

1976/24. Geology and hydrology of the Tertiary and Quaternary sediments near Greens Beach, northern Tasmania.

W.C. Cromer
D.J. Sloane

The Department of Mines was requested by the Beaconsfield Council and the Rivers and Water Supply Commission to investigate the groundwater potential of the Greens Beach area, northern Tasmania. It is unlikely that the towns of Greens Beach [782515]* and Kelso [824492] will be connected to the Tamar Regional Water Supply, and future residential water requirements may exceed 250 000 m³/year, and 2500 m³/day in peak periods.

A previous survey (Cromer, 1974) reported on the groundwater supply at the Greens Beach caravan park and found that sufficient water existed to cater for the summer influx of holidaymakers. The present investigations extended the original geophysical and augering programmes. In addition thirty mechanically augered holes were drilled in unconsolidated sediments throughout the area. Some of the holes were pump-tested by spear bore and the water samples analysed. A survey of existing residential groundwater use at Kelso and Greens Beach was undertaken.

GEOLOGY

The area has been mapped by Gee and Legge (1971) (fig. 1), while Sutherland (1971) described the geology and petrology of the Tertiary basalts in the Tamar Valley.

Jurassic dolerite

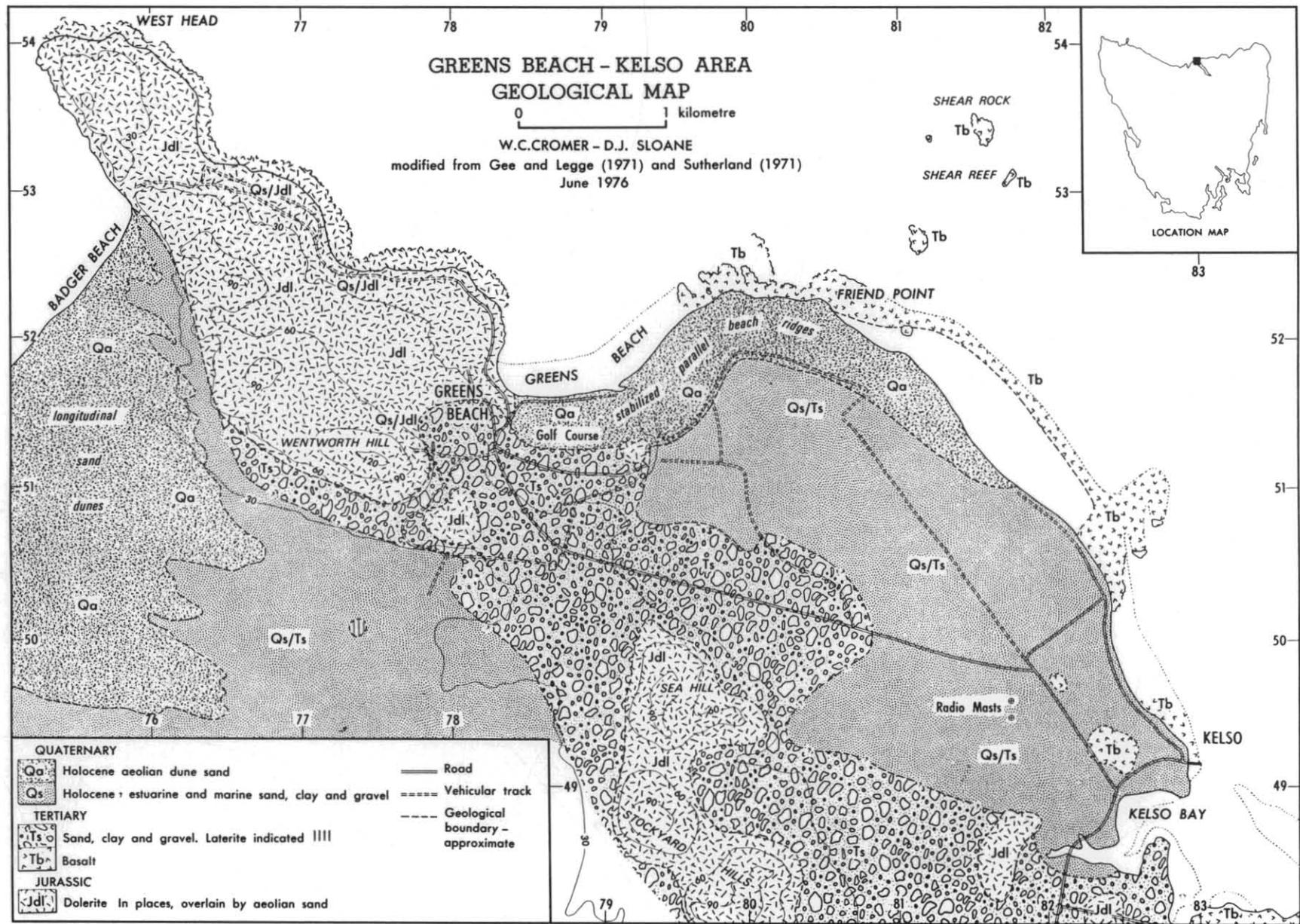
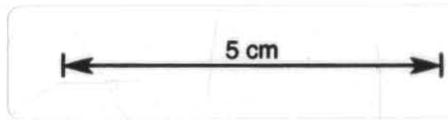
The western boundary of the Tamar Graben is delineated by a series of partly buried dolerite horsts extending south-east from West Head to Kelso. The western side of Wentworth Hill and West Head appears to be fault-controlled, and may represent the eastern boundary of a small graben south-east of Badger Beach. Generally, the lower slopes of the dolerite hills are buried beneath Tertiary sediments. Behind Greens Beach and at the eastern end of Badger Beach, where the dolerite extends almost to sea level, it is overlain by Quaternary deposits. A previously unrecorded dolerite body occurs at [793513].

Tertiary basalts

Sutherland (1971) described in detail the petrology of the basalts in the lower Tamar Trough. He established the presence of two major volcanic episodes, represented by a Lower Basalt and an Upper Basalt. The Lower Basalt overlies Eocene sediments and is in turn overlain by interbasaltic post-Upper Eocene gravel, sand and clay. Quaternary and Upper Tertiary sediments overlie the Upper Basalt. The volcanism disrupted the course of the ancestral Tamar, and Sutherland (1971, p.5) suggests the river was once diverted north of Beaconsfield between West and Badger Heads.

The Lower Basalt is exposed on extensive shore platforms between Friend Point and Kelso. The unit also occurs at shallow depth beneath the flat, low-lying coastal plain north-west of the township, where it was intersected in profile Holes 6-12 (fig. 2). Drilling revealed that the eroded upper surface of the basalt is irregular, but in general dips westward. According to Sutherland (1971, p.21) its base rises gently inland, although drilling control to support such a premise is lacking.

*All localities lie within the AMG 100 kilometre grid square DQ.



24-2

Figure 1.

