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GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

HYDROGEOLOGY REPORT 1995/13

CORAMUP - BANDY CREEK
ESPERANCE GROUNDWATER INVESTIGATION

by

L.J. BADDOCK

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NOTE

Perth 1995

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SUMMARY

A groundwater investigation was conducted over about 150 km^2 in the Coramup Creek - Bandy Creek area, located from 12 km to 25 km north to northeast of Esperance, to assess the extent of fresh groundwater. The investigation included a transient electromagnetic and gravity survey along six transects totalling 19.6 km in November/December 1994, followed by drilling a total of 225.9 m in six bores at five sites situated on the transect lines in February 1995. Piezometers were installed for sampling and monitoring.

The geophysical and drilling program successfully identified a region of low salinity groundwater. Three different resistivity layers were indentified in the geophysical survey; an upper high resistivity layer 20 to 35 m thick, normally overlying a low resistivity layer up to approximately 60 m thick, and a low resistivity zone representing unweathered basement up to about 90 m depth. The subsequent drilling program intersected sediments of the Tertiary Pallinup Siltstone, although no bores reached basement. It was found that the upper low resistivity layer identified in the geophysics correlated with an oxidised, unconsolidated sand and silt unit containing low salinity groundwater, except east of Bandy Creek where it comprised interlayered clay and spongolite with good yields of fresh quality groundwater. The underlying low resistivity layer was a moderately consolidated, carbonaceous claystone, siltstone and fine grained sandstone sequence that yielded brackish groundwater.

INTRODUCTION

Location and physical environment

Esperance is a coastal town fringing Esperance Bay, 600 km east-southeast of Perth, and has a population of about 9000. The town is a service centre and port for the surrounding agricultural and inland mining areas, and is a popular tourist and retirement town. The Coramup - Bandy Creek investigation area is located from about 12 km to 25 km north and northeast of the town. The investigation area is approximately bounded by Gibson Road in the north and the scarp with the coastal plain in the south, and is east of a line made by Campbells Road, Benje Benjemup Lake and Coramup Creek, extending to approximately 5 km east of Bandy Creek (Fig. 1). The investigation area covers approximately 150 km^2.

Esperance experiences cool, wet winters and warm, dry summers. February is the hottest month with a mean maximum temperature of 26.4°C, and July is the coolest month with a mean maximum of 17.1°C. The average annual rainfall is 617 mm, which falls mainly in the winter months. The annual potential evaporation from free water surfaces is approximately 1700 mm (class A pan evaporimeter).

The physiography of the area is dominated by the Esperance Sandplain, which is a plateau separated from the low lying coastal plain by an erosional coastal scarp (Fig. 2). The plateau is relatively flat, sloping up to about 120 m AHD (Australian Height Datum) at the northern margin of the investigation area, and is incised by Coramup Creek and Bandy Creek. Several granite hills are present in the southern and eastern portions of the area, and reach elevations of between about 60 and 170 m AHD. There is a large salt lake, Benje Benjenup Lake, on the western margin of the area, with other freshwater or salt lakes on the northeastern and eastern margins.

Almost all of the area has been cleared of native vegetation for agricultural land-uses, mainly pasture.

Groundwater in the Esperance area is predominantly saline, and fresh groundwater resources are limited. The Esperance town water supply is drawn from Quaternary sediments extending between the town and Lake Gore, approximately 30 km west (Baddock, 1994). Fresh groundwater occurs within Tertiary sediments in the Coramup Creek - Bandy Creek area, and also in a small area about Mount Merivale, 21 km east-northeast of Esperance, and at Gibson, 23 km north-northwest of Esperance. A potentially very large brackish groundwater resource occurs in an area covering about 250 km^2 east of Esperance, extending approximately 20 km east of Mt Merivale and 15 km south to Cape Le Grand.

Purpose of study

The objective of the program was to assess the extent of low salinity groundwater and aquifer distribution within the Tertiary Plantagenet Group sediments in the Coramup Creek and Bandy Creek area, for their potential as a future water supply to Esperance or for other activities.

Limited data on farm bores indicated that low salinity groundwater, and modest yields of up to about 100 m^3/day had been obtained. A geophysical survey was conducted in order to provide targets for exploratory drilling, and this was followed by drilling of narrow diameter test bores.

indicated in Transects 3 through to 6, although no known outcrops occur along any of the transects. The TEM indicates that a large portion of Transects 4 and 6 are underlain by shallow basement, although there may still be some cover of the top, low salinity layer.

DRILLING PROGRAM

The drilling was carried out by the Water Authority Drilling Branch under contract to GSWA using an Edson 7000 rig and employing the twin tube reverse circulation air coring method. A total metreage of 225.9 m was drilled in six bores at five sites. One site was drilled on geophysical transects 3, 4, 5 and 6, and a shallow and a deep bore were drilled on Transect 1. The sites have been named CBC 1 to 5, with S designating shallow and D designating deep piezometers. Bore completion reports are presented in Hydrogeology Report 1995/6 (Baddock, 1995a), and lithologies intersected in the holes are summarised diagrammatically in Figure 3.

The piezometers were constructed with 50 mm Class 12 PVC and a 6 m slotted interval. The bore annulus was gravel packed to the surface with 8/16 graded sand and developed by airlifting for up to 1 hour. At the end of development water samples were taken for chemical analysis, and the following day a static water level was taken. The piezometers are protected by a 100 mm galvanised iron pipe with a locking cap and square cement block. Construction details are summarised in Table 1.

Drilling intersected sediments of the Pallinup Siltstone. A boundary within the formation between an underlying carbonaceous claystone and siltstone unit and overlying oxidised sand, silt and clay sediments, or clay and spongolite east of Bandy Creek, closely corresponded to the contact of the low resistivity zone and the overlying high resistivity zone identified in the TEM survey. All of the piezometers were installed above the boundary, except CBC-1D which was within the underlying carbonaceous unit. The salinity of groundwater from the piezometers installed in the high resistivity layer ranged from 260 mg/L (CBC-1S) to 1100 mg/L (CBC-4), and CBC-1D installed below the boundary had a salinity of 3310 mg/L, although this may have been diluted with water from above through the hole annulus during airlifting.

Table 1. Bore data

Piezometer	Eastings	Northings	Casing Depth (m*)	Slotted Interval (m*)	Salinity (mg/L)	SWL (m*)	Airlift Rate (m^3/d)
CBC 1S	402 103	6 265 580	24.5	18 - 24.5	320	10.03	37
CBC 1D	402 103	6 265 580	65.5	59 - 65.5	3310	15.48	trace
CBC 2	404 200	6 267 600	35.55	17.55 - 23.55	370	8.625	20
CBC 3	402 340	6270 300	35.7	23.7 - 29.7	880	21.60	4
CBC 4	401 350	6 271 900	35.57	23.57 - 29.57	1200	21.42	<2
CBC 5	409 850	6 269 600	29.60	20.6 - 26.6	530	4.04	70

* below ground level

GEOLOGY

Regional geology

The geology of the Esperance - Mondrain Island 1:250 000 scale map sheet is described by Morgan and Peers (1973). The Esperance district lies on the Albany - Fraser Orogen, which in the investigation area comprises mid-Proterozoic granitic gneiss bedrock. Overlying the bedrock are sediments of the Plantagenet Group, which are late Middle to Late Eocene age (Stover and Partridge, 1982; Quilty, 1969, 1981), and comprise the Werillup Formation at the base and the overlying Pallinup Siltstone (Cockbain, 1968).

The Werillup Formation is a sedimentary sequence deposited in fluvial, swamp and marine environments, and occurs as broad sheets or distinct channels. Its distribution and thickness is controlled by basement relief, and has a maximum thickness of approximately 40 m. The deeper sections of the formation consist of coarse fluvial sands, with marine intercalations of the Nanarup Limestone Member higher up the formation. The upper portion of the formation comprises swamp deposits of carbonaceous clay, silt and sand, grading into lignite (brown coal) in some areas.

