2005 and replaced by the 500 ML Discharge Dam
Swan Lake	22852	20	Accepts water from the southern part of the North Pit via the pit ramp. Pumped water also includes leakage from Tailings Dam 2 that migrates down the ramp – Filled by year 10 and replaced by a small sump and/or pumping booster station.
CD pit	3315	+2000	Void storage accepts water from Woodlands pit (east), and South pits via undisturbed catchment UD7 draining northwards to the void. Also accepts significant leakage from Tailings Dam 2 and to a lesser extent Tailings Dam 1 – to be dewatered and mined through.
North Pit Transfer Dam	2868	40	Accepts water pumped from the northern part of the North Pit and from undisturbed catchments to the west of the highwall (Sandy Hollow Ck and Dights Ck) – may be replaced by a larger transfer dam in Longford Creek catchment.
Sed Dams 1,2,3	36857	90	Accepts water pumped from Swan lake, West Pit 400ML Dam and CD-Pit. The dams act as settling ponds decanting to the Main Water Storage Dam.
West Pit Settling Ponds	35485	100	Accepts water from West Pit and acts as settling ponds decanting to the West Pit 400ML Dam - partly silted. Will be decommissioned and mined through in 2005.
Tailings Dam 1	4286	+100	May hold water temporarily but either pumped to Sed Dam 2 via the Tailings Clarified Water Dam or water is lost through leakage downwards (reporting to CD Pit).
Tailings Dam 2	4303	+200	May hold water temporarily but either pumped to Sed Dam 2 or water is lost through leakage downwards (reporting to CD Pit). Will be filled in 2008
Discharge Dam		500	Will be constructed to replace the West Pit Storage Dam. A new HRSTS discharge point will be located at this dam.
South Transfer Dam		150	Will be constructed to replace the existing sedimentation dam and provide storage and staging capacity in the south west area when remaining catchment runoff cannot be pumped to Doctors Creek.

Results of selected simulation periods are provided in the following Figures G12 to G17. These periods include the wettest term (1940 to 1958), the driest term (1930 to 1948) and a period during which, climate was less extreme (1970 to 1988).

All model simulations have been summarised in the form of percentile (probability) exceedance plots for the main pits, the main dams and total mine water storage – Figures G18 to G20. Make up water from the Mt. Thorley Scheme is also included.

G2.5 Sedimentation dams in rehabilitated areas

With the exception of a number of small catchments in the eastern part of the site, rehabilitated areas have been diverted from the mine water management system and have not been included in water management system modelling. These diverted areas are assumed to be sufficiently regenerated to permit runoff to return the natural watersheds with sediment control established at the watershed discharge points. Sediment dams will be maintained or constructed on a needs basis. Where new dams are to be constructed, design criteria will comply with the following and will aim to minimize release of impaired quality water:

- design capacity based upon a 1 in 20 years ARI (t_c) storm event and inlet/spillway structures designed to convey a 1 in 10 years ARI (t_c), minimum settling depth of 0.6m.
- and/or prescribed in *Managing Urban Stormwater – Soils and construction* (NSW Department of Housing, 1998) for Type C or D basins
- and/or other design criteria considered appropriate to local conditions and appreciation of micro climate influences.

A schedule of indicative sedimentation dam capacities for the current watersheds and rehabilitation stage, is provided in the following Table G4 assuming:

- a high top soil erodibility with moderate subsoil erodibility
- low to moderate infiltration capacity (shallow permeability and moisture store)
- average slope of 14% and contour bank spacing of 45 metres
- an average soil erodibility factor of 0.05
- a rainfall erosivity of 1750
- a volumetric runoff coefficient of 0.5

Table G4: Schedule of sedimentation dam storage needs (for whole catchments)

Dam ID	Year 10		Year 18	
	Area - ha	Storage - ML	Area - ha	Storage - ML
RH2	147	40	147	40
RH5	75	20	75	20
RH6	50	14	50	14
RH7	49	20	26	20
RH8	51	20	40	20
RH9	41	11	105	29
RH10	81	22	81	22
RH11	179	49	200	54
RH12	42	12	229	62
RH13	20	6	161	44
RH14	38	11	88	24

References for model development:

Abromowitz, M. and I.A. Stegun, 1968. Handbook of mathematical functions. New York Dover Publications.

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0 1000 2000 3000 Metres

see water management schematic for storage and pumping details

Scale 1:40000 Base map information from 1:25,000 topo series (Central Mapping)
Additional data supplied by Warkworth Mine

-200 - -80	10 - 20	110 - 120	10m topo. contours	mine water
-80 - -70	20 - 30	120 - 130	contour drain	sed. dam
-70 - -60	30 - 40	130 - 140	diversion drain	tailings
-60 - -50	40 - 50	140 - 150	railway	void water
-50 - -40	50 - 60	150 - 160	major road	
-40 - -30	60 - 70	160 - 170	minor road	
-30 - -20	70 - 80	170 - 180	drainage	
-20 - -10	80 - 90	180 - 190	pipeline	
-10 - 0	90 - 100	190 - 200		
0 - 10	100 - 110	200 - 210		

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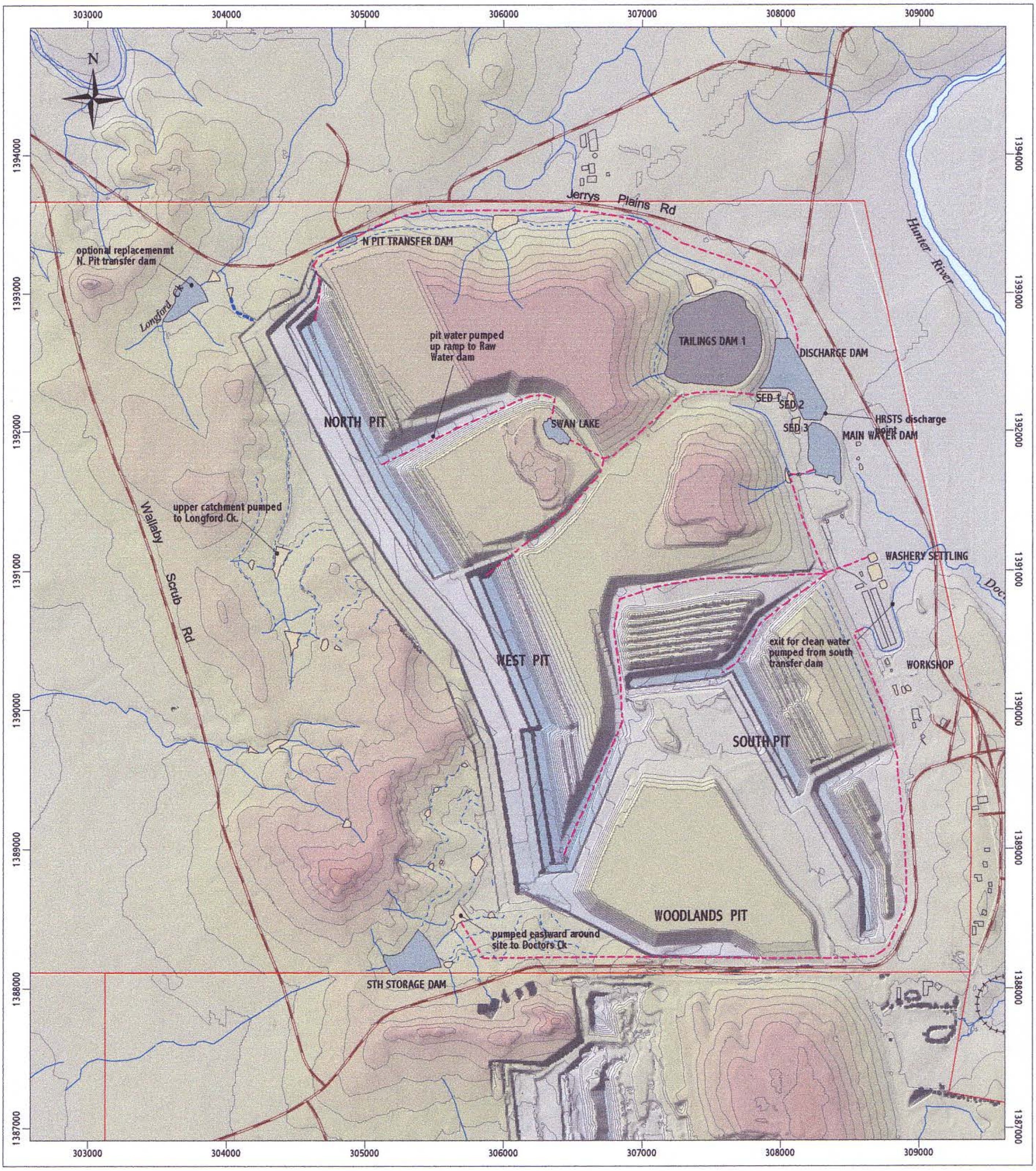
WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

