Technical and Environmental Problems Related to Dewatering the Proposed Ohinewai Opencast Lignite Mine, New Zealand

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ABSTRACT

Coal measures at the proposed Ohinewai opencast mine in the Waikare Coalfield, New Zealand, are overlain by up to 70 m thickness of unconsolidated, fluviatile sediments of the Quaternary Tauranga Group, and surface peat. The site is in a low-lying area close to Lake Waikare and other smaller lakes, and the Waikato River. Sediments of the Tauranga Group include permeable beds of sand and gravel that extend beneath the lakes, and to the river.

The results of numerical modelling of dewatering requirements indicate that up to 82 operating bores and more than 100 bores in total will be required at any one time to intercept groundwater throughflow and to dewater the Tauranga Group ahead of mining. They will need to be of large diameter to maximize yield when water-levels are lowered to near the base of the aquifer, but even so, some secondary in-pit means will be required to complete dewatering. Air-injection reverse circulation drilling is considered to be the most suitable means of installing large diameter bores in unconsolidated sediments.

A large cone of depression will form around the dewatering borefield, extending up to 5 km north of the mine, to the Waikato River in the west and Huntly North in the south. To the east, the aquifer is bounded by greywacke of low permeability. Sediments overlying the aquifer beneath Lake Waikare are leaky; this characteristic will prevent the cone of depression from reaching the environmentally-sensitive Whangamarino Swamp to the north.

Dewatering, and drainage of surface peat will result in up to one metre of subsidence within the mine, but less than 600 mm outside the mine boundaries. Subsidence could, however, change the southern shoreline of Lake Waikare which is already close to lake level. In the mine area, compressible bore casings will be required to prevent the subsidence from causing bores to collapse.

INTRODUCTION

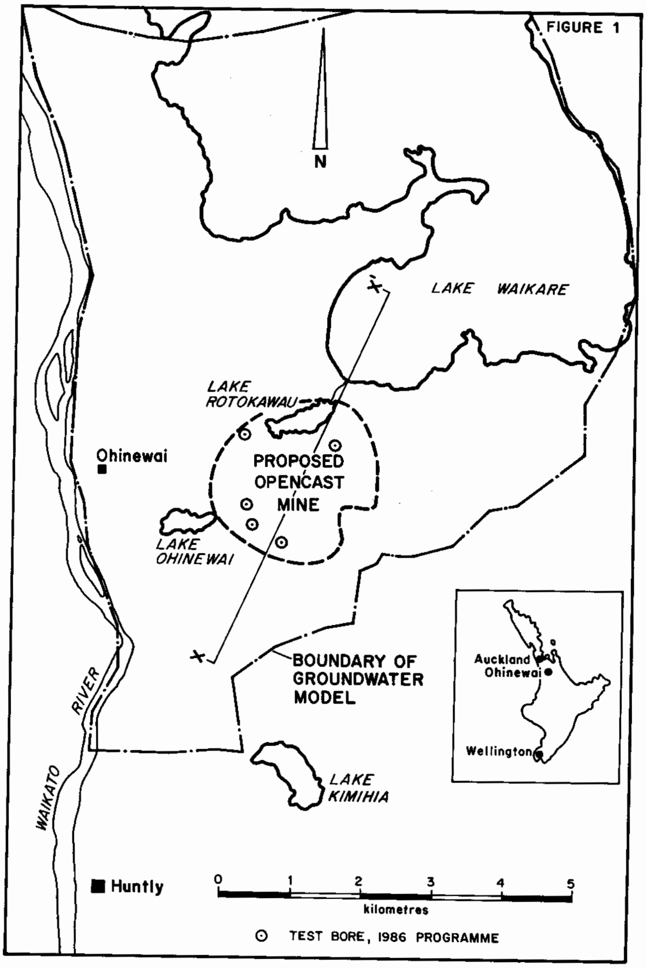
In 1983 RWL Mining Consultants, a joint venture between Rheinbraun-Consulting of West Germany, Worley Consultants of New Zealand and

Longworth-McKenzie of Australia, were engaged to study the feasibility of mining lignite by opencast methods at Ohinewai in the Waikare Coalfield, New Zealand. The study was completed in 1987, and recommends the operation of a 30 million tonne opencast mine with an annual extraction of 1.1 million tonnes of coal.