The Pallinup Siltstone is an extensive marine deposit laid down in large shallow embayments during a period of high sea-level, and either conformably overlies the Werillup Formation or unconformably overlies basement. It is typically a dark brown siltstone, frequently containing glauconite, but may also consist of pale grey and pale green clay, and fine grained, clayey sandstones. The formation is normally moderately to well consolidated. A highly fossiliferous spongolite facies occurs within the formation, and comprises molluscs, gastropods, bryozoa, corals, sponge spicules, echinoids and foraminifera. There is a change from the sponge-mollusc rich claystone-siltstone sequence near the coast to an unfossiliferous claystone-siltstone-sandstone sequence farther inland (Morgan and Peers, 1973). A large degree of silicification has occurred in the spongolite facies, with abundant vugs and solution channels.

Geology of Coramup-Bandy Creek area

The general distribution of geological units within the investigation area is shown in Figure 4, while the schematic cross-section in Figure 5 shows the stratigraphic relationship of the Pallinup Siltstone and its various facies, with the Werillup Formation and granitic basement.

The granitic basement in the investigation area forms northeast trending ridges and outcrops as hills, such as Coramup Hill, and within parts of Coramup Creek and Bandy Creek. The TEM survey transects also indicate areas of shallow basement with a relatively thin cover of sediments.

The Plantagenet Group sediments are widely distributed in broad areas up to several kilometres wide between the basement ridges, and were intersected in all of the CBC investigation bores and by the Eucla Mining/Placer Exploration Joint Venture drillholes (Fig. 3). The deepest bore (CBC-1D) penetrated 65 m of sediments, while the geophysical surveys indicate a general thickness of about 80 m.

The spongolite facies within the Pallinup Siltstone was intersected east of Bandy Creek in CBC-5 between 6 and 29 m below ground level, and comprised pale grey brown clay with interlayered hard, brown, spongolite, which was overlain by sandy clay with 3 m of surficial sands at the top. Most of the Eucla Mining/Placer Exploration drillholes also intersected the spongolite facies, where it was overlain by fine grained clayey sand, and show that the spongolite facies thins westward until is it absent approximately 2 km west of CBC-5. Figure 3 shows the approximate boundary between the spongolite facies and the sand/silt facies to the west. Spongolite is known to occur extensively east of the investigation area.

All CBC bores drilled west of Bandy Creek intersected up to 35 m of unconsolidated sand and silt with some sandy clay in the upper section. The sand/silt facies comprises oxidised, pale brown to red, fine grained quartz sand and silt. A thin layer of spongolite occurred in CBC-1 at about 9 m associated with brown clay, but spongolite was absent elsewhere west of Bandy Creek (CBC 1 to 4). The sand/silt facies probably represent sediments deposited in a moderately low energy coastal or estuarine environment, which prevented the growth of marine corals and sponges of the spongolite facies.

Both the spongolite and sand/silt facies overlie carbonaceous clay and silt belonging to a lower facies of the Pallinup Siltstone. CBC-1D intersected 35 m of the unit, which included moderately to well consolidated carbonaceous, dark brown, micaceous siltstone and clay, with some green, fine grained sandstone. In all bores the upper few metres of the unit was found to be oxidised.

Coarse sands of the Werillup Formation were not intersected in the investigation area, but probably occur in the deeper sections between the basement ridges as broad sand sheets or distinct channels.

HYDROGEOLOGY

Aquifer types and yields

In the investigation area, aquifer systems occur in the upper Pallinup Siltstone and in the Werillup Formation. The spongolite and sand/silt facies are two distinct aquifer types in the upper Pallinup Siltstone. These overly a carbonaceous claystone-siltstone-sandstone aquitard which separates them from the underlying sands of the Werillup Formation.

The sand/silt facies aquifer system is an unconfined to semi-confined aquifer with a saturated thickness that decreases from 20 m in the south at CBC-1S where the watertable is 10 m bgl, to 8.6 m in the north at CBC-4 where the watertable is 21.4 m bgl. Airlifted yields from the piezometers in the sand/silt facies ranged from 37 m^3/day at CBC-1S down to <2 m^3/day at

CBC-4. It is considered that properly constructed bores could yield about 100 m^3/day in the southern portion of the area, with yields decreasing to the north.

The spongolite facies aquifer east of Bandy Creek is a semi-confined to confined aquifer. At CBC-5 the spongolite aquifer was confined by overlying clay, and private artesian bores in the Bandy Creek valley probably intersect this aquifer. The spongolite can be highly permeable due to the presence of solution channels, and bores are often high yielding. The piezometer CBC-5 was airlifted at 70 m^3/day, which was probably limited by the piezometer rather than the aquifer. Similar sediments in the aquifer 37 km east-northeast of Esperance yielded 300 m^3/day with a stable 3.65 m drawdown (Baddock, 1995b). The yield from bores drawing from the spongolite aquifer probably varies through the region, and depends on the proportion of spongolite present and the development of solution channels.

The Werillup Formation, if present, is a confined aquifer overlain by clays and silts, and bores constructed within the coarse sands could potentially yield several hundred cubic metres per day.

Groundwater salinity

The distribution of groundwater salinities within the Pallinup Siltstone is shown on Figure 6, and the chemical analysis of groundwater from CBC piezometers is presented in Table 2. The aquifer contains groundwater with a salinity <1000 mg/L T.D.S. over approximately 45 km^2 of the area. Almost all groundwater between Coramup Creek and Bandy Creek, and south of Blumanns Road is fresh, and most has a salinity below 500 mg/L. CBC piezometers 1, 2 and 3 in this area produced groundwater with salinities between 320 mg/L (CBC-1S) and 880 mg/L (CBC-3). Fresh groundwater also occurs east of Bandy Creek, extending about 1 km east of Old Smokey Road, and includes a poorly defined area where the groundwater salinity is about 500 mg/L, including CBC-5 (530 mg/L).

Brackish to saline groundwater surrounds the investigation area. On the coastal plain south of the scarp, groundwater is generally saline and the land surface is salt affected. Groundwater salinity increases rapidly to the west, north and northeast of the investigation area, and is generally between 1000 and 4000 mg/L toward Gibson in the northwest. Benje Benjenup Lake, west of the area, is a large salt lake with a salinity of over 75 000 mg/L (December, 1993), and salt lakes are common to the northeast. In the east of the investigation area groundwater salinities range up to about 6000 mg/L within the spongolite aquifer, and further east exceed 7000 mg/L.

No groundwater salinity data is available for the Werillup Formation aquifer in the investigation area, although a water sample taken at 57 m depth from the lower facies of the Pallinup Siltstone while drilling CBC-1D had a salinity of 4400 mg/L, compared with a water sample from the piezometer of 3310 mg/L(which may have been diluted by leakage from above through the annulus). A bore screened within the Werillup Formation at Shark Lake, 7 km southwest of CBC-1, contained groundwater with a salinity of 9720 mg/L (Baddock, 1995b). It is therefore believed that the aquifer contains brackish to saline groundwater within the investigation area.

In all water samples sodium is the dominant cation and chloride is the dominant anion. The major ions in the groundwater are plotted as a percentage of their total milli-equivalent per litre concentrations on a trilinear diagram (Fig. 7).

Groundwater recharge

Groundwater within the Pallinup Siltstone is recharged by the direct infiltration of rainfall. Recharge rates are probably greater over the sand/silt facies than the spongolite facies, due to the presence of an extensive clay unit overlying much of the spongolite. The rate of groundwater recharge is likely to be greater adjacent to the granite hills in the area, particularly around a prominent hill adjacent to Dempster Road near Fisheries Road, and around the hills near Old Smokey Road, where there is an area of low salinity water within the spongolite facies aquifer. Groundwater recharge rates are probably much greater now under agricultural land cleared of natural vegetation than under the original undisturbed conditions.