97/e

Basalt also underlies the Tertiary sediments near the Kelso-Greens Beach road north-east of Sea Hill, and was intersected in proline Holes 17 and 19 (fig. 2), at depths of 3 and 7 m respectively. Ten metres lower, at the base of the Tertiary escarpment, basalt occurred in Hole 13 at a depth of 14 m. Because none of the drill holes penetrated the basalt, it is not possible to assign stratigraphic positions to any of the three occurrences of the rock. Three explanations are possible:

- (a) All the basalt intersected represents Sutherland's Lower Basalt. If this is so, the unit is much thicker than previously supposed;
- (b) the basalt in Holes 17 and 19 belongs to the Upper Basalt, and both the upper and lower flows are represented in the area;
- (c) all holes except Hole 13 intersected the Lower Basalt, and the basalt in Hole 13 represents a previously undetected and earlier volcanic episode.

A solution to the problem requires detailed petrological work, and additional deeper drilling to establish the sequence and thickness of each unit.

The present drilling and seismic programmes suggest the presence of a narrow buried erosional channel extending north-west along the base of the Tertiary escarpment towards Greens Beach. Such a channel may delineate part of a former course of the Tamar. The basement geology along Greens Beach is shown in Figure 8.

Tertiary sediments

Post-basaltic Tertiary sediments mantle the dolerite horsts south of Greens Beach and form an extensive almost level surface about 20 m above sea level extending south-east from Wentworth Hill. Low-lying areas behind Badger Beach and north-west of Kelso have previously also been mapped as Tertiary, but such areas were inundated during Quaternary higher sea levels. As a result, parts of the original Tertiary sequence have been reworked and these are included among the Quaternary deposits (fig. 1) in this report.

The Tertiary rocks consist mainly of unconsolidated fine-medium grained slightly clayey sand. Clay and gravel are ubiquitous but generally minor constituents. Behind Badger Beach the sequence contains clayey gravel and grit derived from the Asbestos Range and Wentworth Hill.

Quaternary sediments

The Quaternary sequence comprises aeolian, marine and probably estuarine deposits. Fine-medium grained sand predominates, with small amounts of clay and gravel. The sand near Greens Beach contains a well-preserved shell fauna, indicating a marine origin. Shells are absent however in the fine-grained sediments behind Badger Beach and north-west of Kelso. Some of these deposits probably consist of Tertiary sediments, but they may contain Quaternary estuarine (and lacustrine?) material.

Brown carbonaceous clay containing wood fragments was struck at a depth of about 8 m below sea level in proline Hole 1 at Greens Beach [739516]. The clay is interbedded with marine sand (appendix 1) but the age of the clay is not known, possibly being of early Holocene or late Late Last Glacial age. Wood fragments were also recovered from Tertiary(?) sediments at a depth of 12 m in proline Hole 13.

Aeolian sand forms extensive Holocene dune systems behind Greens and

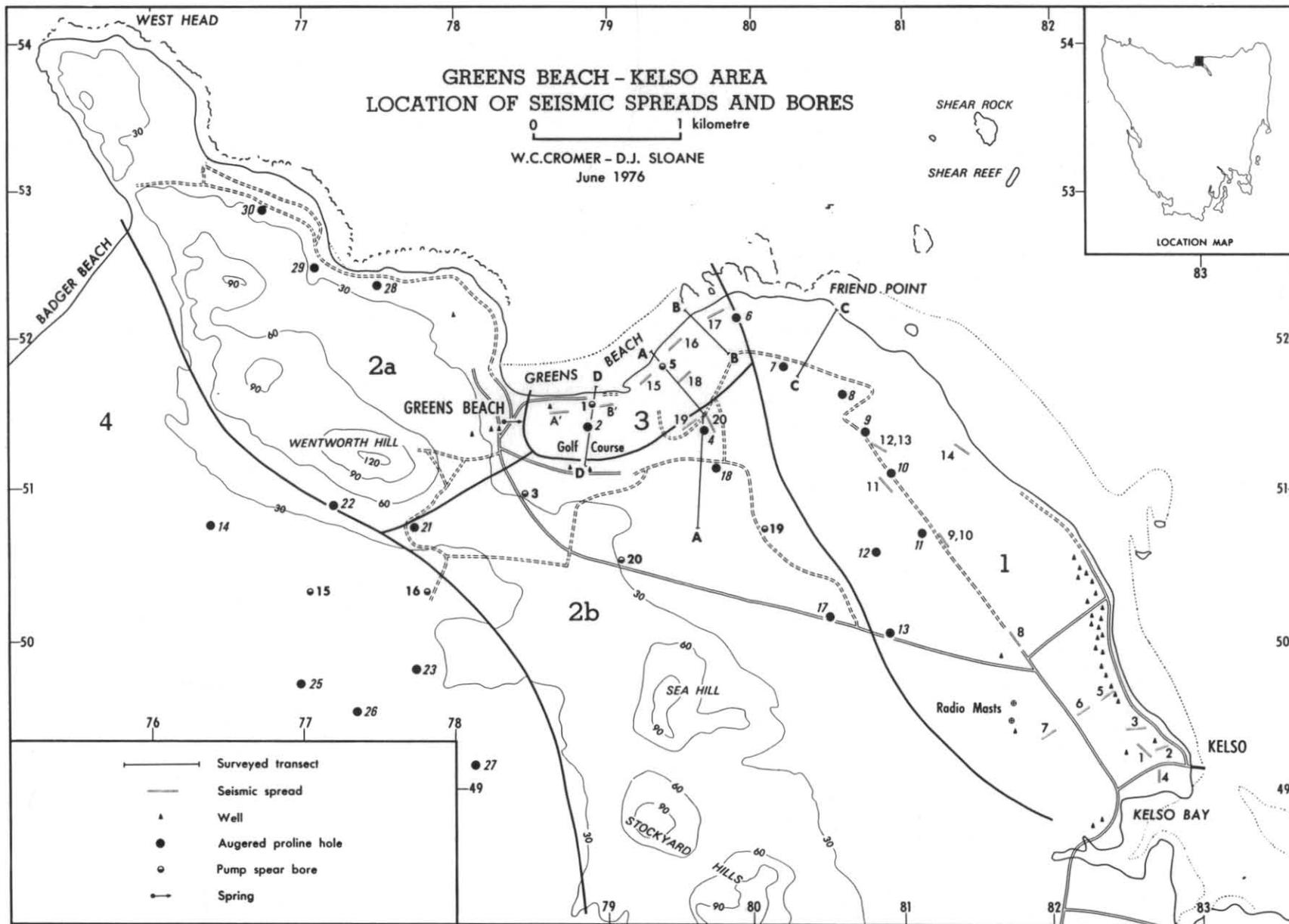


Figure 2.

24-4

4146

Badger Beaches. At Greens Beach the dunes form a complex series of stabilised, parallel to sub-parallel beach ridges overlying marine sand. At Badger Beach, longitudinal blow-out dunes overlie a well-developed Late Last Glacial palaeosol (N. Chick, pers. comm.) developed on marine sand. Relatively thin patches of wind-blown sand overlie Jurassic dolerite between Wentworth Hill and West Head.

Logs of all proline holes drilled in Tertiary and Quaternary sediments are given in Appendix 1, and geological sections of Greens Beach are shown in Figures 6-8.