Current mine water management elements

Figure G1



0 1000 2000 3000 Metres

see water management schematic for storage and pumping details

Scale 1:40000 Base map information from 1:25,000 topo series (Central Mapping)
Additional data supplied by Warkworth Mine

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-80 - -70	20 - 30	120 - 130
-70 - -60	30 - 40	130 - 140
-60 - -50	40 - 50	140 - 150
-50 - -40	50 - 60	150 - 160
-40 - -30	60 - 70	160 - 170
-30 - -20	70 - 80	170 - 180
-20 - -10	80 - 90	180 - 190
-10 - 0	90 - 100	190 - 200
0 - 10	100 - 110	200 - 210

- 10m topo. contours
- contour drain
- diversion drain
- railway
- major road
- minor road
- drainage
- pipeline

- mine water
- sed. dam
- tailings
- void water

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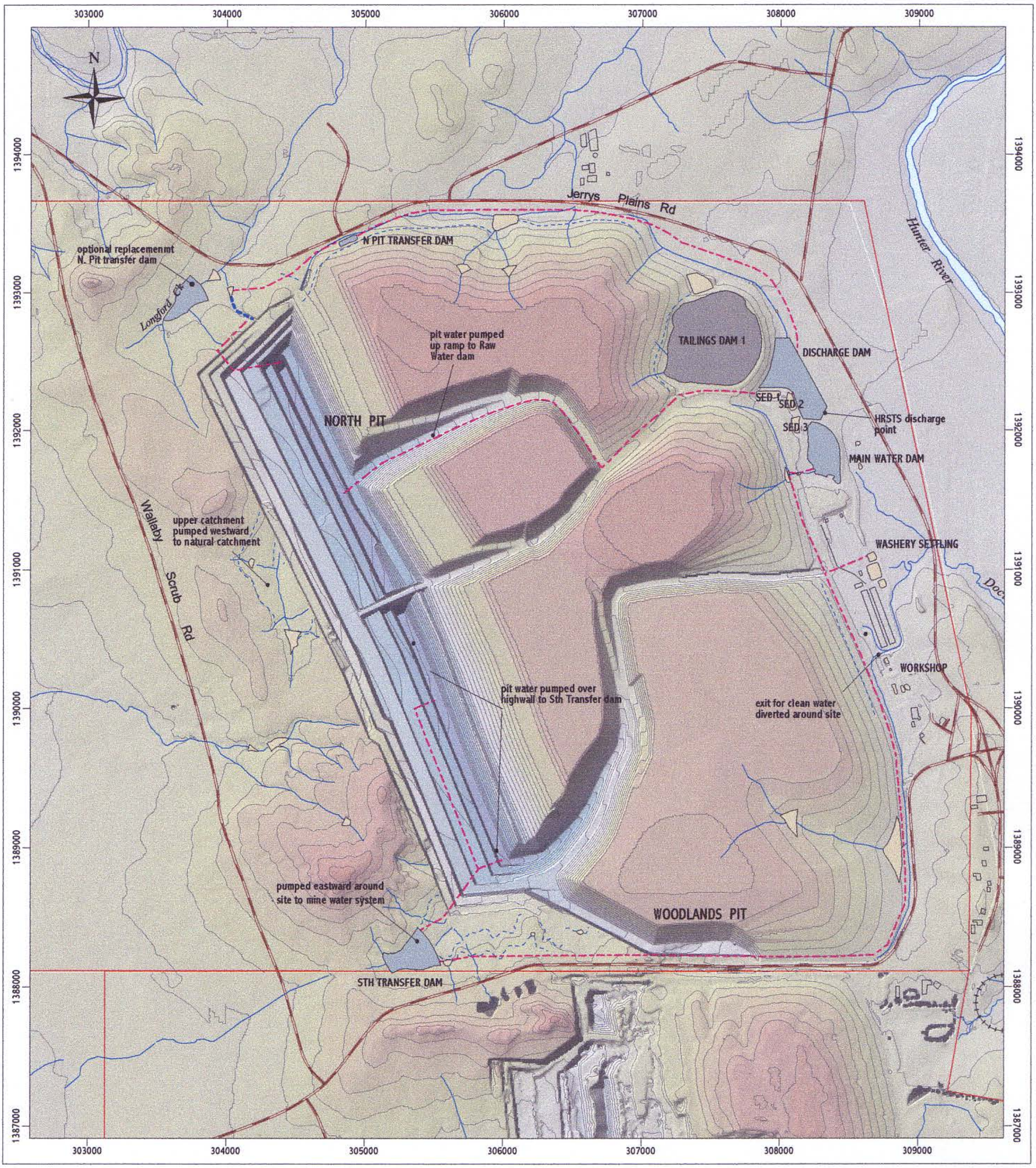
WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

Water management elements after 5 years

Figure G2



0 1000 2000 3000 Metres

see water management schematic for storage and pumping details

Scale 1:40000 Base map information from 1:25,000 topo series (Central Mapping)
Additional data supplied by Warkworth Mine

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-80 - -70	20 - 30	120 - 130
-70 - -60	30 - 40	130 - 140
-60 - -50	40 - 50	140 - 150
-50 - -40	50 - 60	150 - 160
-40 - -30	60 - 70	160 - 170
-30 - -20	70 - 80	170 - 180
-20 - -10	80 - 90	180 - 190
-10 - 0	90 - 100	190 - 200
0 - 10	100 - 110	200 - 210

- 10m topo. contours
- contour drain
- diversion drain
- railway
- major road
- minor road
- drainage
- pipeline

- mine water
- sed. dam
- tailings
- void water

WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

Water management elements after 10 years

Figure G3

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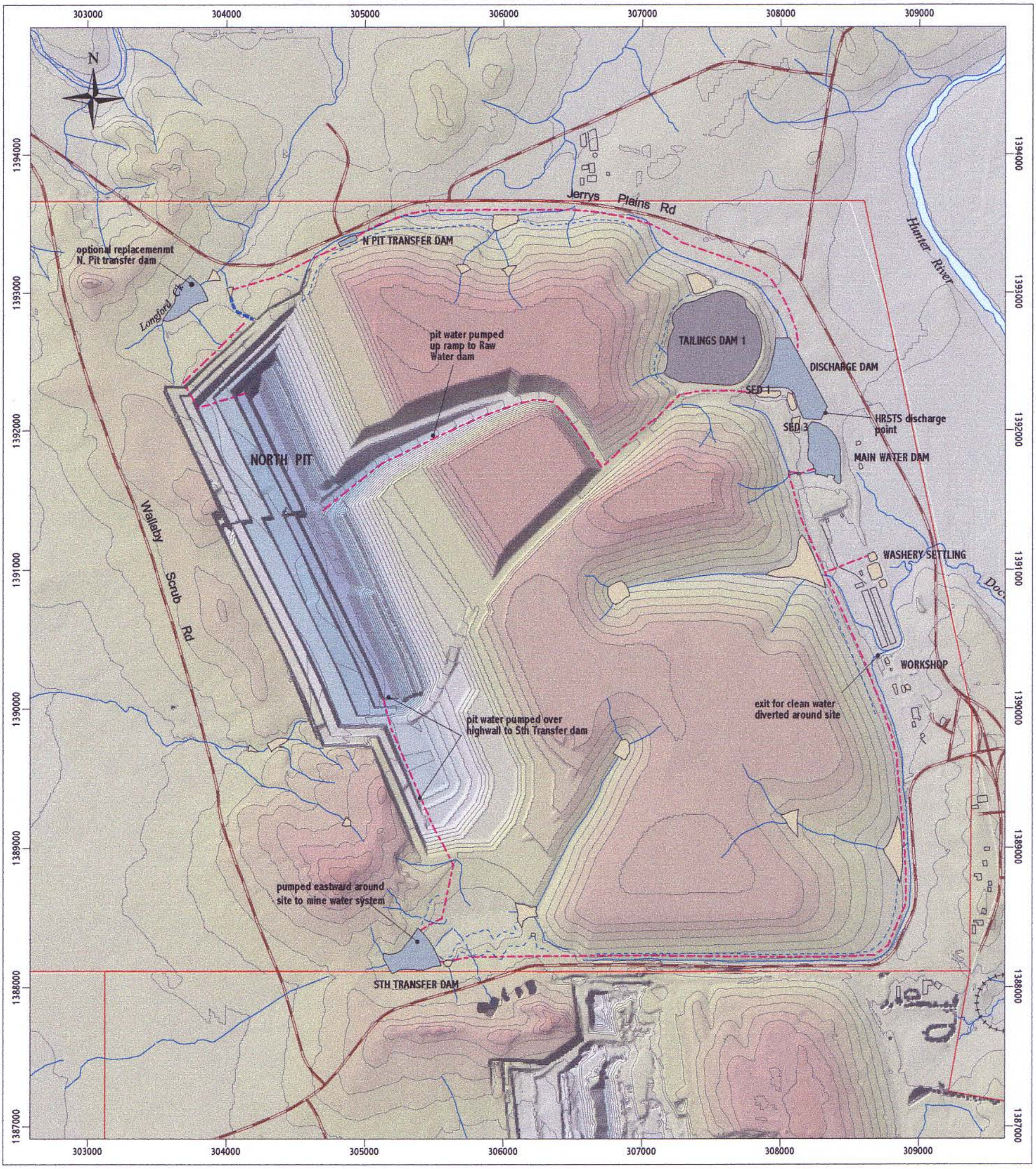