In the absence of surface runoff the groundwater recharge rate can be estimated using the ratio between the input concentration of chloride in rainfall and dryfall, and the chloride concentration in groundwater, although where there is a high proportion of runoff to infiltration the recharge rate may be overestimated. At Esperance the sea-salt input is 178 kg/ha (Hingston and Gailitis, 1976), which is equivalent to an input concentration of about 15 mg/L chloride (Cl^-). The chloride ion concentration for groundwater from CBC piezometers within the sand/silt and spongolite facies of the Pallinup Siltstone ranges from 125 to 505 mg/L, representing estimated rechare rates ranging between 3% and 12% of rainfall (Table 3). Over the sand/silt facies, runoff is probably small compared to infiltration, so the recharge estimate should be valid; however runoff may be greater from land surfaces over the spongolite facies. The recharge rate at CBC-3 and CBC-4 may be under-estimated due to elevated salinities caused by groundwater of high salinity flowing into these areas. The average recharge over the sand/silt aquifer appears to be about 10% of rainfall; possibly about half of this rate applies over the spongolite aquifer.

The Werillup Formation is recharged by slow leakage through the Pallinup Siltstone. In some areas recharge may also occur through more permeable sediments within the Pallinup Siltstone where the formation abuts basement highs.

Groundwater flow and discharge

The approximate watertable contours and groundwater flow directions are shown on Figure 5 and 8. Groundwater in the investigation area generally flows southward and towards either Coramup Creek or Bandy Creek. Most groundwater flow is through the upper facies of the Pallinup Siltstone, and groundwater is deflected around areas of shallow basement or weathered profile which have a low permeability.

Groundwater discharges from seeps on the flanks of the creeks and along the scarp. Discharge from the spongolite aquifer is probably limited by overlying clay, with some discharge occurring as springs where the clay is absent.

Table 2. Chemical analyses of groundwater.

Piezometer	CBC-1S	CBC-1D	CBC-2	CBC-3	CBC-4	CBC-5
Conductivity (mS/m at 25°C)	55	550	60	145	200	90
Colour (TCU)	<1	<1	<1	<1	<1	<1
pH lab	7.6	7.6	7.8	7.5	7.7	7.6
TDS (calc) (mg/L)	320	3310	370	880	1200	530
TDS (sum) (mg/L)	300	3150	330	820	1040	570
Total Hardness (mg/L)	32	475	15	145	265	20
Total Alkalinity (mg/L)	53	305	64	91	165	86
(mg/L)						
Calcium, Ca	4	65	1.1	19	39	3.4
Magnesium, Mg	5.3	76	3.1	24	41	2.7
Sodium, Na	94	1200	115	270	350	165
Potassium, K	3.3	31	3.5	8.1	10	5.2
Carbonate, CO_3	<1	<1	<1	<1	<1	<1
Bicarbonate, HCO_3	65	375	78	110	200	105
Chloride, Cl	125	1600	135	370	505	205
Sulphate, SO_4	22	270	30	82	93	39
Nitrate, NO_3	1.1	0.2	1.3	6.6	12	2.1
Silica, SiO_2	9.2	8	10	8.2	6.7	25
Boron, B	0.2	0.2	0.3	0.3	0.2	0.3
Fluoride, F	0.4	1.2	0.7	0.4	0.9	0.6

Table 3. Recharge rates from chloride ratios.

Bore	Slotted interval (m bgl)	SWL (m bgl)	Cl^- (mg/L)	% Recharge
CBC-1S	18-24	10.7	125	12
CBC-2	17.5-23.5	9.2	135	11
CBC-3	23.7-29.7	22.3	370	4
CBC-4	23.6-29.6	22.2	505	3
CBC-5	20.6-26.6	4.8	205	7.3

GROUNDWATER RESOURCES

There is a significant resource of low salinity groundwater in the sand/silt and spongolite facies of the Pallinup Siltstone, but there is probably no fresh groundwater within the Werillup Formation.

Storage

The total storage of groundwater within the upper facies of the Pallinup Siltstone is estimated to be 250 x 10^6 m^3 over about 105 km^2 of the investigation area, assuming an average saturated thickness of 15 m and a storativity of 15%. About 100 x 10^6 m^3 of groundwater is estimated to be contained in the sand/silt facies which covers about 50 km^2, with approximately 70 x 10^6 m^3 having a salinity below 1000 mg/L over an area of about 30 km^2.

The volume of groundwater stored within the spongolite facies is difficult to estimate due to the high clay content and abundant voids within the spongolite. The facies covers an area of about 55 km^2, and assuming that the spongolite has an effective saturated thickness of 10 m and a storativity of 25%, there will be approximately 140 x 10^6 m^3 of stored groundwater with a salinity up to about 6000 mg/L. An estimated 35 x 10^6 m^3 of the groundwater within the spongolite has a salinity below 1000 mg/L.

Recharge

The annual groundwater recharge can be estimated by assuming a recharge rate of 10% of the average annual rainfall over the sand/silt facies, and 5% over the spongolite facies. Recharge over the area with groundwater salinity <1000 mg/L is therefore about 2.2 x 10^6 m^3, comprising 1.8 x 10^6 m^3 over the sand/silt facies and 0.4 x 10^6 m^3 over the spongolite facies. Approximately half of the annual groundwater recharge may be available for abstraction, although it may be possible to intercept a greater portion of recharge in the spongolite facies aquifer due to its high permeability. The spongolite aquifer has a relatively shallow watertable which may reduce the potential for groundwater recharge, and could be responsible for the build-up of salts in the aquifer. Groundwater abstraction may increase the rate of recharge to the spongolite aquifer by lowering water levels, and subsequently cause a decrease in groundwater salinity in areas with high salinity.

Throughflow

A calculation of throughflow toward each creek can be made for the sand/silt facies aquifer using Darcy's equation and the following parameters:

k (hydraulic conductivity) = 1.6 m/day
b (saturated thickness) = 15 m
i (hydraulic gradient) = 0.01
l (width of throughflow section) = 7000 m (7 km length of creek)
Q (throughflow) = Kbil = 0.6×10^6 m^3/year

The annual throughflow for the investigation area between Coramup Creek and Bandy Creek is therefore estimated to be 1.2×10^6 m^3/year, with another 0.6×10^6 m^3/year discharging into Coramup Creek from the west.

There is insufficient hydraulic data for the spongolite facies aquifer to estimate groundwater throughflow.

CONCLUSIONS

The TEM survey successfully identified the approximate extent and lower limit of a freshwater aquifer in the upper Pallinup Siltstone which covers approximately 45 km^2, and also identified areas of shallow basement. Drilling confirmed the occurrence of low salinity groundwater within an upper sand/silt and spongolite facies of the Pallinup Siltstone.

The sand/silt facies occurs mainly west of Bandy Creek and comprises up to 35 m of unconsolidated, mainly fine grained sand and silt. The spongolite facies occurs extensively east of Bandy Creek, and was intersected down to 29 m depth, where it comprised spongolite with solution channels and interlayered clay, overlain by several metres of clay. Both facies overlie a moderately consolidated, carbonaceous claystone-siltstone facies of the Pallinup Siltstone containing brackish quality groundwater.

Bores within the southern portion of the sand/silt aquifer can potentially yield up to about 100 m^3/day where the saturated thickness is about 20 m, but both potential yields and saturated thickness decrease northward. The spongolite facies aquifer can potentially yield several hundred cubic metres per day per bore.