GEOPHYSICS

In addition to the two seismic spreads fired previously (Cromer, 1974; fig. 2, A¹ and B¹), a survey of twenty spreads was made along the coastal strip from Greens Beach to Kelso. This survey was designed to indicate the thickness of unconsolidated sediments in the area and to locate sites for proline drilling and spear-bore tests. Details of all spreads are listed in Table 1, with selected seismic profiles given in Figures 3-5. With the exception of weathering Spreads 9 and 12 (geophone spacing 3 m), all employed geophone spacings of 7.6 m. Seismic velocities less than about 500 m/s are interpreted as representing dry-damp sand or gravel; velocities of about 1500 m/s indicate saturated sand, clay or gravel. Higher values up to about 6000 m/s represent basement rocks (Jurassic dolerite or Tertiary basalt) in various stages of weathering.

Table 1. SEISMIC RESULTS, GREENS BEACH-KELSO AREA

Spread number	AMG Grid reference	Refractor	Seismic velocity (m/s)	Refractor thickness (m)	Interpretation
A*	787515	1	375-470	3	Dry-damp sand.
		2	1590-1620	c.24	Saturated sand and clay.
		3	3500-6000	-	Basement-dolerite in various stages of weathering.
B*	790516	1	330-340	4	Dry-damp sand.
		2	1600	c.25	Saturated sand and clay.
		3	3500-6000	-	Basement - dolerite in various stages of weathering.
1	827493	1	330	1-2	Dry sand and basalt boulders.
		2	2300	2-3	Saturated boulder beds and weathered basalt.
		3	4200	-	Tertiary basalt.
2	828493	1	380	1-2	Topsoil and basalt boulders.
		2	3160	-	Saturated boulder beds and weathered basalt
		3	5600	-	Tertiary basalt.
3	826495	1	380	1-2	Dry sand and boulder beds.

*Cromer, 1974; Spread 1 and Spread 2.

Table 1. (continued)

Spread number	AMG Grid reference	Refractor	Seismic velocity (m/s)	Refractor thickness (m)	Interpretation
3	826495	2	2135	3-9	Saturated boulder beds and weathered basalt.
		3	4080		Tertiary basalt.
4	828492	1	380	1.5-4	Basalt boulder beds.
		2	2570	-	Weathered Tertiary basalt.
5	824497	1	380	0.5-3	Dry sand
		2	2640	c.10	Saturated boulder beds and weathered basalt.
		3	4270	-	Tertiary basalt.
6	823496	1	380	1.5-3	Dry sand.
		2	1660	c.30	Saturated sand, boulder beds and possibly clay.
		3	4270	-	Tertiary basalt.
7	821494	1	390	2-2.5	Dry sand
		2	1500	8-10	Saturated basalt boulder beds, and clay.
		3	2700	-	Weathered Tertiary basalt.
8	818501	1	380	3-4	Dry sand.
		2	3290	-	Weathered Tertiary basalt.
9,10	813507	1	300	3-4	Dry sand
		2	3000	-	Weathered Tertiary basalt.
11	809511	1	495	3-4	Dry-damp sand.
		2	2900	-	Weathered Tertiary basalt.
12,13	809513	1	380	3-4	Dry sand.
		2	3300	-	Tertiary basalt.
14	814513	1	380	3-4	Dry sand.
		2	3000	-	Weathered Tertiary basalt.
15	793517	1	300	3-4	Dry sand.
		2	1500	15	Saturated sand.
		3	4200	-	Tertiary basalt.
16	795520	1	380	2-3.5	Dry sand.
		2	1800	12	Saturated sand.
		3	5000	-	Tertiary basalt.
17	798522	1	380	3-4	Dry sand.
		2	1500	8-10	Saturated sand.
		3	3500	-	Tertiary basalt.
18	795518	1	300	3-4	Dry sand
		2	1500	10-15	Saturated sand.
		3	4050	-	Tertiary basalt.

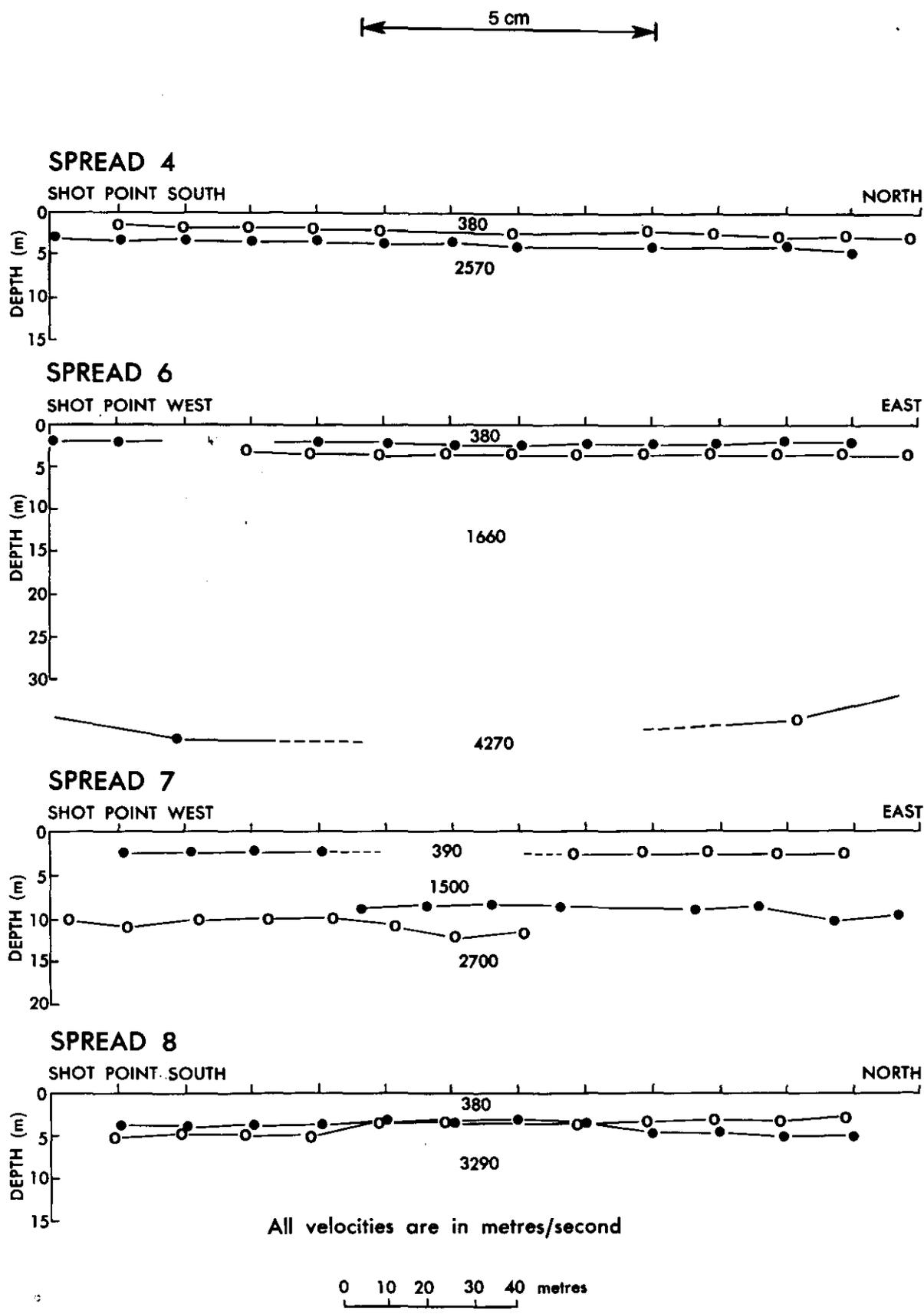


Figure 3. Seismic profiles from the Greens Beach-Kelso area. Vertical interval 5 m, V = H. Seismic velocities are in m/s.