0 1000 2000 3000 Metres

see water management schematic for storage and pumping details

Scale 1:40000 Base map information from 1:25,000 topo series (Central Mapping)
Additional data supplied by Warkworth Mine

-200 - -80	10 - 20	110 - 120	10m topo. contours	mine water
-80 - -70	20 - 30	120 - 130	contour drain	sed. dam
-70 - -60	30 - 40	130 - 140	diversion drain	tailings
-60 - -50	40 - 50	140 - 150	railway	void water
-50 - -40	50 - 60	150 - 160	major road	
-40 - -30	60 - 70	160 - 170	minor road	
-30 - -20	70 - 80	170 - 180	drainage	
-20 - -10	80 - 90	180 - 190	pipeline	
-10 - 0	90 - 100	190 - 200		
0 - 10	100 - 110	200 - 210		

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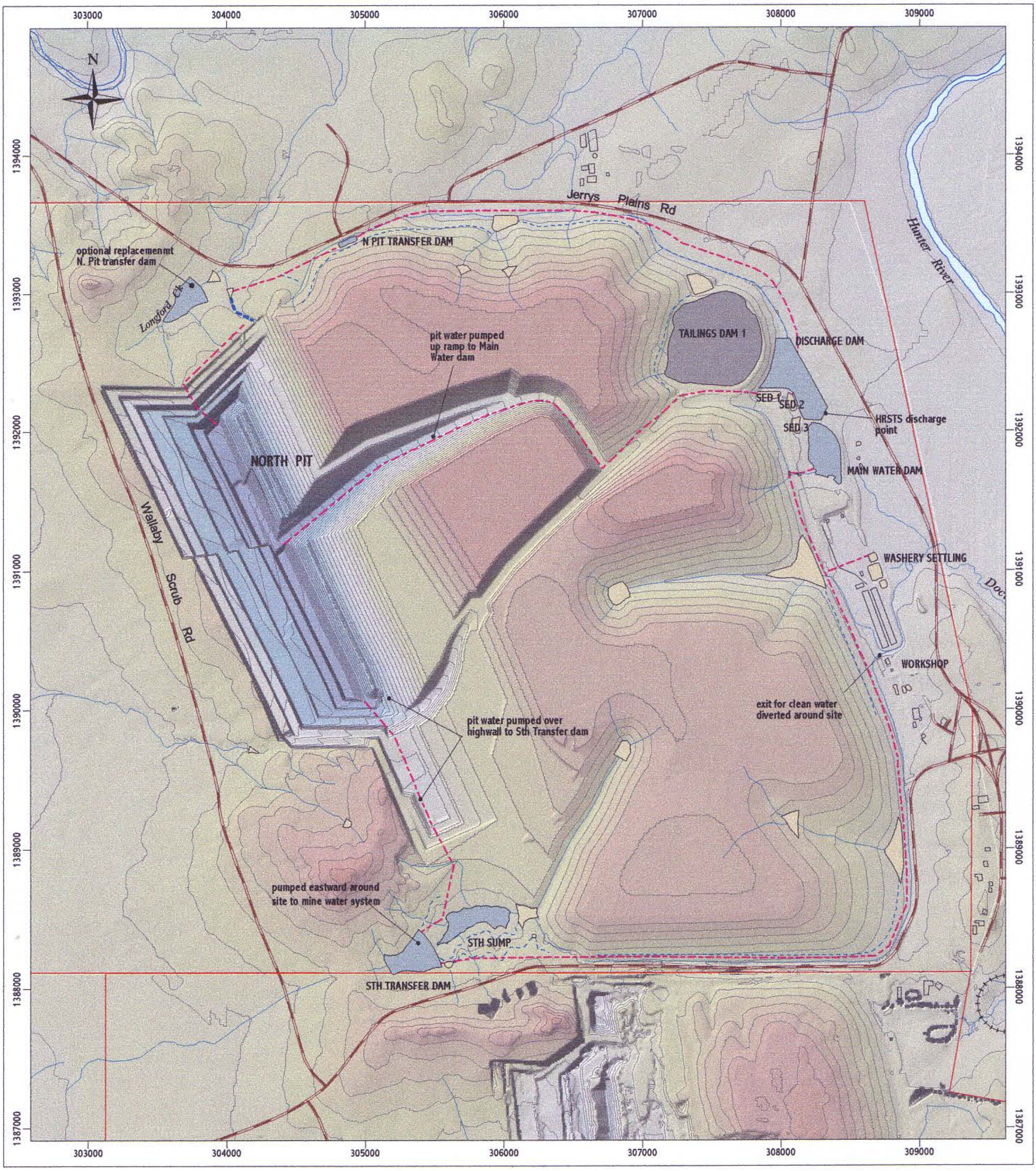
WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

Water management elements after 15 years

Figure G4



0 1000 2000 3000 Metres

see water management schematic for storage and pumping details

Scale 1:40000 Base map information from 1:25,000 topo series (Central Mapping)
Additional data supplied by Warkworth Mine

-200 - -80, -80 - -70, -70 - -60, -60 - -50, -50 - -40, -40 - -30, -30 - -20, -20 - -10, -10 - 0, 0 - 10

10 - 20, 20 - 30, 30 - 40, 40 - 50, 50 - 60, 60 - 70, 70 - 80, 80 - 90, 90 - 100, 100 - 110

110 - 120, 120 - 130, 130 - 140, 140 - 150, 150 - 160, 160 - 170, 170 - 180, 180 - 190, 190 - 200, 200 - 210

- 10m topo. contours
- contour drain
- diversion drain
- railway
- major road
- minor road
- drainage
- pipeline