It is estimated that 250 x 10^6 m^3 of groundwater is stored within the upper facies of the Pallinup Siltstone, with approximately 70 x 10^6 m^3 of this water having a salinity below 1000 mg/L within the sand/silt facies, and another 35 x 10^6 m^3 within the spongolite aquifer. Groundwater recharge rates over the sand/silt aquifer have been estimated by chloride ratios to be 10% of rainfall, with recharge to the spongolite aquifer about half of this rate. The annual groundwater recharge over areas with groundwater salinity <1000 mg/L is estimated to be about 2.2 x 10^6 m^3, of which over half may be available for abstraction. Groundwater abstraction from the spongolite aquifer may increase recharge rates to the aquifer.

REFERENCES

BADDOCK, L.J., 1994, Esperance town water supply investigation drilling 1993: Geological Survey of Western Australia Hydrogeology Report 1994/4 (unpublished).

BADDOCK, L.J., 1995a, Bore completion reports, Coramup - Bandy Creek, Esperance: Geological Survey of Western Australia Hydrogeology Report 1995/6 (unpublished).

BADDOCK, L.J., 1995b, Esperance water deficiency groundwater drilling program completion reports: Geological Survey of Western Australia Hydrogeology Report 1995/9 (unpublished).

BERLIAT, K., 1952, Report on exploratory drilling for water, Esperance Plain; Geological Survey of Western Australia, Annual Report 1952, p. 21-26.

COCKBAIN, A.E., 1968, The stratigraphy of the Plantagenet Group, Western Australia: Geological Survey of Western Australia Annual Report 1967, p. 61-63.

HINGSTON, F.J., and GAILITIS, V., 1976, The geographic variation of salt precipitation over Western Australia: Australian Journal of Soil Research, 14, pp 319-335.

MORGAN, K.H., and PEERS, R., 1973, Esperance - Mondrain Island: Western Australia: Geological Survey of Western Australia 1:250 000 Geological Series Explanatory Notes.

PERRY, A., 1994, Geophysical surveys for fresh water mapping, Coramup - Bandy Creek Paleochannel: World Geoscience Corporation Report 3011 for the Geological Survey of Western Australia.

QUILTY, P.G., 1969, Upper Eocene planktonic foraminifera from Albany, Western Australia: Royal Society of Western Australia, Journal, v. 52, p. 41-58.

QUILTY, P.G., 1981, Late Eocene benithic Forminiferida, south coast, Western Australia: Royal Society of Western Australia, Journal, v. 64, p. 79-100.

STOVER, L.E., and PARTRIDGE, A.D., 1982, Eocene spore-pollen from the Werillup Formation, Western Australia: Palynology, v.6, p. 69-95.

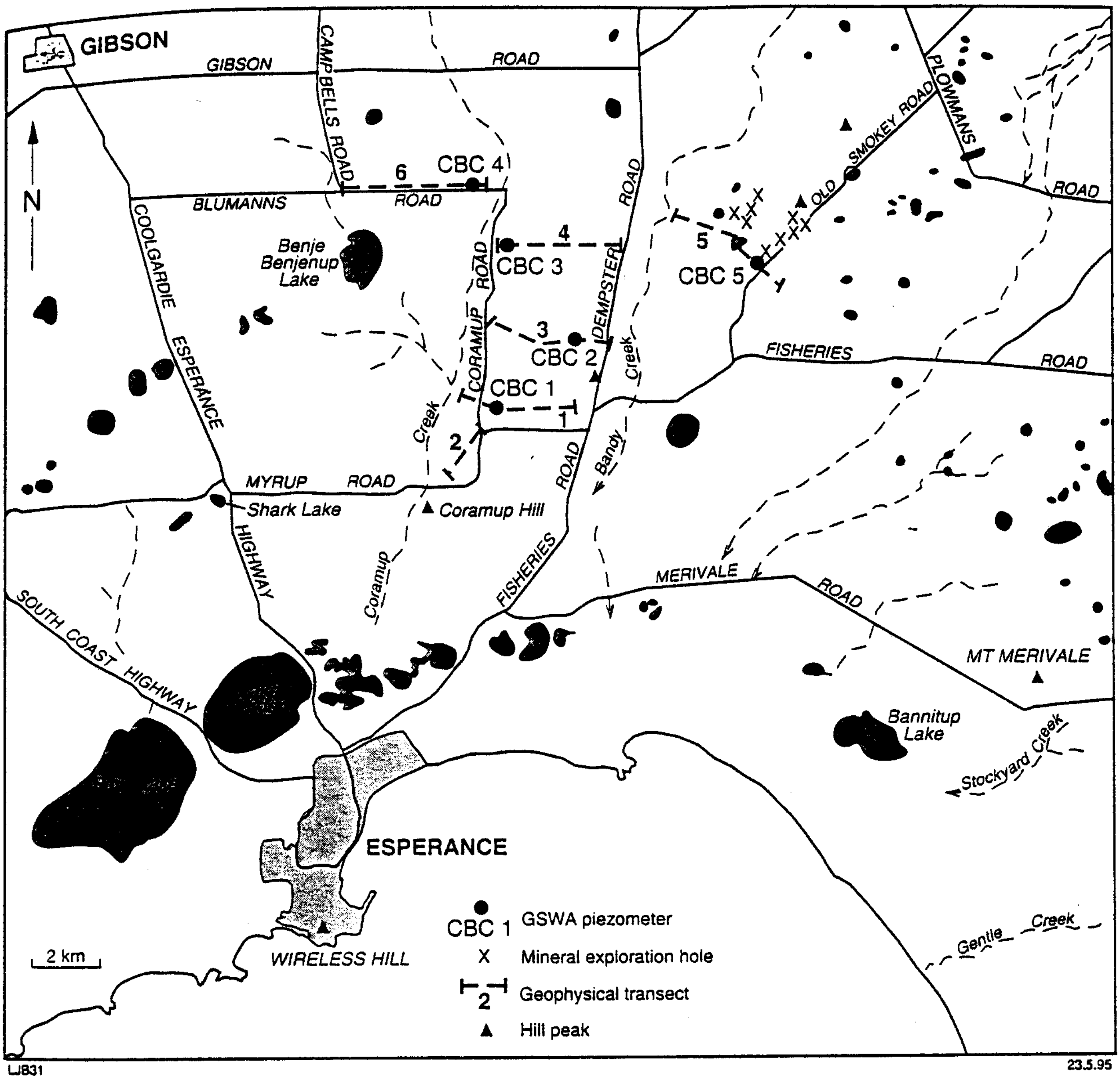
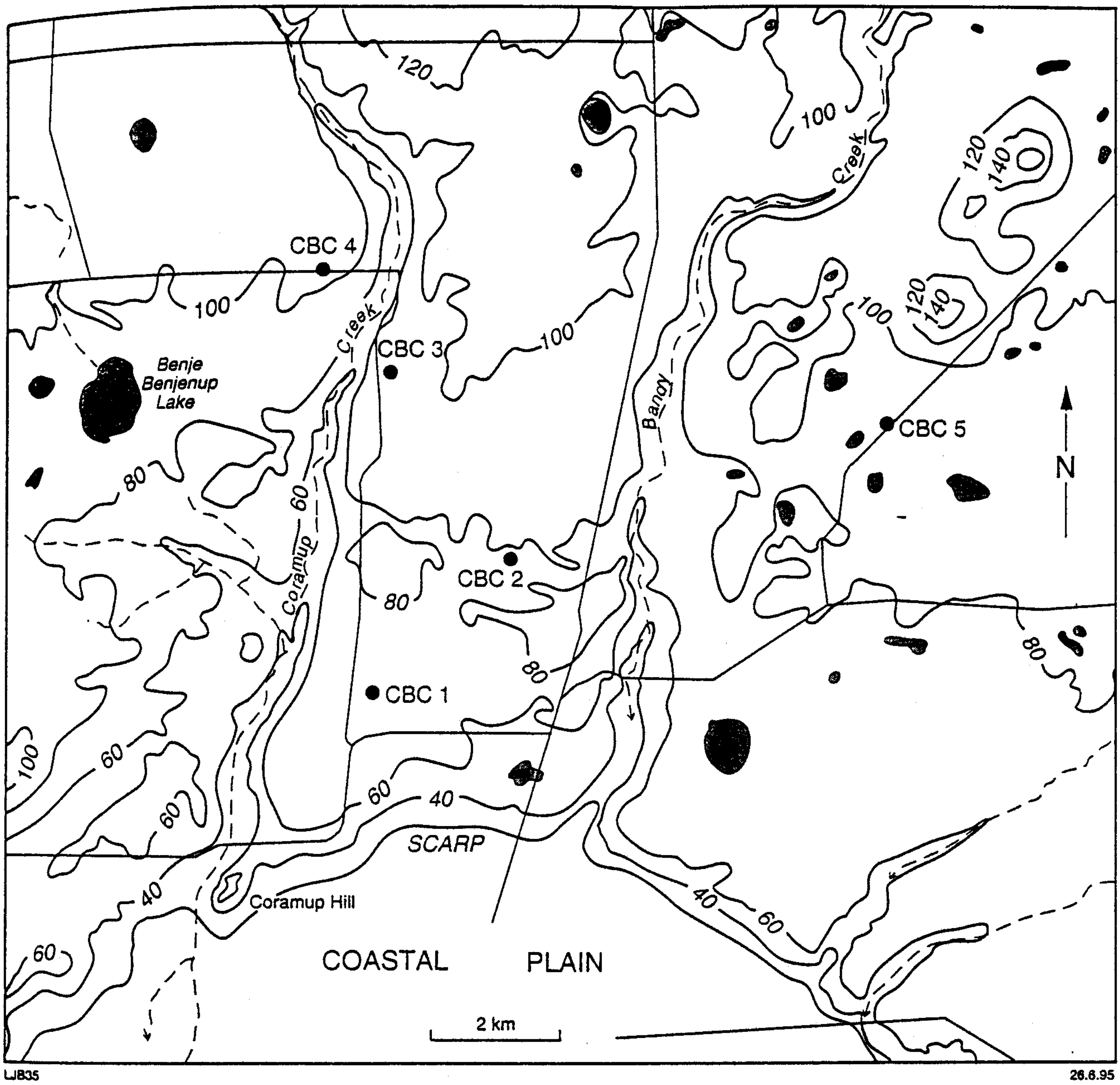