The mining process will be unusually complex:

- dredging surficial peat deposits from polders
- recovering the overburden waste by means of bucket-wheel excavators with conveyor belt stacker systems
- extracting the coal using mechanical shovels

The proposed mine is situated in a generally low-lying area, two kilometres east of the Waikato River, and about 300 m south-west of Lake Waikare (Figure 1). This area, within a wide valley formed by the ancient Waikato River, is underlain by unconsolidated and semi-consolidated sediments of the Pliocene to Holocene Tauranga Group, forming the overburden of the coal deposit.



Previous geological investigations had shown that hydrological and geomechanical properties of the Tauranga Group are very complex and unfavourable with respect to opencast mining. Also, water-bearing formations occur mainly in the Tauranga Group. Consequently, hydrological investigations for the feasibility study were mainly confined to the Tauranga Group.

Objectives of the investigation were:

1. To assess dewatering requirements and methods for the proposed mine.

2. To determine the effects of dewatering on groundwater levels, surface water bodies and ground surface levels.

3. To collect sufficient data on the groundwater regime for preparation of an Environmental Impact Study.

The geology and stratigraphy at Ohinewai are summarised in a cross-section through the site of the proposed mine (Figure 2).

FIELD INVESTIGATIONS AND AQUIFER SIMULATION

THE AQUIFER

The Tauranga Group forms an anisotropic and inhomogeneous sequence of water-bearing sediments, deposited in a low energy fluviatile environment of the ancestral Waikato River.

Evaluation of all available drillhole logs has shown that correlation of individual beds is not possible, even between closely spaced drillholes. Although permeable beds are discontinuous, pumping test results indicate they are hydraulically connected. Consequently, sand and gravel beds of the Karapiro, Puketoka and Whangamarino Formations of the Tauranga Group and around the proposed mine are conceived as single, heterogeneous aquifer. Along the Waikato River, the sandy Hinuera Formation has also been included in the aquifer.

Lithological logs for drillholes within the coalfield were used to prepare an isopach map of cumulative thickness of permeable beds in the Tauranga Group. The aquifer thickness generally increases to the north towards Lake Waikare (maximum about 40 m), and there are some northerly trending features of greater than average thickness, possibly representing palaeochannels of the Waikato River.

Standard laboratory and field tests were conducted to establish hydrologic properties of the aquifer. The most useful results were obtained from long-term constant rate and constant drawdown tests on five bores (Figure 1). Aquifer parameters determined from the tests and evaluated during calibration of the aquifer model were used to establish transmissivity and storativity domains over a substantial part of the area under investigation. Table 1 shows typical ranges of parameters, determined from the response of piezometers around each test bore.