- mine water
- sed. dam
- tailings
- void water

WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

Water management elements after 18 years

Figure G5

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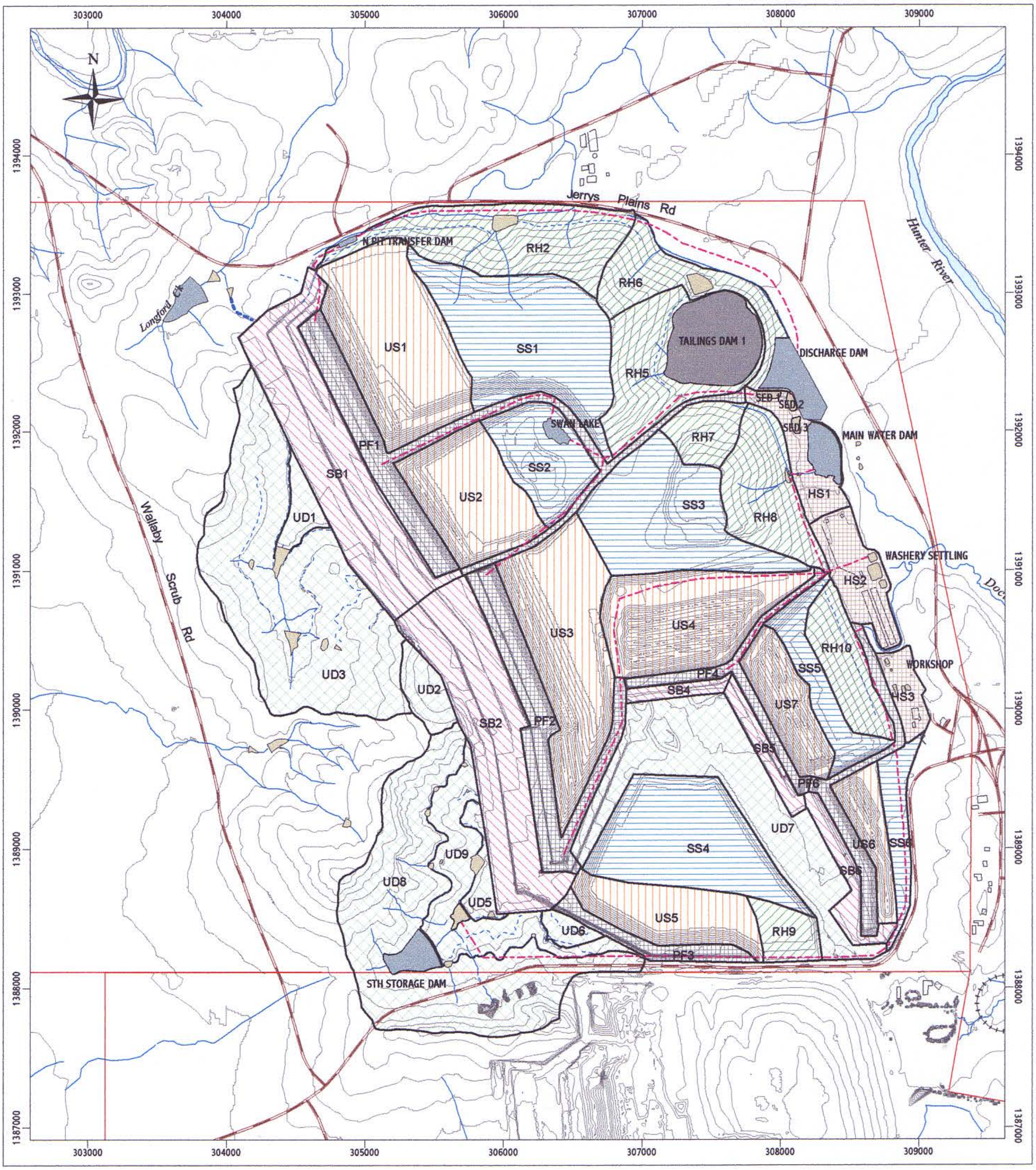

0 1000 2000 3000 Metres

see water management schematic for storage and pumping details

Scale 1:40000 Base map information from 1:25,000 topo series (Central Mapping)
Additional data supplied by Warkworth Mine

- 10m topo. contours
- contour drain
- diversion drain
- railway
- major road
- minor road
- drainage
- pipeline
- mine water
- sed. dam
- tailings
- void water
- hardstand
- pit floor
- rehabilitated
- strip and bench
- shaped spoils
- tailings
- undisturbed
- unshaped spoils

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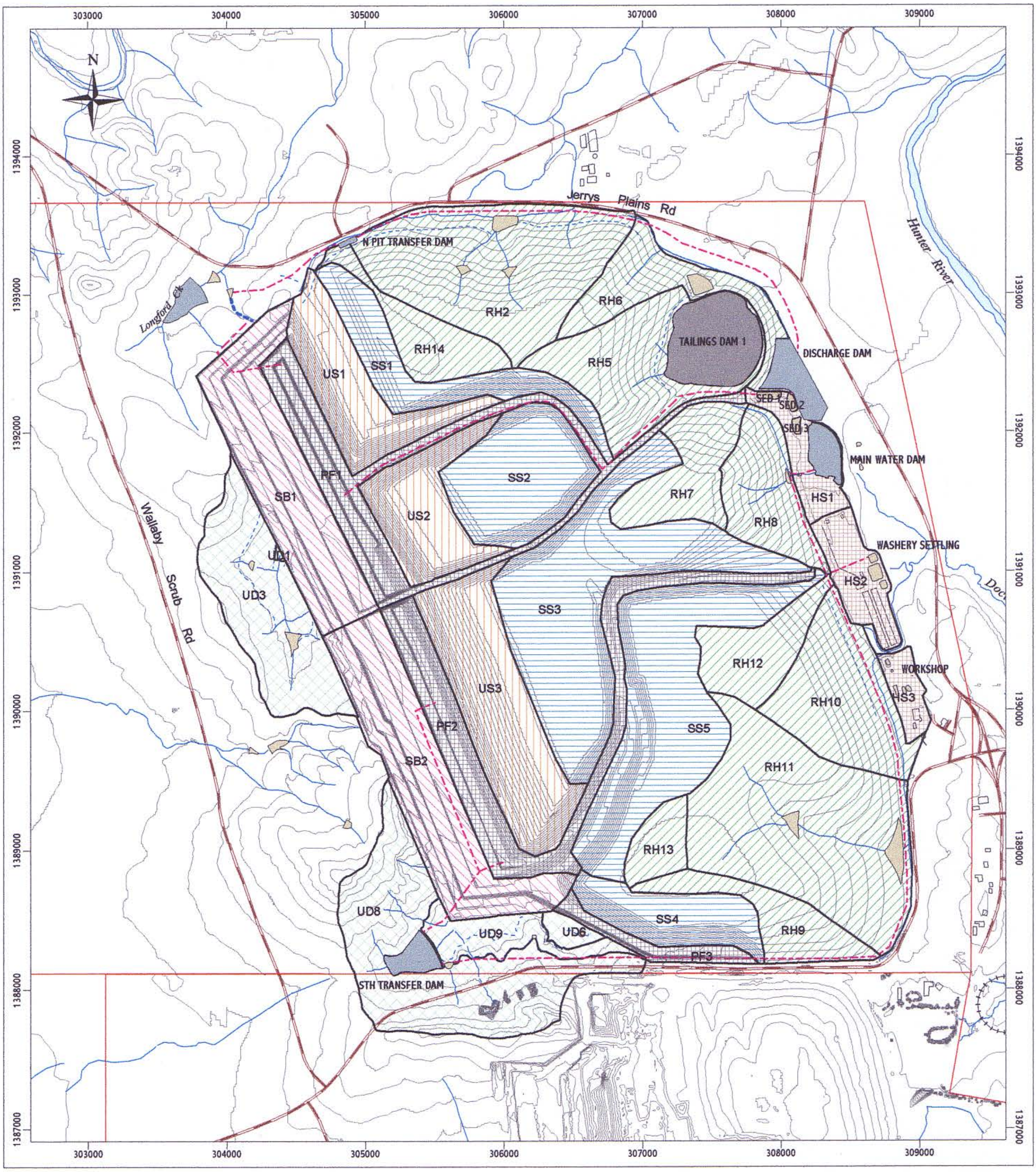
WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

Water management catchments after 5 years

Figure G6



see water management schematic for storage and pumping details

Scale 1:40000 Base map information from 1:25,000 topo series (Central Mapping)
Additional data supplied by Warkworth Mine

10m topo. contours	mine water	hardstand
contour drain	sed. dam	pit floor
diversion drain	tailings	rehabilitated
railway	void water	strip and bench
major road		shaped spoils
minor road		tailings
drainage		undisturbed
pipeline		unshaped spoils

WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

Water management catchments after 10 years

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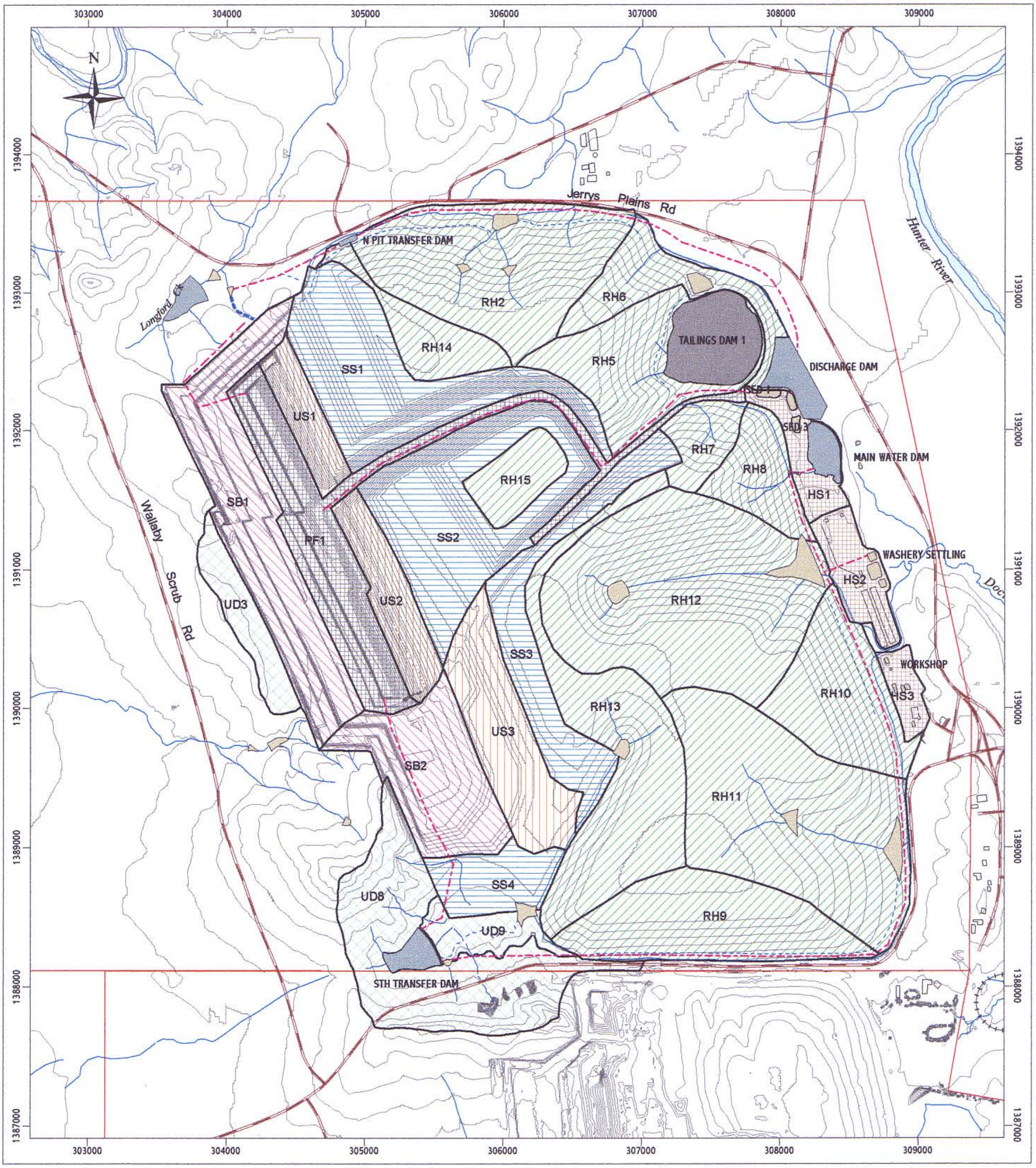
Figure G7



0 1000 2000 3000 Metres

see water management schematic for storage and pumping details

Scale 1:40000 Base map information from 1:25,000 topo series (Central Mapping)
Additional data supplied by Warkworth Mine

- 10m topo. contours
- contour drain
- diversion drain
- railway
- major road
- minor road
- drainage
- pipeline
- mine water
- sed. dam
- tailings
- void water
- hardstand
- pit floor
- rehabilitated
- strip and bench
- shaped spoils
- tailings
- undisturbed
- unshaped spoils

WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

Water management catchments after 15 years

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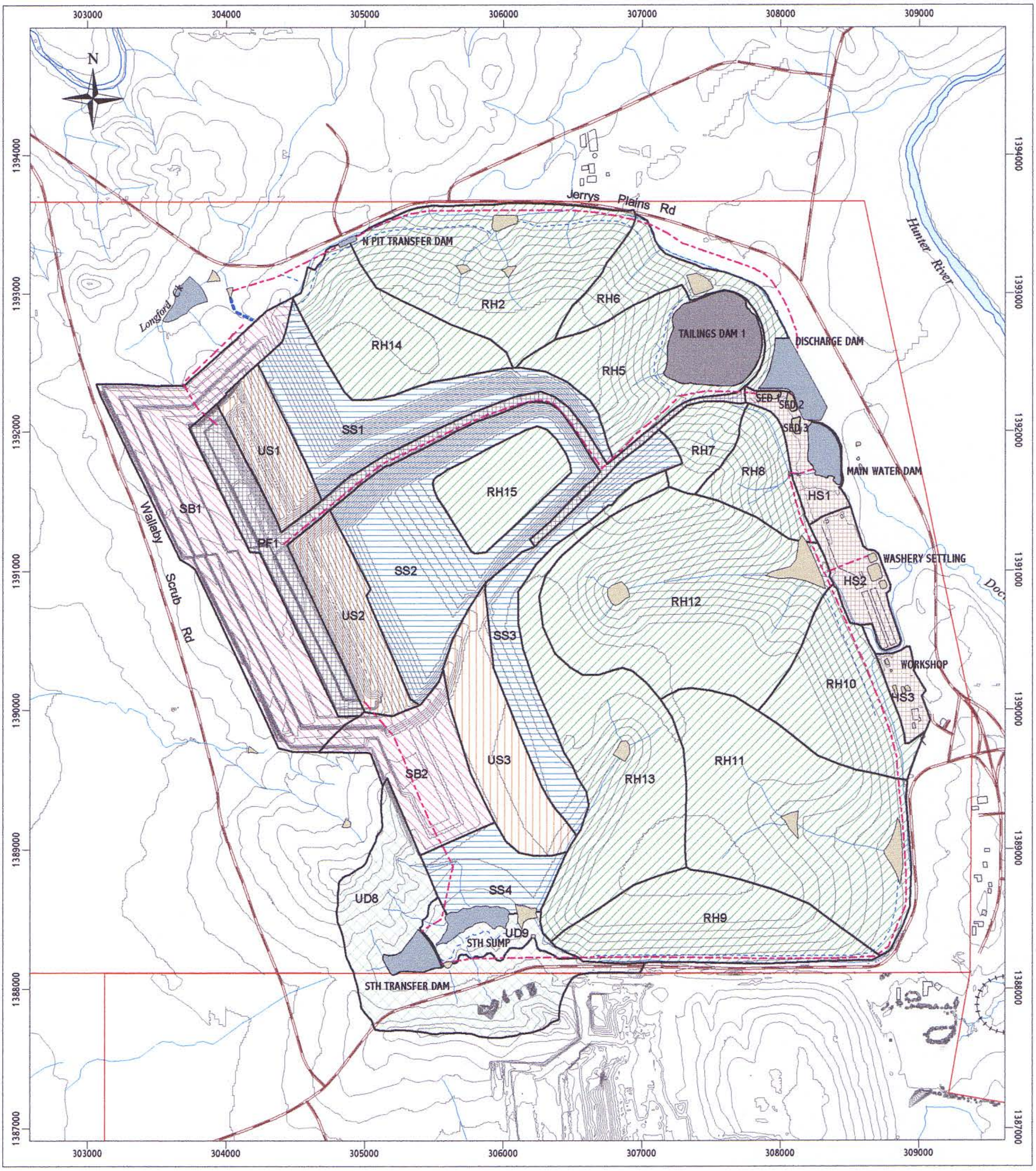
Figure G8



see water management schematic for storage and pumping details

Scale 1:40000 Base map information from 1:25,000 topo series (Central Mapping)
Additional data supplied by Warkworth Mine