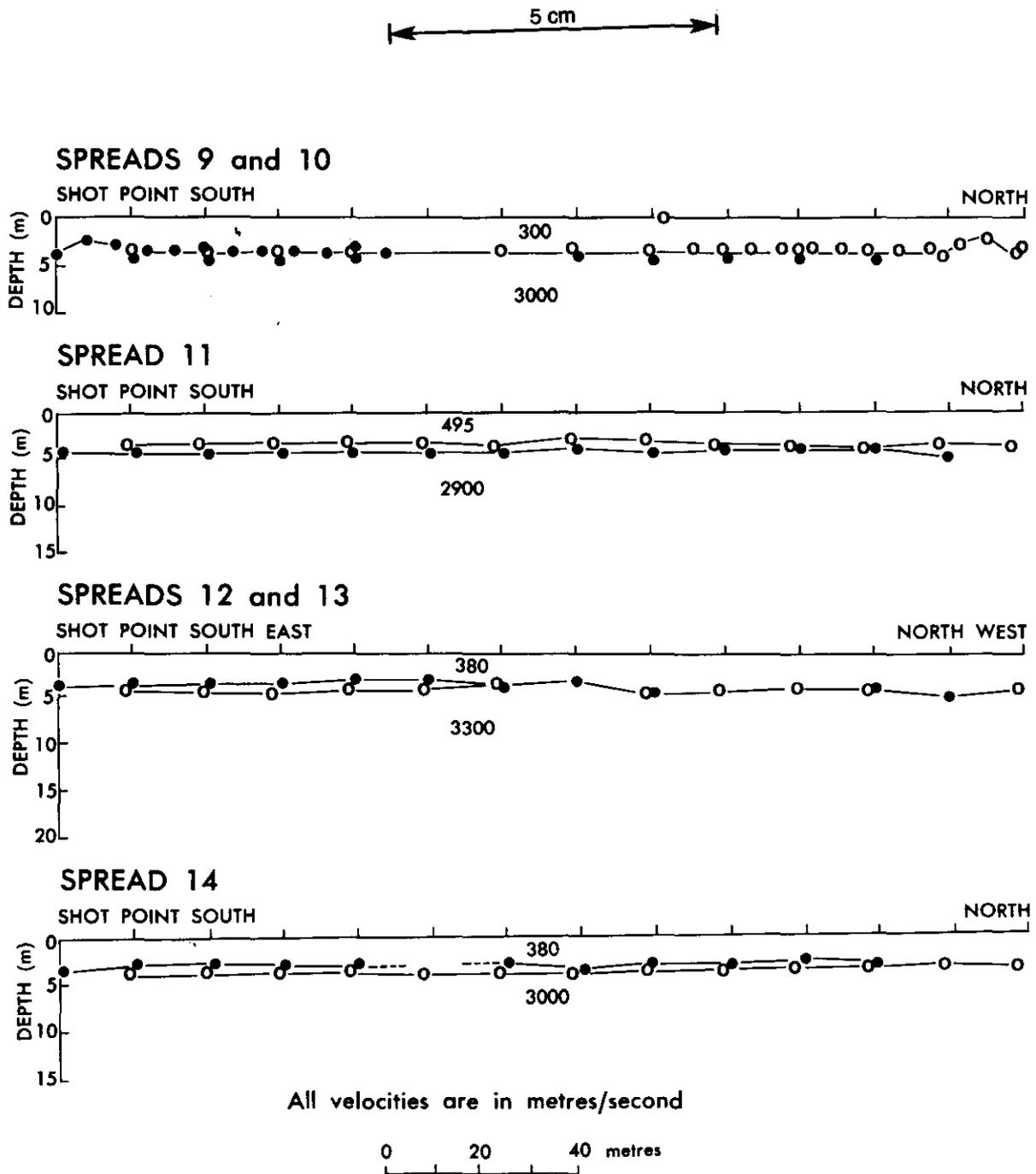


Figure 4. Seismic profiles from the Greens Beach-Kelso area. Vertical interval 5 m, $V = H$. Seismic velocities are in m/s.