Figure 1. Locality plan



— 60 — Elevation contour (m AHD)

● CBC 1 GSWA piezometer

Lake

Figure 2. Physiography

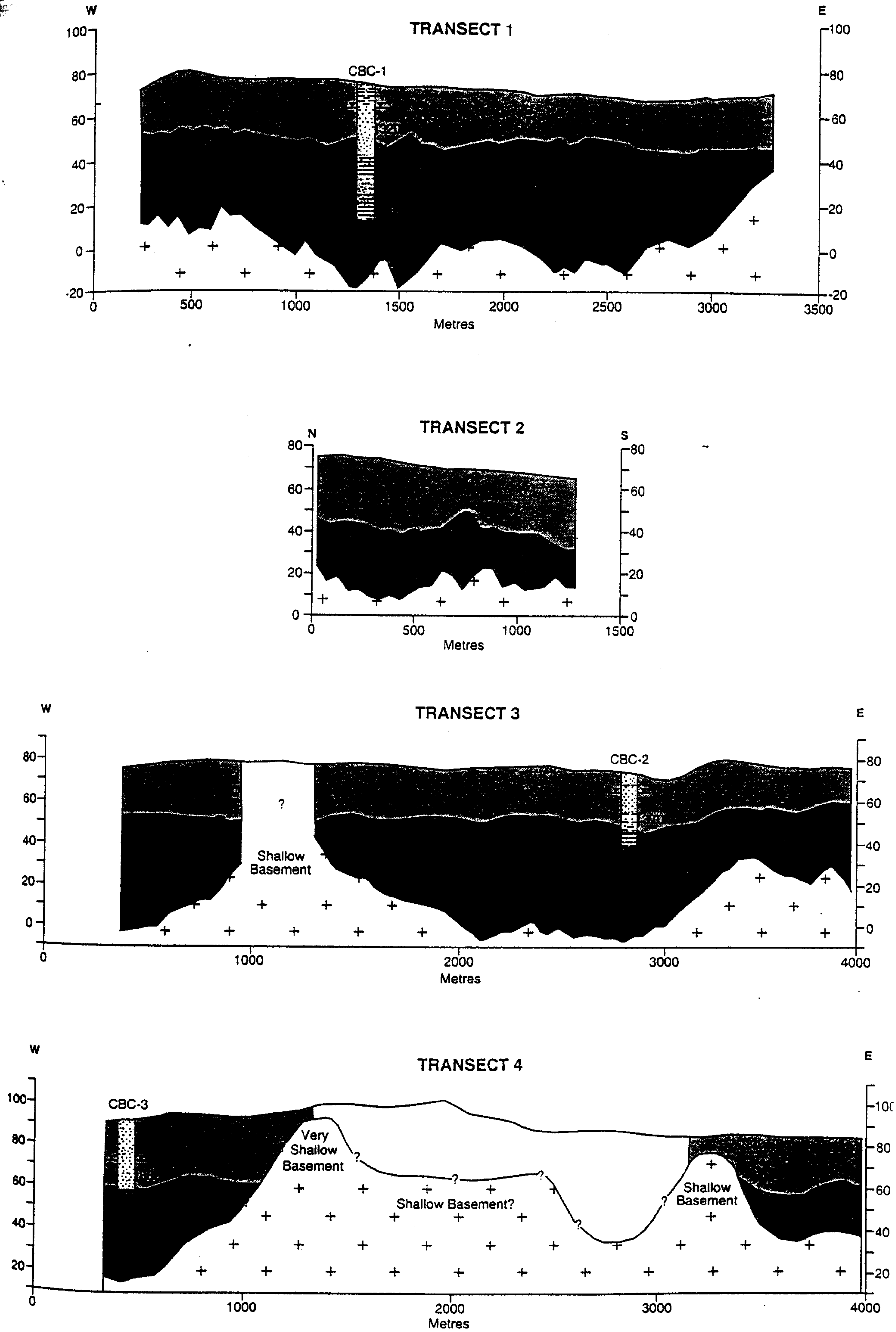
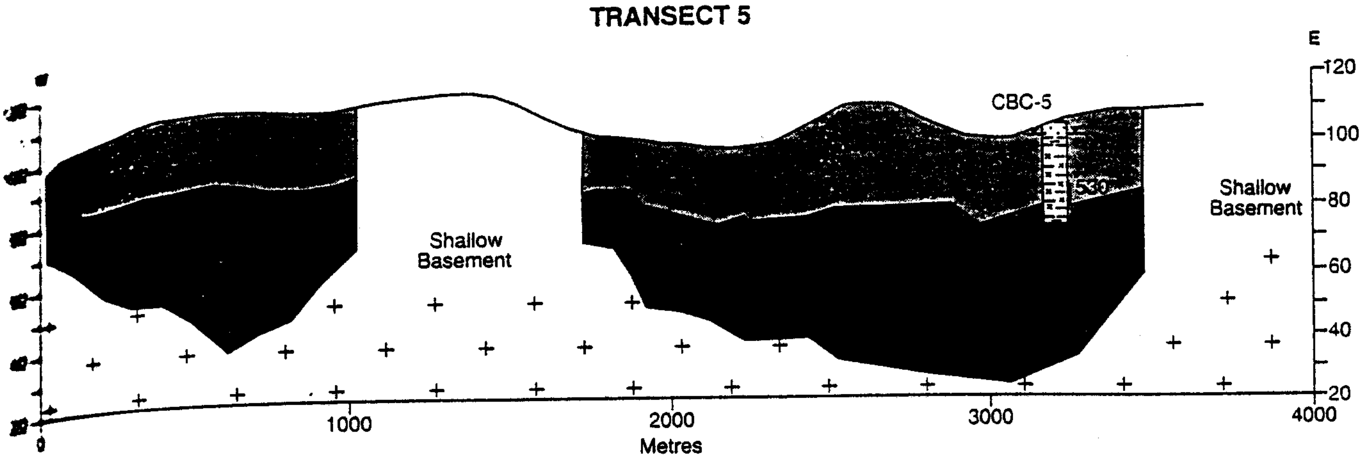
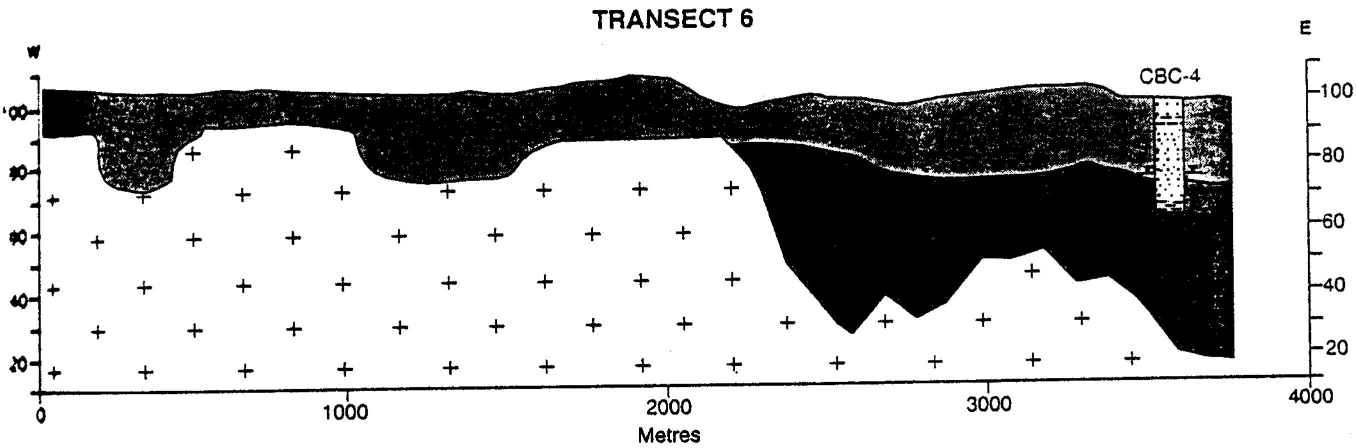