10m topo. contours	mine water	hardstand
contour drain	sed. dam	pit floor
diversion drain	tailings	rehabilitated
railway	void water	strip and bench
major road		shaped spoils
minor road		tailings
drainage		undisturbed
pipeline		unshaped spoils

WARKWORTH MINE EXTENSION - WATER MANAGEMENT STUDY

Water management catchments after 18 years

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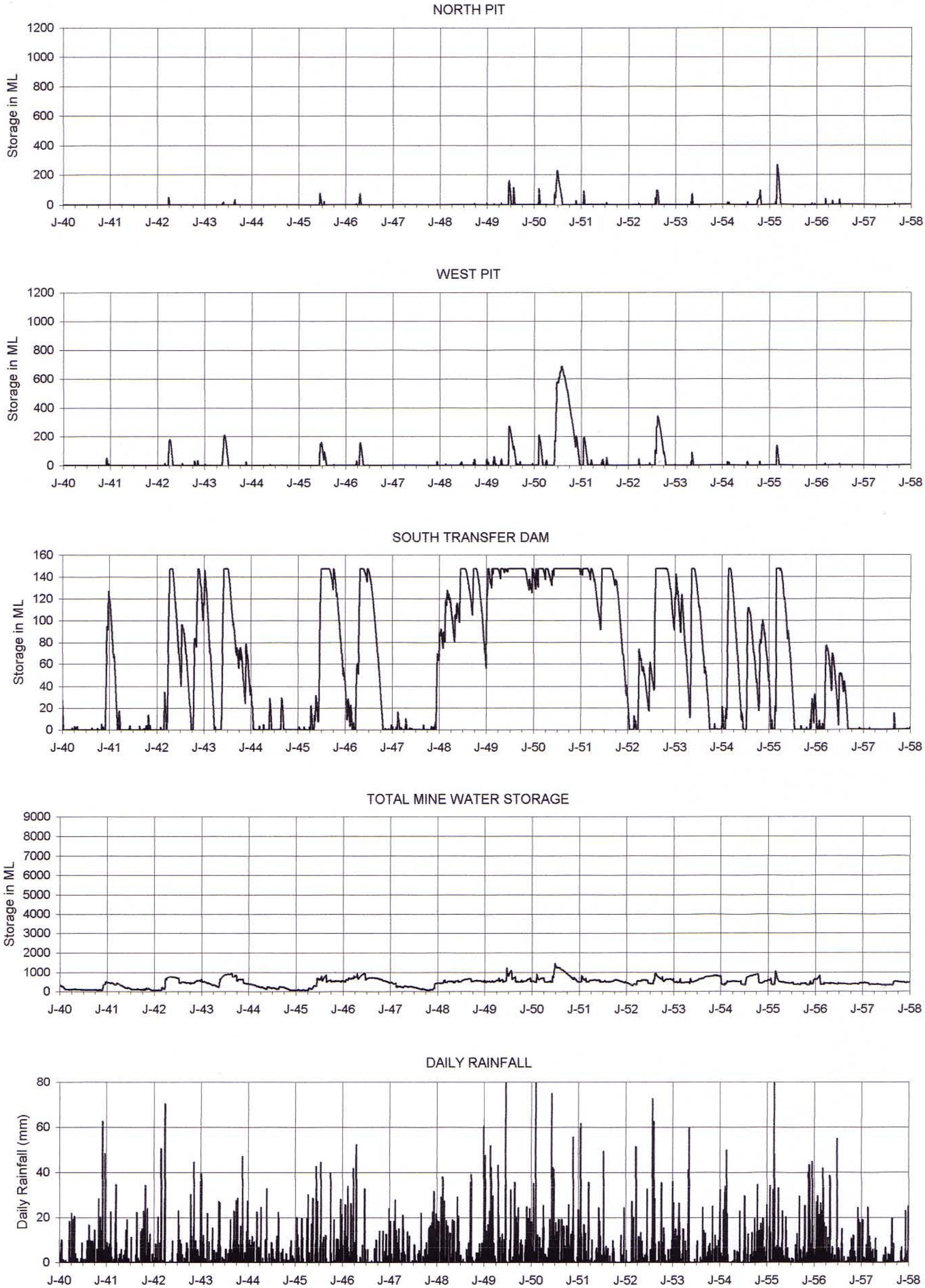
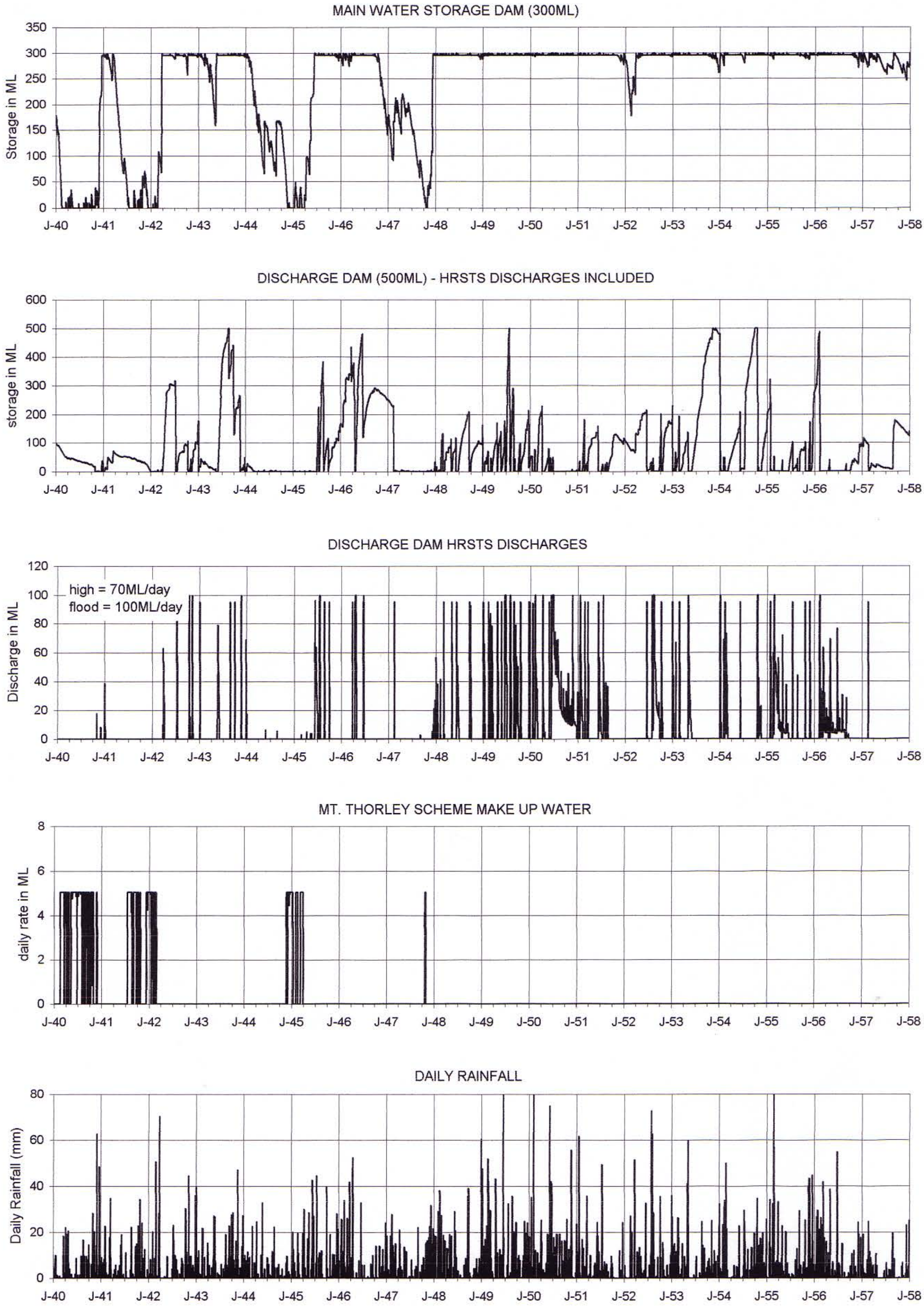
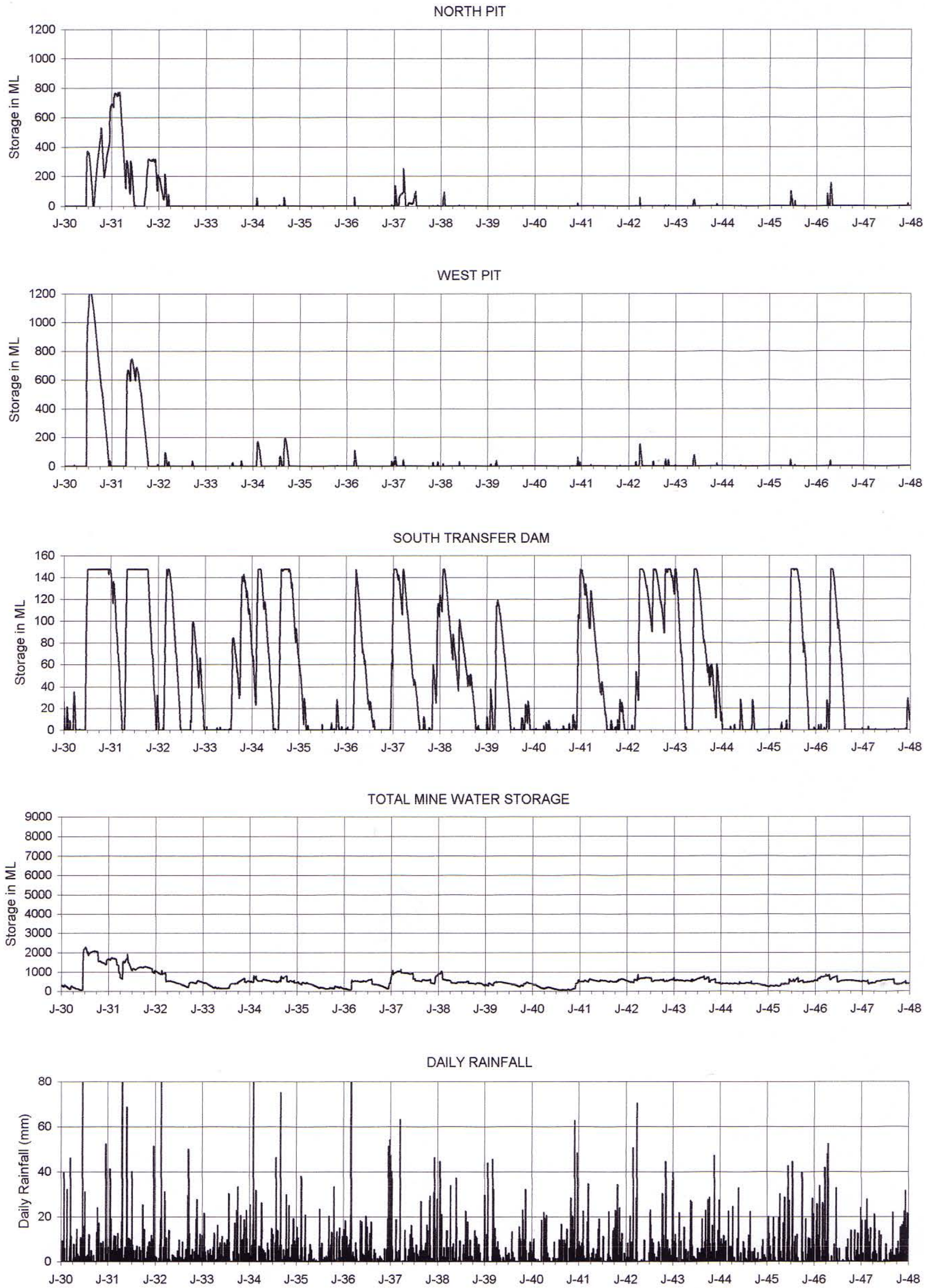
Figure G9