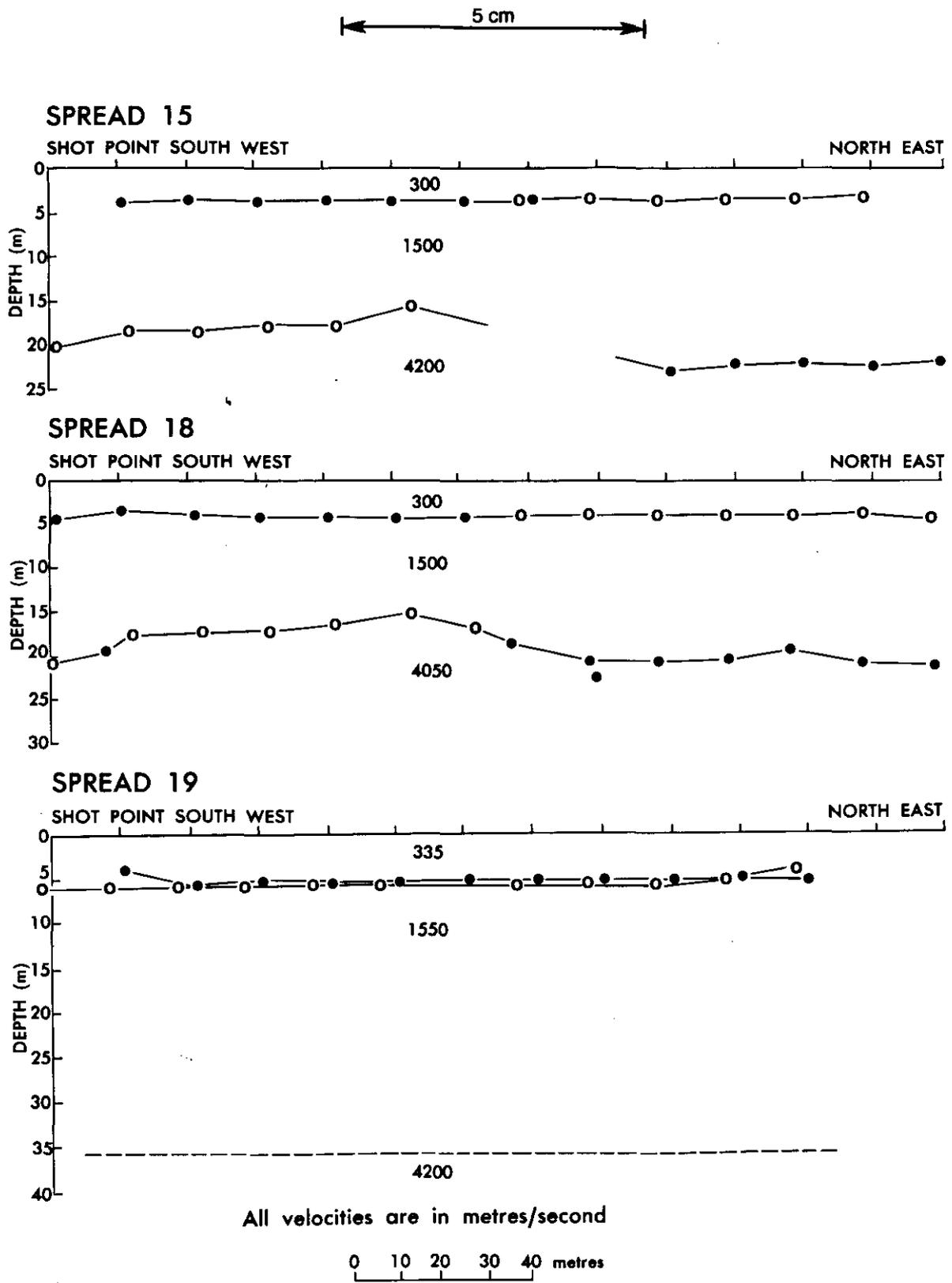


Figure 5. Seismic profiles from the Greens Beach-Kelso area. Vertical interval 5 m, $V = H$. Seismic velocities are in m/s.

Table 1. (continued)

Spread number	AMG Grid reference	Refractor	Seismic velocity (m/s)	Refractor thickness (m)	Interpretation
19	796515	1	335	4-5	Dry sand.
		2	1550	c.30	Saturated sand.
		3	4200	-	Tertiary basalt or Jurassic dolerite.
20	797514	1	300	2-3	Dry sand.
		2	1400	-	Saturated sand.
		3	4500	-	Tertiary basalt or Jurassic dolerite.

HYDROLOGY

All the major rock types in the region contain groundwater, but only the Tertiary and Quaternary sequences are expected to yield economic quantities. Elsewhere in Tasmania Jurassic dolerite has generally been found to be an unreliable source, producing only small yields of moderate-poor quality water. Bores are relatively deep and drilling is expensive. Tertiary basalts, especially varieties exhibiting well developed vesicularity, are reliable aquifers often producing large yields of excellent quality water. However, the basalts in the area remain unexplored and untapped, and little is known of their morphology and hydrological characteristics.

The unconsolidated sediments offer the most promising prospects for groundwater. The drilling and seismic surveys were confined to these sediments and considerable thicknesses of water-bearing deposits have been proven. Favourable sites were investigated further by spear bore pump tests, while less promising areas were excluded from consideration. For the purpose of discussion, the whole region has been subdivided into five main areas (fig. 2).

AREA 1

This flat low-lying area is covered by a thin veneer of Quaternary and reworked Tertiary sediments overlying Tertiary basalt. The sediments include aeolian and marine sand, clay, shelly grit, gravelly clay and basalt boulder beds. The eroded upper surface of the basalt generally dips gently landwards, but steepens near the base of the Tertiary escarpment which approximates the western boundary of the area.

The area includes the township of Kelso, where about half the residents supplement domestic tank water with groundwater from shallow wells (fig. 2, appendix 2). The aquifer is a narrow deposit of aeolian and shelly marine sand only a few metres thick. It wedges out rapidly west of the residential strip where some older (and deeper) wells obtain water from basalt boulder beds.

The wells are generally sited from 3-6 m above high water mark, and in most cases water is struck at depths less than 2.5 m. During winter, the farming land west of the town is often inundated, and most residents report that groundwater levels then approach the ground surface.

Without exception the water is used for gardening and domestic (excluding drinking) purposes. Chemically (table 6, appendix 2) it is only

marginally suitable for human consumption, and the proximity of septic tanks necessitates biological analysis prior to drinking.

Because the unconsolidated sediments are thin and variable in lithology, groundwater reserves are small and best utilised as at present, for small-scale gardening purposes. Future wells excavated in sand or boulder beds will be successful, and there is little chance of depleting the supply. However for large-scale economic extraction of groundwater from shallow wells or spears the area is unfavourable. The underlying Tertiary basalt may be a reliable aquifer, but at this stage no information is available.

AREA 2a

This area includes the small and often separate aeolian sand deposits overlying Jurassic dolerite on Wentworth Hill and West Head. Most are too thin and restricted to contain permanent groundwater (proline holes 28, 29 and 30 were dry) although temporary water tables may persist after wet periods. Some are large enough and thick enough to supply domestic quantities of water, which is used by a few residents of Greens Beach (appendix 3), but the area is clearly incapable of supplying larger amounts.

AREA 2b

This area comprises the Tertiary sediments mantling the dolerite horsts south of Greens Beach. Its northern boundary approximates the landward limit of aeolian beach ridges near the Greens Beach golf course. Proline drilling (holes 3, 4, 17, 18, 19 and 20) indicates a considerable variation in the overall thickness of the deposits and in their lithology. Clayey sand is the predominant rock type (e.g. holes 3, 4 and 20) but clay, gravelly clay and lag deposits of gravel, quartz grit and basalt boulder beds occur. This variety of rock types makes the selection of sites for pump testing difficult, but three localities (holes 3, 19 and 20) were tested. The sediments appear to thin to the east where basalt was struck in Holes 17 and 19.

In the test holes, spear bores were jetted or lowered to depths of 6-7 m and pumped for short periods. The results (table 2) were unfavourable, as none of the bores sustained yields greater than about 8 l/min. This is mainly because the aquifer contains appreciable amounts of clay which reduces its permeability. However, the spears tested only the upper levels of the aquifer and higher yields can be expected from greater depths. Deeper drilling and pumping of larger diameter screened bores is needed to effectively evaluate the aquifer, but this is outside the scope of the present investigation.

AREA 3

This area includes the aeolian beach ridge system and the underlying marine sand behind Greens Beach. The unconfined aquifer underlies the caravan park and most of the golf course, and its effective eastern limit occurs west of Friend Point where the rising basalt basement approaches the surface (fig. 8). The sequence is about 25 m thick beneath the caravan park (table 1, spread A, B). Parts of it may be Tertiary but most of the aquifer is probably Quaternary in age. Clay and gravelly clay horizons occur in the sequence especially along the southern margin of the area (appendix 1, hole 2) where the material is probably derived from weathered dolerite and Tertiary gravel beds. Clay was also struck in Hole 1 at a depth of about 9.5 m. These fine-grained aquicludes reduce the effective thickness and permeability of the aquifer. Locally confined groundwater may exist beneath them.