Figure 3. Geophysical and hydrogeological cross-sections...





Sand

Silt

Clay/Shale

Spongolite

Carbonaceous siltsone/claystone facies

High resistivity layer (geophysical survey)

Low resistivity layer (geophysical survey)

Basement (geophysical survey)

Watertable

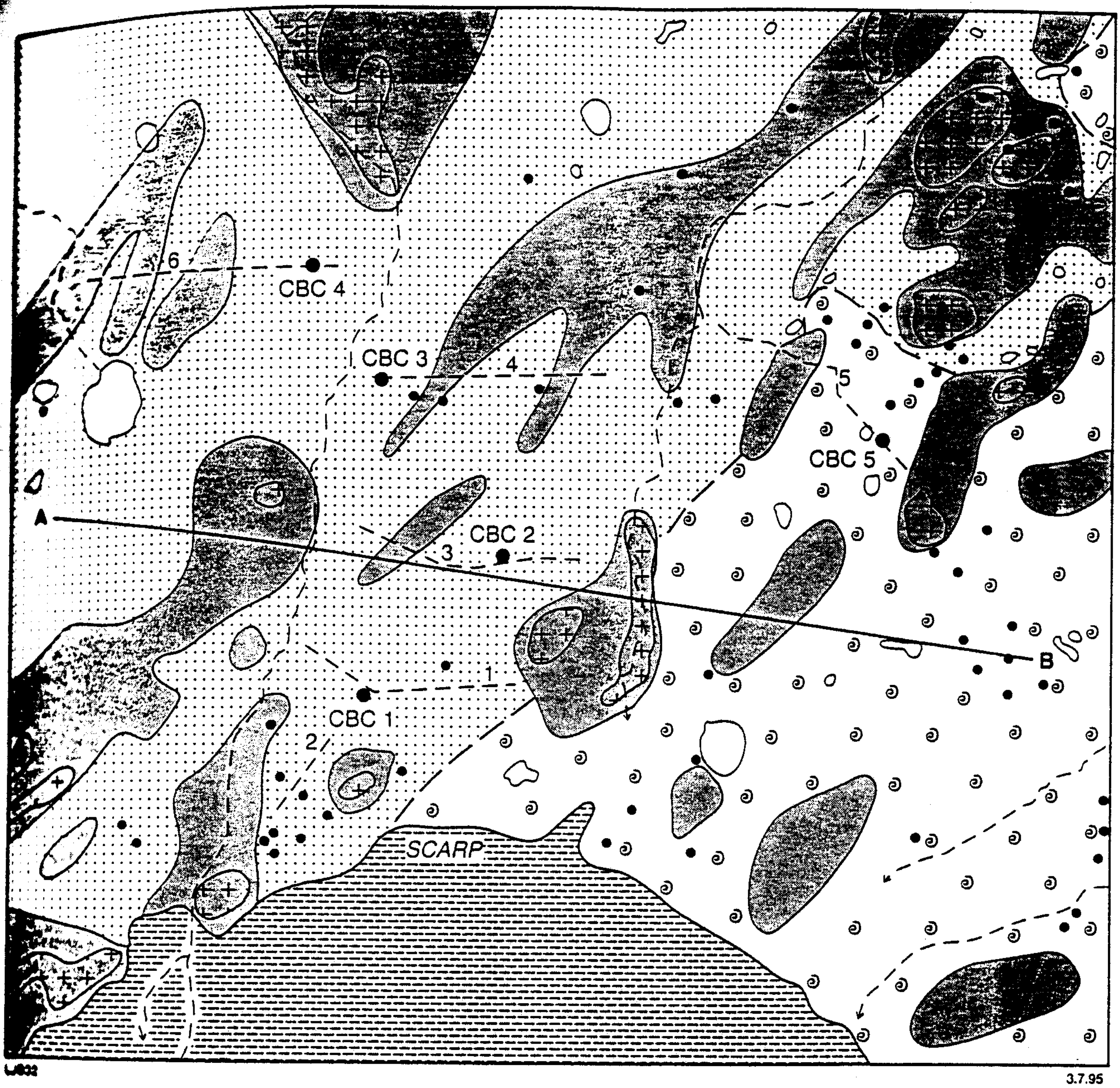
Slotted interval

370 Groundwater salinity (mg/L) from slotted interval (chemical analysis by calculation)

LJ838

16.6.95

Figure 3. Geophysical and hydrogeological cross-sections



Coastal Plain deposits - sand, silt

Pallinup Siltstone - sand/silt facies

Pallinup Siltstone - spongolite facies

Proterozoic granitic gneiss - outcrop

Lake

Approximate limit of spongolite facies

CBC 1 GSWA piezometer

Bore hole

Geophysical survey transect line

A——B Cross section line (Fig 5.)