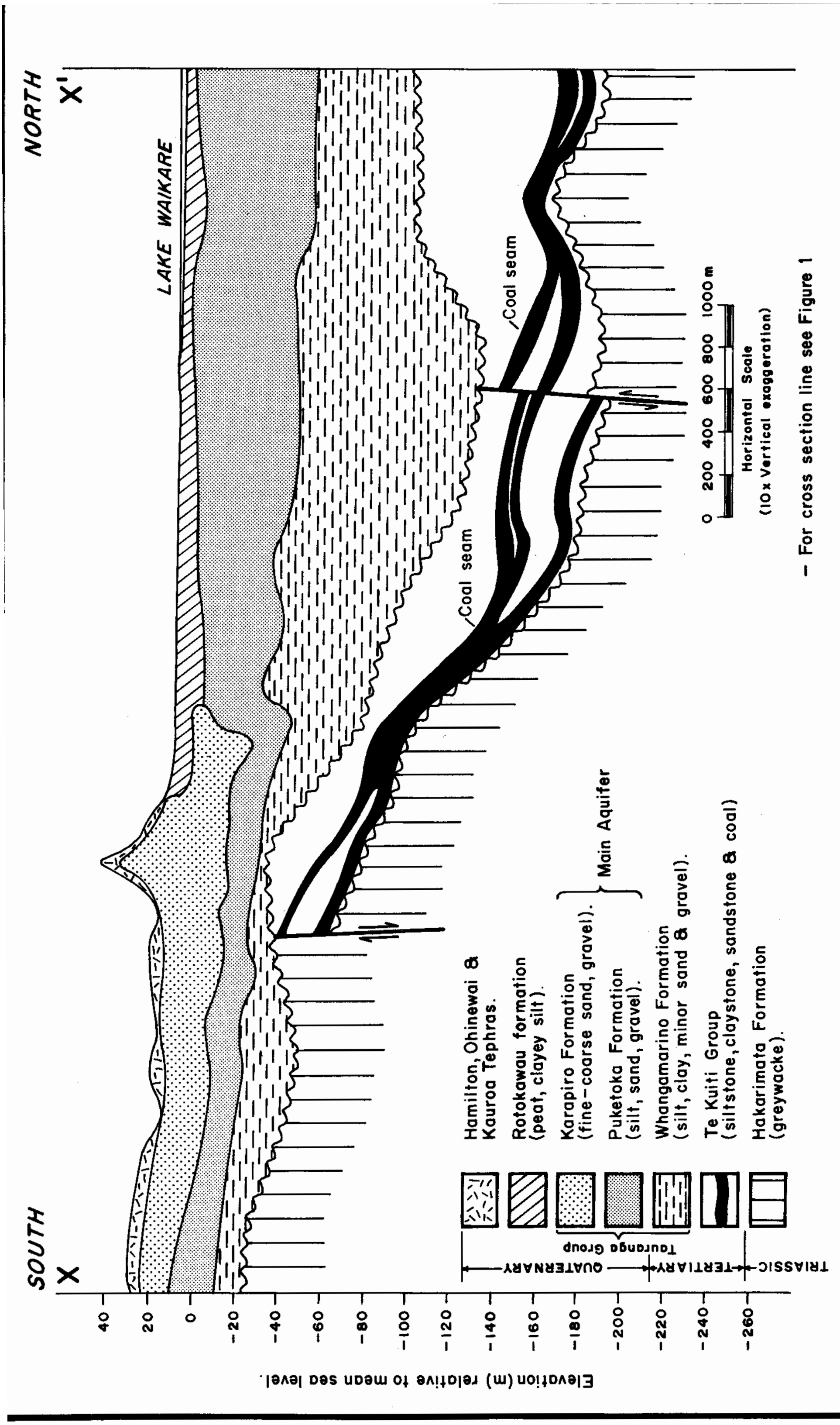


FIGURE 2: GEOLOGICAL CROSS SECTION, OHINEWAI SECTOR

Over much of the area the aquifer is confined by fine-grained beds within the Puketoka Formation and by the overlying Rotokawau formation. The aquifer is recharged by rainfall infiltration in an area near the southern margin of the proposed mine where it is unconfined or semi-unconfined. Where the aquifer is confined, there is still considerable vertical leakage between sandy beds of the Tauranga Group and overlying peat of the Rotokawau formation, and Lake Waikare. In fact, groundwater principally discharges by upward leakage into the peat and the lake.

TABLE 1

CHARACTERISTIC VALUES OF TRANSMISSIVITY AND STORATIVITY

TEST BORE	TRANSMISSIVITY RANGE (sqm/day)	STORATIVITY EARLY TIME (Sc)	STORATIVITY LATE TIME (Sy)
TW 2	40 - 120	$1 - 4 \times 10^{-3}$	
TW 3	220 - 300	$0.5 - 1.7 \times 10^{-3}$	0.01 - 0.14
TW 5	25 - 70	$0.7 - 3 \times 10^{-3}$	
TW 6	10 - 80	$0.5 - 5 \times 10^{-3}$	
TW 7	10 - 60	$3 - 11 \times 10^{-3}$	

Boundaries to the aquifer that are likely to be affected by dewatering measures for the proposed mine have been defined as follows for the numerical modelling:

Western boundary - Waikato River as an infinite source.

Southern boundary - Outcropping greywacke of low permeability, minor inflows to aquifer.

Eastern boundary - Outcropping greywacke on the eastern shore of Lake Waikare, as above.

Northern boundary - Open boundary beneath Lake Waikare. Calculations indicate that the cone of depression will extend 5 km north of the mine if the leakage coefficient for the Rotokawau formation is about $1 \times 10^{-9}\ S^{-1}$, or 3 km north of the mine if leakage coefficient is about $1 \times 10^{-8}\ S^{-1}$ (dewatering will reverse the direction of leakage).

THE AQUIFER MODEL

A numerical groundwater model was employed to simulate flow patterns in the undisturbed aquifer, and to assess groundwater control requirements and their impact. An earlier version of the model was described by Boehm, Schneider and Voigt (1979). It is a twodimensional finite difference model which utilizes a non-uniformly spaced grid of nodes forming acute triangles. This nodal system allows accurate modelling of irregularly shaped aquifer boundaries.