Nevertheless, the sand contains a large amount of groundwater and offers

Table 2. RESULTS OF SPEAR BORE PUMP TESTS, GREENS BEACH AREA.

Hole No.	Coordinates	Approximate standing water level (m)	Discharge rate (l/min)	Pumping duration (min)	Total drawdown (m)	Approximate safe yield ¹ (l/min)	WATER QUALITY			Aquifer	Remarks	
							TDS ² (mg/l)	Colour	Taste			Smell
1	789516	1.5	30	400	c.3	40	730-800	None	Slight H ₂ S	Slight H ₂ S	Quaternary marine sand	Water initially grey and muddy; clears rapidly. Salinity increased slightly during pumping.
3	785510	1	8	<5	6	<3		Muddy yellow	None	None	Tertiary clayey sand and clay	Failure.
5	794518	1.5	30	90	1	40-50	480	None	None	Slight H ₂ S	Quaternary marine sand	Water initially cloudy clear after 5 min. Sustained a discharge of 60 l/min for short period; drawdown 1.6 m
15	770504	1	3	15	c.3	<5	520	Initially muddy	None	None	Tertiary(?) clayey sand	Water gradually clears on pumping.
16	778504	0.6	30	95	c.3	30	350	Initially muddy	None	None	Tertiary(?) clayey sand	Water clears rapidly on pumping. Unacceptably high iron content.
19	801508	0.5	10	60	c.6	10		Initially muddy	H ₂ S	H ₂ S	Tertiary clayey sand	Recovers strongly. Strong H ₂ S smell; water clears gradually.
20	792506	1	6	60	5	6		Initially muddy	None	H ₂ S	Tertiary clayey sand	Clears gradually.

Notes:

¹Safe yield is considered to mean the pumping rate which a bore can sustain indefinitely.

²TDS = Total dissolved solids; obtained from chemical analyses, Table 5 and Table 6.

24-12

12/11/01

the region's best prospects for large-scale use of the resource. Two sites (holes 1 and 5) were pump tested by spear bore. Yields from both were encouraging (table 2) with each sustaining only a small drawdown when pump tested at a rate of 30 l/min, and the safe yield is probably greater than this.

Shape of the aquifer

Surveyed transects (A, B and D, fig. 2, 6-8) across Area 3, together with surveyed water levels from hand augered holes, make it possible to determine the shape of the water table and to estimate the reserve of the aquifer.

Irrespective of the overlying beach ridge system topography, the water table exhibits a smooth, almost horizontal seaward sloping profile (fig. 6-8). It has a gradient of about 1:250 (0.004 m/m) and a maximum elevation between 2 and 3 m above HWM at the rear of the coastal dunes. Generally the water table lies at shallow depth (between 1 and 2 m in the depressions between ridges) but towards the eastern edge of the area it temporarily intersects the surface during wet periods.

Groundwater reserves

The aquifer is approximately 1500 m long and 400 m wide, with an average depth of at least 10 m. Its volume is therefore $6 \times 10^6 \text{ m}^3$. Assuming a specific yield of 0.25, it contains $1.5 \times 10^6 \text{ m}^3$ of recoverable groundwater. Such a reserve is almost an order of magnitude greater than the projected yearly requirements for the town.

The area receives recharge from runoff from the higher land to the south as well as from direct precipitation. Greens Beach receives an average annual rainfall of 800 mm (table 3). Of this, about 30% percolates to the water table adding 150 000 m^3 yearly to the groundwater reservoir. This is a minimum figure, and the actual recharge probably exceeds the expected annual residential requirements of about 250 000 m^3 .

Table 3. RAINFALL FIGURES, GREENS BEACH

Month	Average to 1973 (mm)	1974 (mm)	1975 (mm)
January	35	54	26
February	51	24	6
March	43	10	122
April	65	95	47
May	78	68	107
June	81	85	85
July	96	213	224
August	87	71	78
September	60	91	93
October	65	65	63
November	57	34	95
December	52	91	60
Total	770	901	1006

AREA 4

This large, almost flat area extends from West Head to Badger Head, and south to the Stockyard Hills. It has not been studied in detail, and more

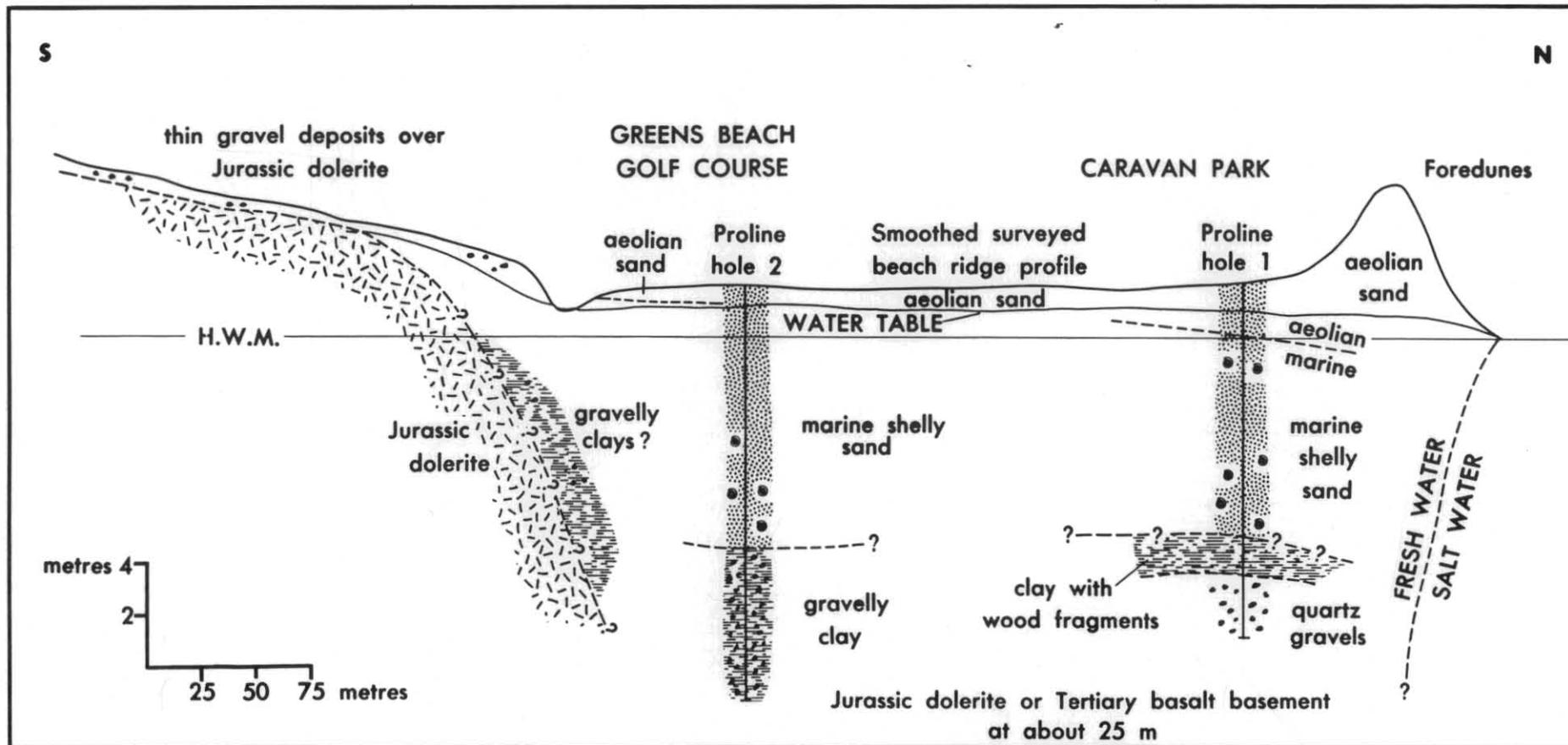


Figure 6. Section along surveyed transect D, Greens Beach, showing shape of water table, and logs of proline holes 1 and 2.