2 km

Figure 4. Geology

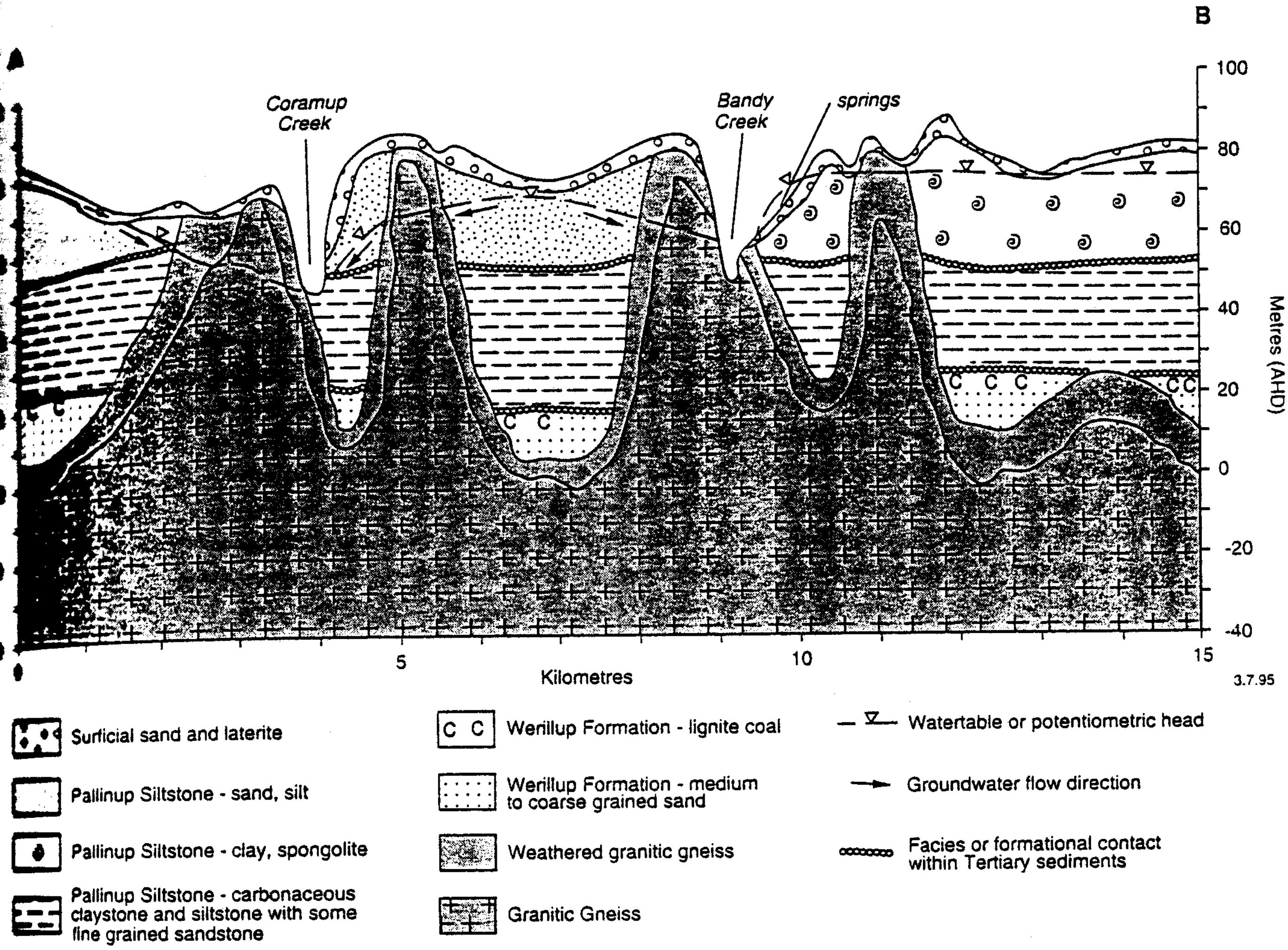
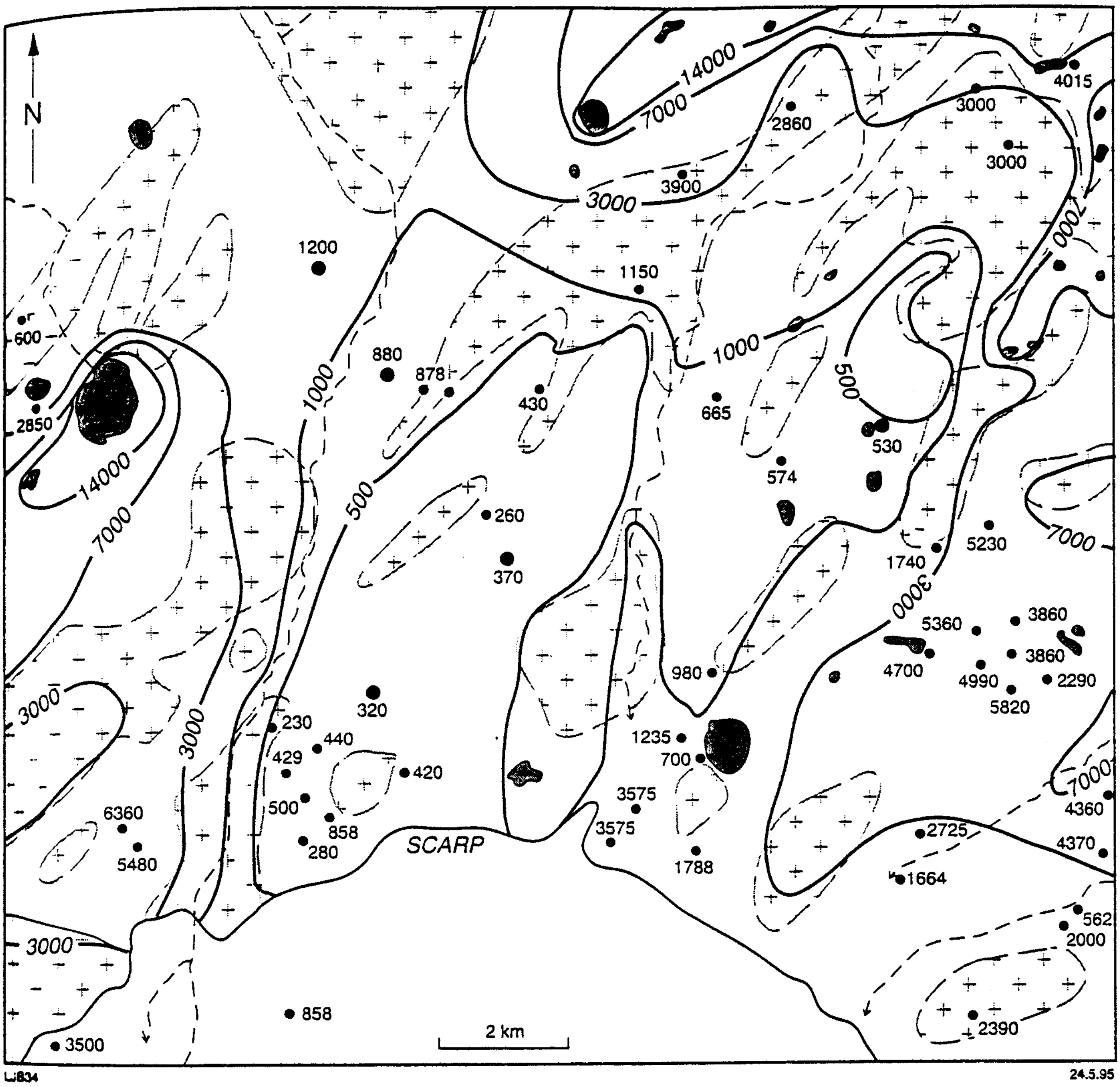


Figure 5. Schematic hydrogeological cross-section



Shallow basement - Tertiary sediments absent

–3000– Isohaline (mg/L)

● 320 GSWA piezometer with groundwater salinity (mg/L)

• 858 Private bore with groundwater salinity (mg/L)