Warkworth Mine Extension - Water Managemenbt Study
Simulated system response for 1940 to 1957 rainfall period
HRSTS discharges from Discharge Dam



Warkworth Mine Extension - Water Managemenbt Study
Simulated system response for 1940 to 1957 rainfall period
HRSTS discharges from Discharge Dam



Warkworth Mine Extension - Water Managemenbt Study
Simulated system response for 1930 to 1948 rainfall period
HRSTS discharges from Discharge Dam

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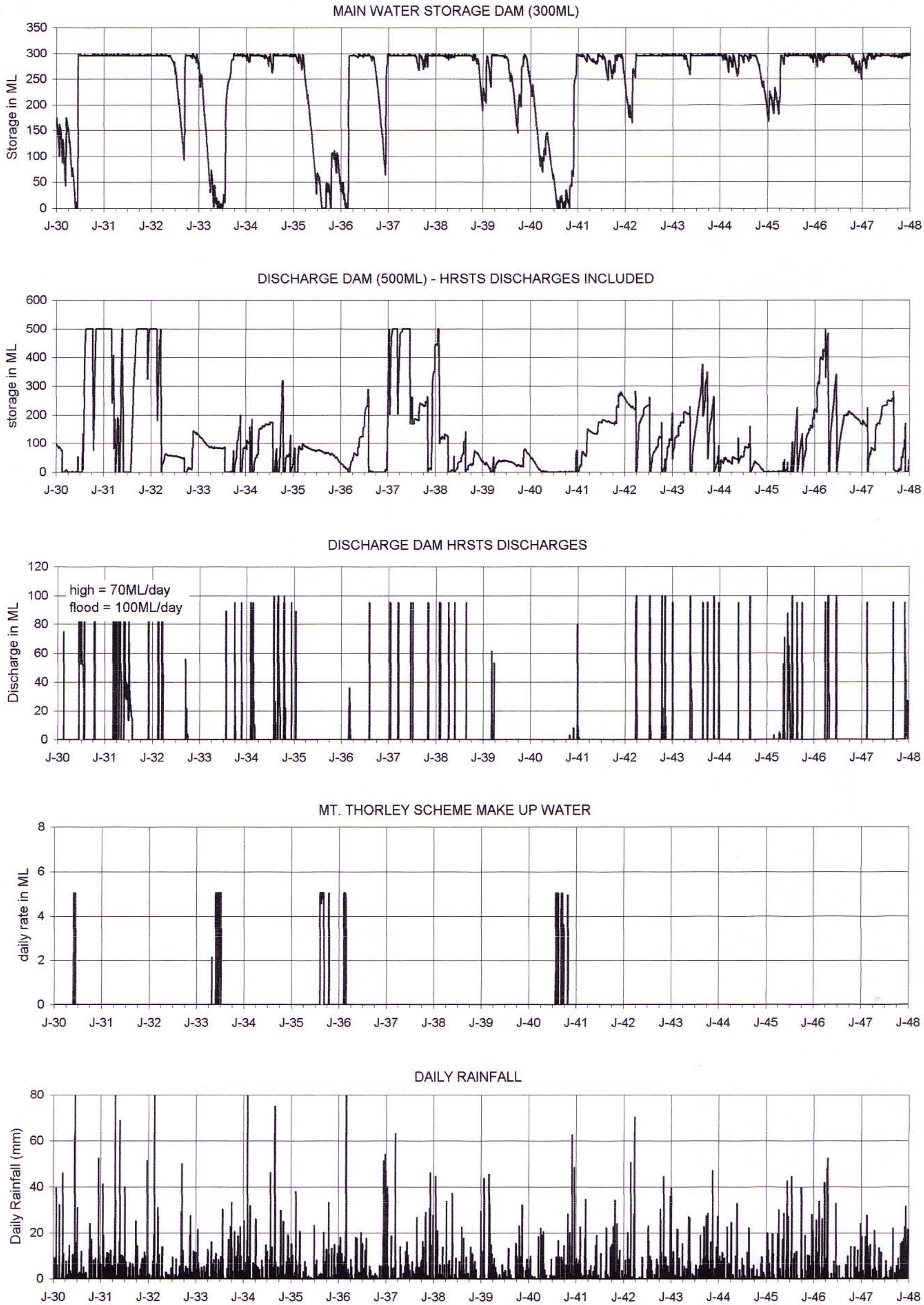
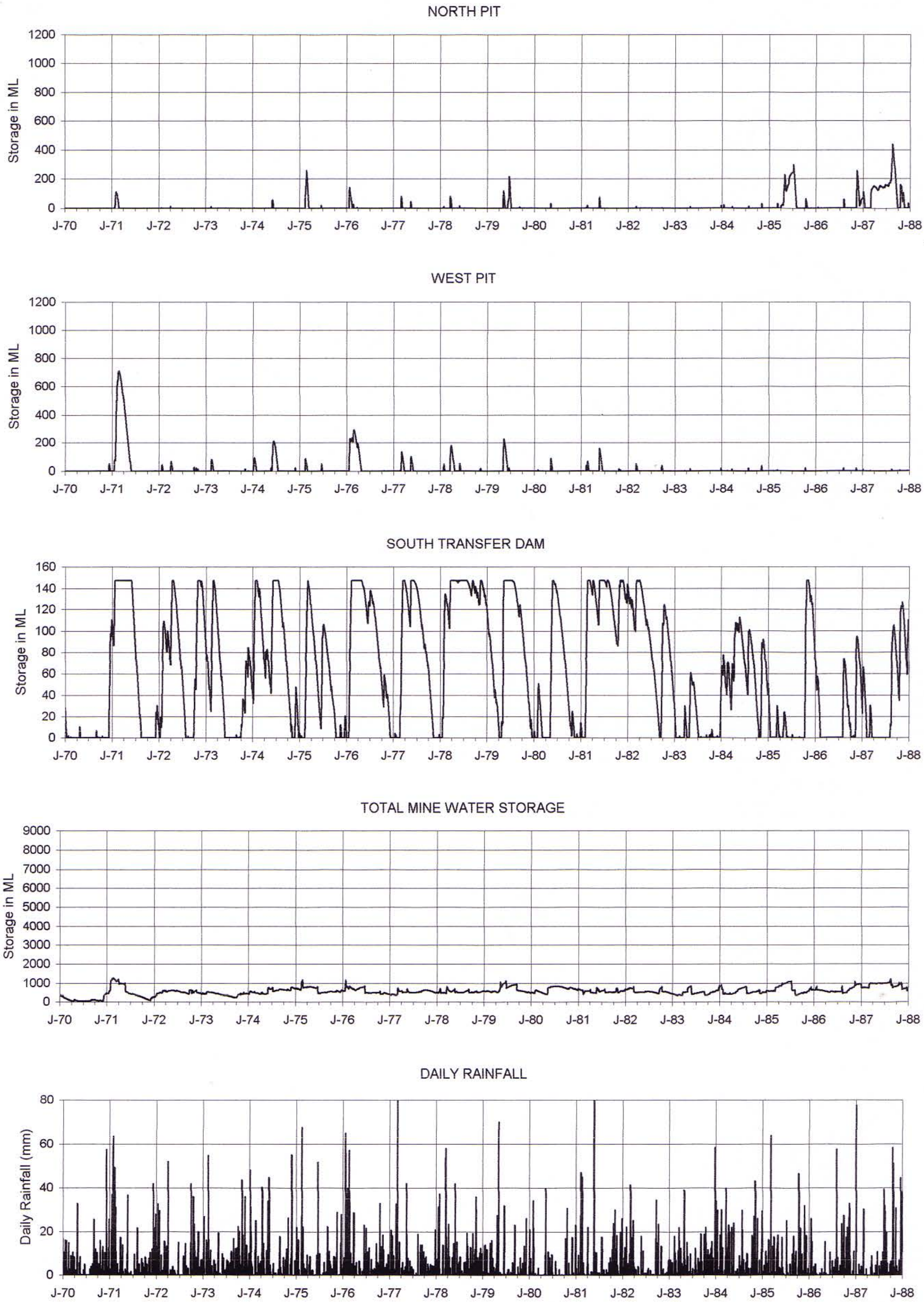