5 cm

24-15

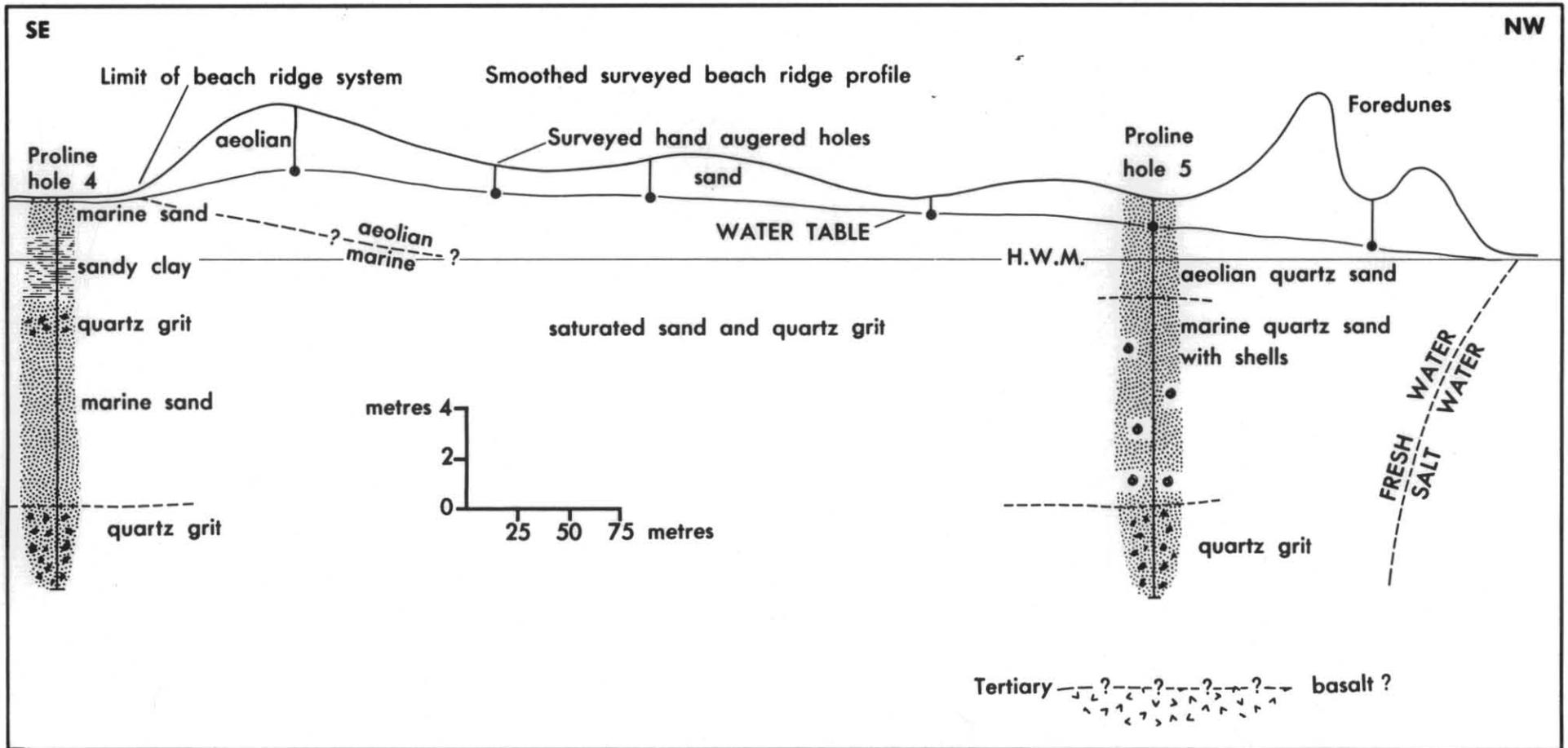
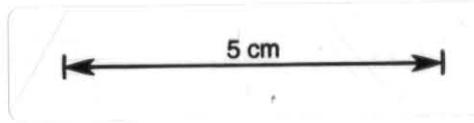


Figure 7. Section along surveyed transect A, Greens Beach, showing shape of water table, and logs of proline holes 4 and 5.



15/11/6

24-16

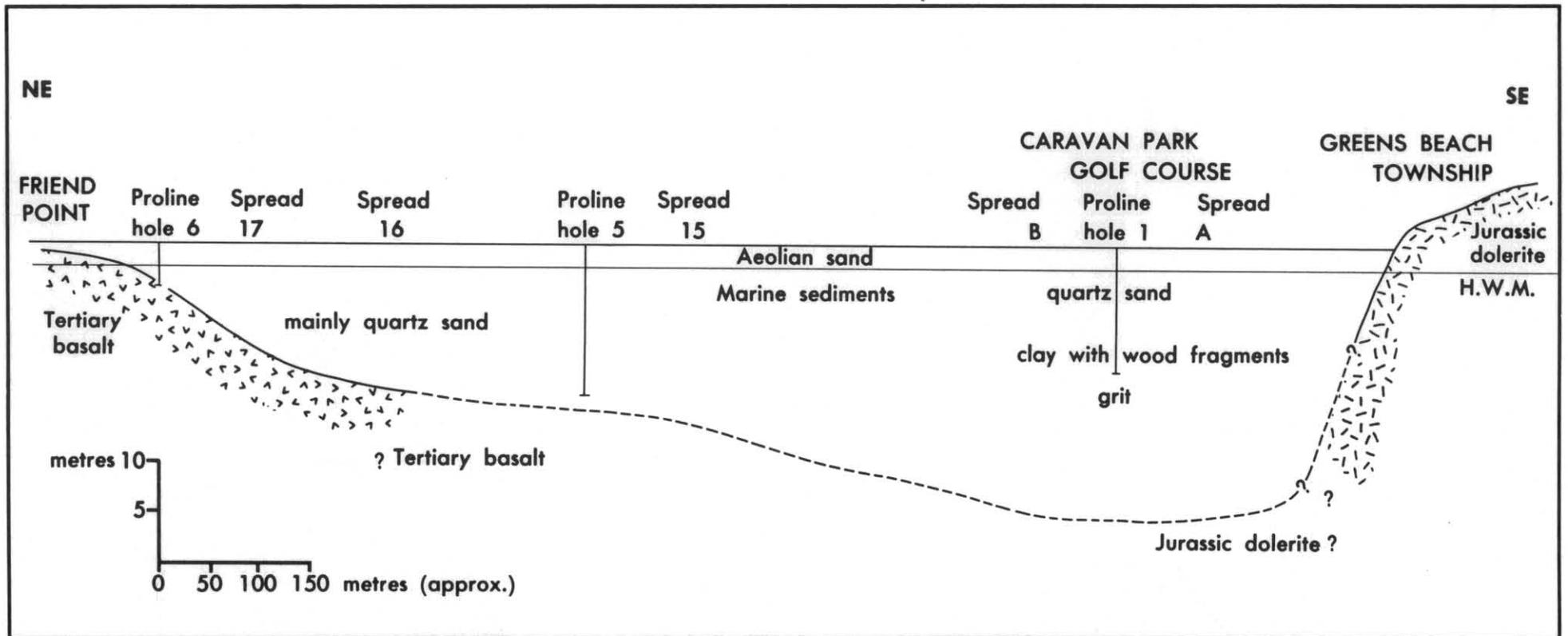
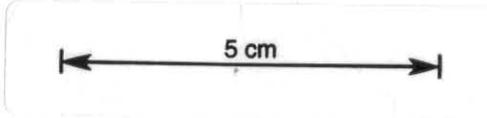