The model automatically computes the declining yield of individual dewatering bores or groups of bores as a function of bore diameter and remnant head, using Sichardt's concept (Sichardt, 1928). It allows for full depletion of aquifers, and simulates leaky conditions, as well as the inter-relationship between groundwater and surface water flows.

SIMULATION OF DEWATERING MEASURES

Four characteristic stages of mining were selected in order to assess the magnitude of dewatering required and the impact of dewatering on the Tauranga Group aquifer:

Year 1 - commencement of mining

Year 6 - early-time stage

Year 13 - maximum development stage

Year 27 - late-time stage

Initial unsteady state modelling runs indicated that around 60 time increments would be needed to accurately simulate dewatering for the whole life of the mine. As such detailed mine scheduling is not practicable in a feasibility study, steady-state simulations were utilized for each of the characteristic stages above. To allow for the withdrawal of water from storage between two simulated stages, the volume removed from storage was calculated from differences in water level at each node.

For each stage, steady-state flow rates to nodes representing dewatering bores were added to average rates required to achieve the reduction in volume of groundwater in storage. This gave the total pumping rate necessary at the beginning and end of the stage to achieve dewatering. Next, bore capacities at the beginning and end of the stage were calculated using Sichardt's concept. For nodes representing more than one bore, individual drawdowns were corrected by the principle of superposition.

Results of the modelling indicate that within the mine perimeter, dewatering bores will need to be spaced 70 to 80 metres apart at the beginning of each stage, reducing to 40 to 50 metres when water levels are lowered to near the base of the aquifer.

Table 2 shows the theoretical number of pumping bores that will be required. On average, the actual number of bores that must be installed will be about 30 percent higher, for the following reasons:

- some bores will be sealed while excavation proceeds on the top benches.
- Pumps will need to be replaced progressively with smaller pumps.

- There will be pump or power failures.
- Bores will be destroyed during mining.

Calculated rates of groundwater extraction and estimated total number of bores that will be installed in and around the mine are shown graphically in Figure 3.

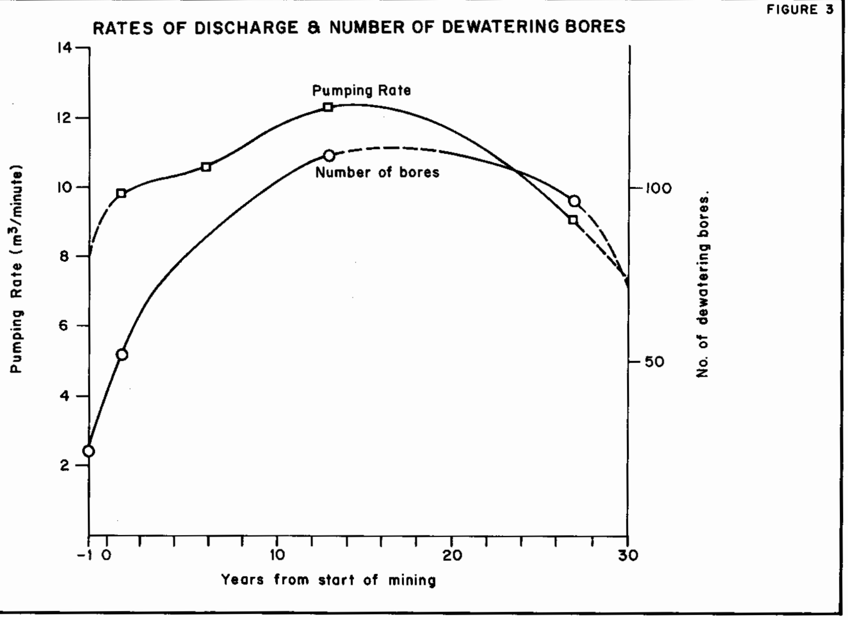
TABLE 2

NUMBER OF OPERATING BORES REQUIRED AT THE PROPOSED OHINEWAI OPENCAST MINE

TIME INTERVAL (YEARS)	NUMBER OF OPERATING EARLY-TIME BORES	NUMBER OF OPERATING LATE-TIME BORES
- 1 to 1	15	36
1 to 6	> 36	60
6 to 13	> 60	82
13 to 27	82 (approx)	67

Modelling results show that most of the water discharged from the bores will be from recharge and throughflow, rather than from storage. Also, approximately 50 percent of water stored within the bounds of the mine will not be recoverable by dewatering bores, but will need to be removed by secondary in-mine dewatering facilities.