Figure G12



Warkworth Mine Extension - Water Managemenbt Study
Simulated system response for 1930 to 1948 rainfall period
HRSTS discharges from Discharge Dam



Warkworth Mine Extension - Water Managemenbt Study
Simulated system response for 1970 to 1988 rainfall period
HRSTS discharges from Discharge Dam

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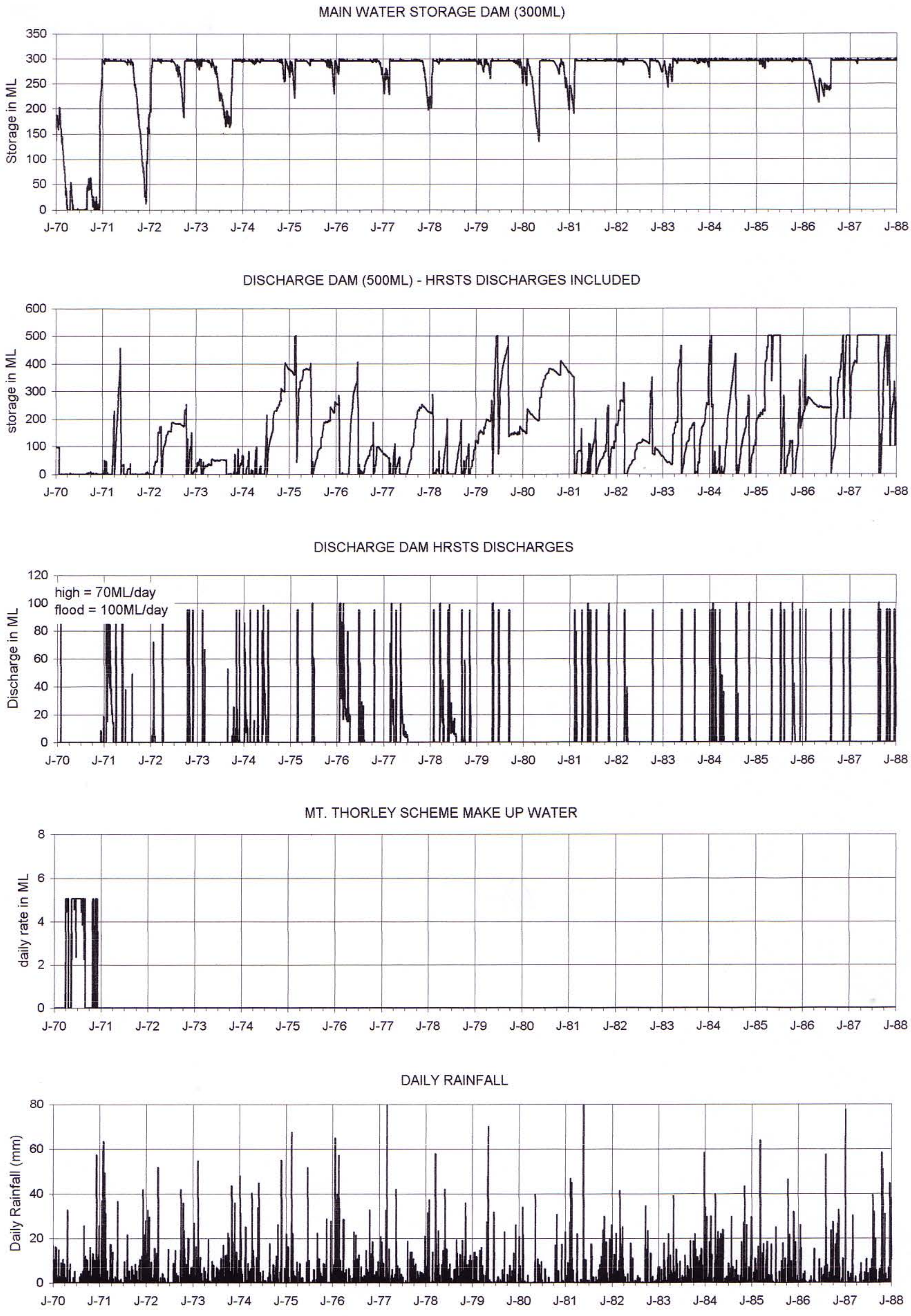
Figure G14



Warkworth Mine Extension - Water Managemenbt Study
Simulated system response for 1970 to 1988 rainfall period
HRSTS discharges from Discharge Dam