Lake

Figure 6. Groundwater salinity: Pallinup siltstone

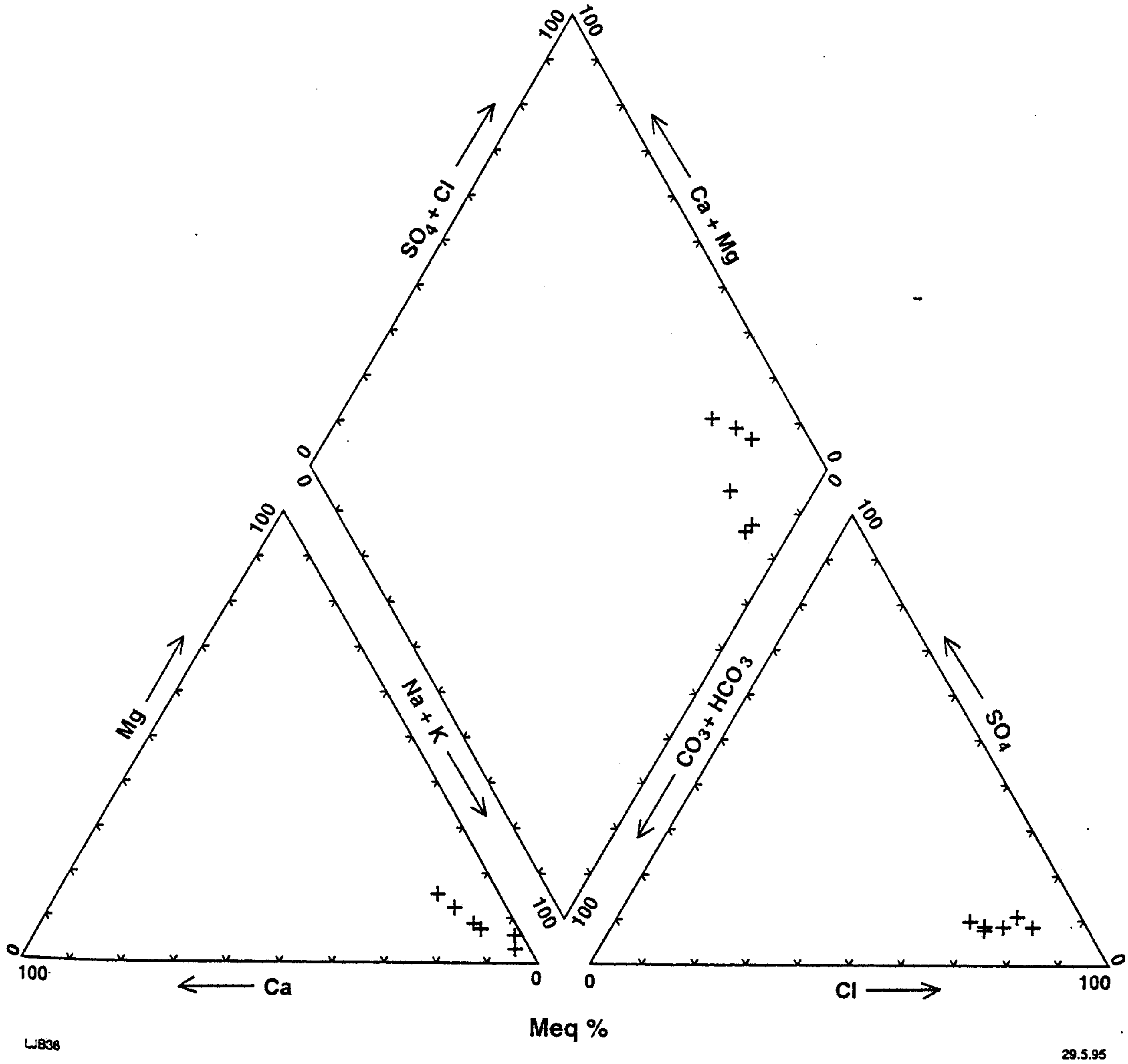
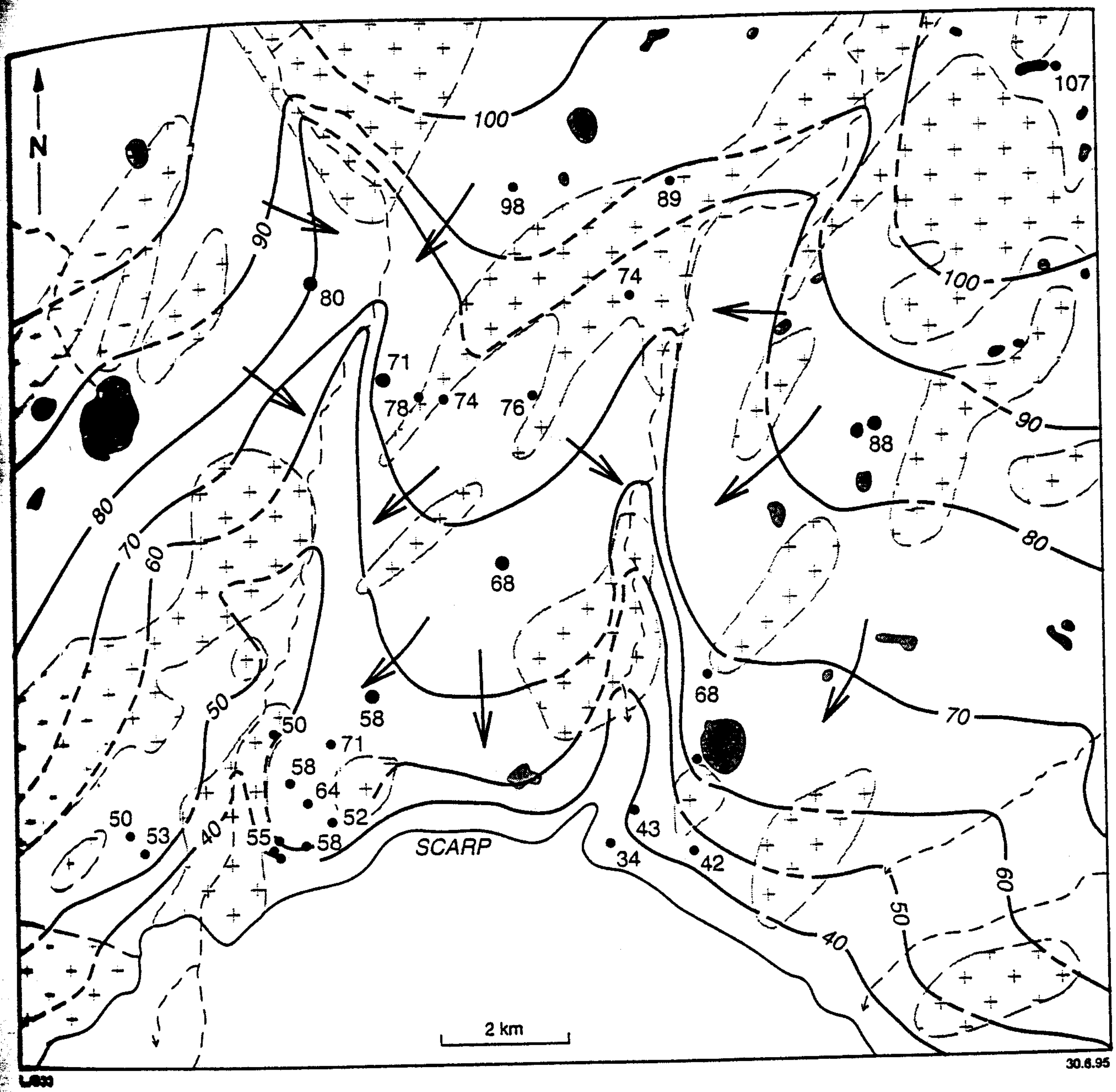


Figure 7. Piper trilinear diagram



— 80 — Watertable elevation contour, approximate (m AHD)

Direction of groundwater flow

● 80 GSWA piezometer with approximate elevation of water table (m AHD)

• 58 Private bore with approximate elevation of watertable (m AHD)

Lake

Drainage

Shallow basement - Tertiary sediments absent

Figure 8. Watertable contours