FIGURE 3



TECHNICAL PROBLEMS

DESIGN OF DEWATERING BORES

Open-cast mining usually requires the hanging wall of exposed seams to be completely dewatered and the footwall to be depressurized. The most effective method to remove water from storage and to intercept throughflow is to install a system of dewatering bores. At Ohinewai, large diameter bores will be required in order to have sufficient pumping capacity in the later stages of dewatering to minimize secondary dewatering requirements. Sichardt's relationship expresses the maximum discharge rate as a function of hydraulic conductivity, remaining saturated thickness, and effective bore diameter. This means that during dewatering, the larger the diameter the higher the discharge capacity. A large diameter bore can then operate until the aquifer is nearly depleted.

Casing and screen requirements are independent of the need for large diameter bores. Evaluation of the dewatering simulation indicates that submersible pumps of between 100 mm and 280 mm diameter will be appropriate, and so the nominal diameter of screens and casings will be within the range of 150 to 400 mm. The annulus between the drillhole walls and screens will be filled with fine gravel to stabilize the hole and maintain filter stability.

It can be difficult to install large diameter bores in unconsolidated sediments. The best means is a reverse circulation method that uses compressed air injected via air nozzles into the drill string. In coarse-grained materials and non swelling clays the hole remains stable due to the differential pressure between the fluid in the drillhole and the aquifer. In swelling clays polymer-based drilling muds are used for stabilization.

CONTROL OF REMNANT WATER IN THE MINE

Evaluation of pumping test results and numerical simulation reveal that the Tauranga Group aquifer cannot be fully depleted even with large diameter bores, because the strata are flat-lying and there will be isolated beds containing remnant water.

In-pit measures such as open ditches or deep trenches containing drain pipes can be used to divert the water. In special cases it might be necessary to install vacuum bores with air-tight caps and annular seals, but because of high costs this method is recommended only where mine safety is of concern. Another potential method is to install horizontal bores, constructed with screens that can be cut by excavation machinery.

A very effective in-pit measure for dewatering thin strata is to use dug wells.

ENVIRONMENTAL PROBLEMS

PREDICTED CONE OF DEPRESSION

A number of simulation runs were made to estimate the area that will be affected by dewatering. Sensitivity analyses indicate that any errors resulting from assumptions made for the modelling or resulting from, for example, infiltration from the inside mine dump, will have little effect on distance - drawdown relationships except within the immediate area of the mine.

By Year 6 the cone of depression will have grown in a westerly direction, leaving the area under Lake Waikare unaffected. This trend will continue to Year 13 so that water levels at the eastern shore of Lake Ohinewai will have declined by 7 m, and the cone of depression will have just reached Lake Waikare in the north (less than 1 m decline). In later stages of mining the cone will extend further and deeper, but there will be two important aspects to this development:

1. The cone will not even reach the northern model boundary and so there can be no affect on the environmentally sensitive Whangamarino Swamp. This statement will remain true even if the leakage coefficient adopted for sediments between the base of the lake and the aquifer is substantially different.

2. In the south, the cone of depression will temporarily reach Frost Road in the Huntly-North area. High rates of downward leakage from Lake Ohinewai may result in the lake drying up.

LAND SUBSIDENCE

The magnitude of likely land subsidence associated with dewatering was investigated, particularly in areas close to the northern mine boundary and the shore of Lake Waikare.

Assuming a worst-case drawdown of 100 m, total potential settlement or land subsidence was calculated to be 700 to 1,500 mm, depending on the range of elasticity and consolidation values used. Considering a drawdown of 23 m, as required for the first year of mining, the maximum settlement after 20 years would be about 600 mm. Even this relatively small amount of settlement would not occur outside the mine, as the modelling results show that less than 5 to 10 m of drawdown is expected beyond the mine boundary.

On the other hand, surface drainage will induce shrinkage and subsidence of the peat. In areas where there is both pre-mining dewatering and peat drainage, special compressible bore casings will be required to prevent casing collapse as a result of subsidence.

After mining is completed, the hydrologic regime will recover to a new steady-state condition. Lake Waikare will have the same water level, but the southern shore may have a different aspect. Bunds near the shore of the lake will protect the mine from possible flooding.

References

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Sichardt, W. Das Fassungsvermogen von Rohrbrunnen und seine Bedeutung fur die Grundwasserabsenkung, inbesondere fur groBere Absenkungstiefen Springer, Berlin, 87 p (1928).