Figure 8. Geological section, at rear of frontal dunes, Friend Point to Greens Beach township, showing established and postulated basement topography.



16/146

work is needed to evaluate its groundwater potential.

Most of the area is underlain by Quaternary and Tertiary sediments which have filled a basin-like structure presumably underlain by Jurassic dolerite and Precambrian quartzite. The sediments are mainly fine sand, clayey sand, clay and gravelly clay. Grey-green clay considered to be weathered Jurassic dolerite basement was struck at 4.6 m in proline Hole 14 (appendix 1), and generally the basin probably deepens towards the centre. Rounded cobbles of Tertiary(?) laterite occur over a restricted area near [775503] but the material does not crop out. The laterite may be more extensive than the surface evidence indicates, since water from proline Holes 15 and 16 contains exceedingly high iron and aluminium levels.

Proline Holes 15 and 16, drilled into Tertiary sediments, were pump tested by spear bore. Hole 15 sustained a low yield (<5 l/min) for only a few minutes, and Hole 16 was pumped at 30 l/min for 95 minutes. These figures reflect the marked variation (which also occurred in area 2) in stratigraphy of the Tertiary sequence. They also show that unless more work is done, successful bores will be more the result of good luck than good management.

Nevertheless, the area has great potential as a source of groundwater. The sediments are a large reservoir extending over about 18 km² and at least 15 m thick in places. The extensive longitudinal sand dunes behind Badger Beach seem especially favourable in this respect, but nothing is known of their groundwater potential.

CHEMISTRY OF THE GROUNDWATER

Samples of water for chemical analysis (tables 4, 5 and 6) were collected during the period December 1975-April 1976 from six pumped proline holes, thirteen wells, a spring and a lagoon. None should be considered totally representative of the aquifer from which it was taken. Moreover, salinity variations from the same locality may be significant (e.g. Greens Beach well, table 4), reflecting changes in water quality due to seasonal distribution of rainfall, degree of utilisation of the well or pumped bore, method of sampling, etc.

None of the samples were tested for biological contamination, although this is known to occur at the Greens Beach caravan park, and undoubtedly is present at Kelso where effluent is discharged directly into the aquifer. Contamination is not expected in bores removed from residential areas, although it is always wise to test any water intended for human consumption.

Salinities

The salinity of the groundwater, expressed as milligrams per litre of total dissolved solids (mg/l TDS), varies from about 500 mg/l to 1800 mg/l (a long disused well near Kelso indicated a salinity of 6500 mg/l). The poorest quality water occurs at Kelso. The salinities of the Tertiary and Quaternary water near Greens Beach are roughly comparable.

Groundwater in unconsolidated sediments is derived mainly from percolating rain water, and as a result the upper levels of the aquifer frequently contain better quality water than the lower levels. This is especially true of Quaternary deposits (Cromer, 1976). The samples selected from pumped spears near Greens Beach therefore represent an average composition of the groundwater removed from the upper levels of the aquifer. Deeper water may in fact be poorer in quality, but the extent of vertical salinity changes is unknown.

Nature of the groundwater

Groundwater from the whole region falls naturally into two main types based on the predominant dissolved species. That from Tertiary sediments may be termed 'sodium chloride water', while 'calcium bicarbonate-sodium chloride water' is confined to the Quaternary rocks. Most samples also contain significant amounts of magnesium and sulphate.

The water analyses are depicted as a series of variation diagrams (fig. 9, 10, 11 and 12) for comparative purposes. In Figures 9 and 10, the Stiff diagrams are plotted as percentage milligram equivalents per litre (% meq/l). Although such a procedure obscures differences in TDS and the width of the diagrams is only an approximate indicator of quality, the shape of each figure is distinctive and readily comparable with others. The difference between the Tertiary and Quaternary waters is apparent.

On triangular diagrams plotted as cation meq/l (fig. 11) and anion meq/l (fig. 12) the analyses fall into two distinct and separate groups.

Origin of dissolved species

Ca, HCO₃, and to a lesser extent Mg, are derived mainly from dissolution of shelly material in the aquifer. This is especially evident in the water from Kelso where the sediments contain abundant shelly horizons. Dissolved atmospheric carbon dioxide (as HCO₃) is also incorporated in the groundwater from percolating rainwater.

The presence of Na and Cl in groundwater from coastal areas is generally attributed to contamination from salt spray, as well as from dissolution of minerals in the sediments themselves. The former is probably the main source of these constituents in the aeolian and marine sands at Greens Beach and Kelso, and the latter probably accounts for their presence in the Tertiary sediments. The small amounts of silica present in the water derives from the breakdown of silicate minerals, predominantly clays.

High iron and aluminium levels occur in the low pH groundwater from the Tertiary sediments, and these ions are at least partly derived from lateritic material. The iron is present in the ferrous state, but is rapidly oxidised in the presence of atmospheric oxygen to rust-brown ferric hydroxide. Precipitates of Fe(OH)₃ were found in sample bottles and it is evident that the total iron content of some of the groundwater is considerably higher than the dissolved iron content analysed. Levels of dissolved iron greatly in excess of 0.3 mg/l are considered highly objectionable for domestic supplies, and the Tertiary waters are totally unacceptable in this regard.

Acceptability of the groundwater for domestic use

Water for drinking should be safe, palatable and aesthetically pleasing. It should contain no pathogenic organisms and be free of deleterious inorganic constituents. Pollution, biological or otherwise, should be avoided or eliminated.

Individuals and communities vary greatly in their tolerance of domestic water supplies. That which is considered acceptable through prolonged use or necessity by one community may be unacceptable and highly objectionable to another. Thus the general recommended limits of chemical constituents (Hart, 1974) given in Table 7 should be studied with these considerations in mind.

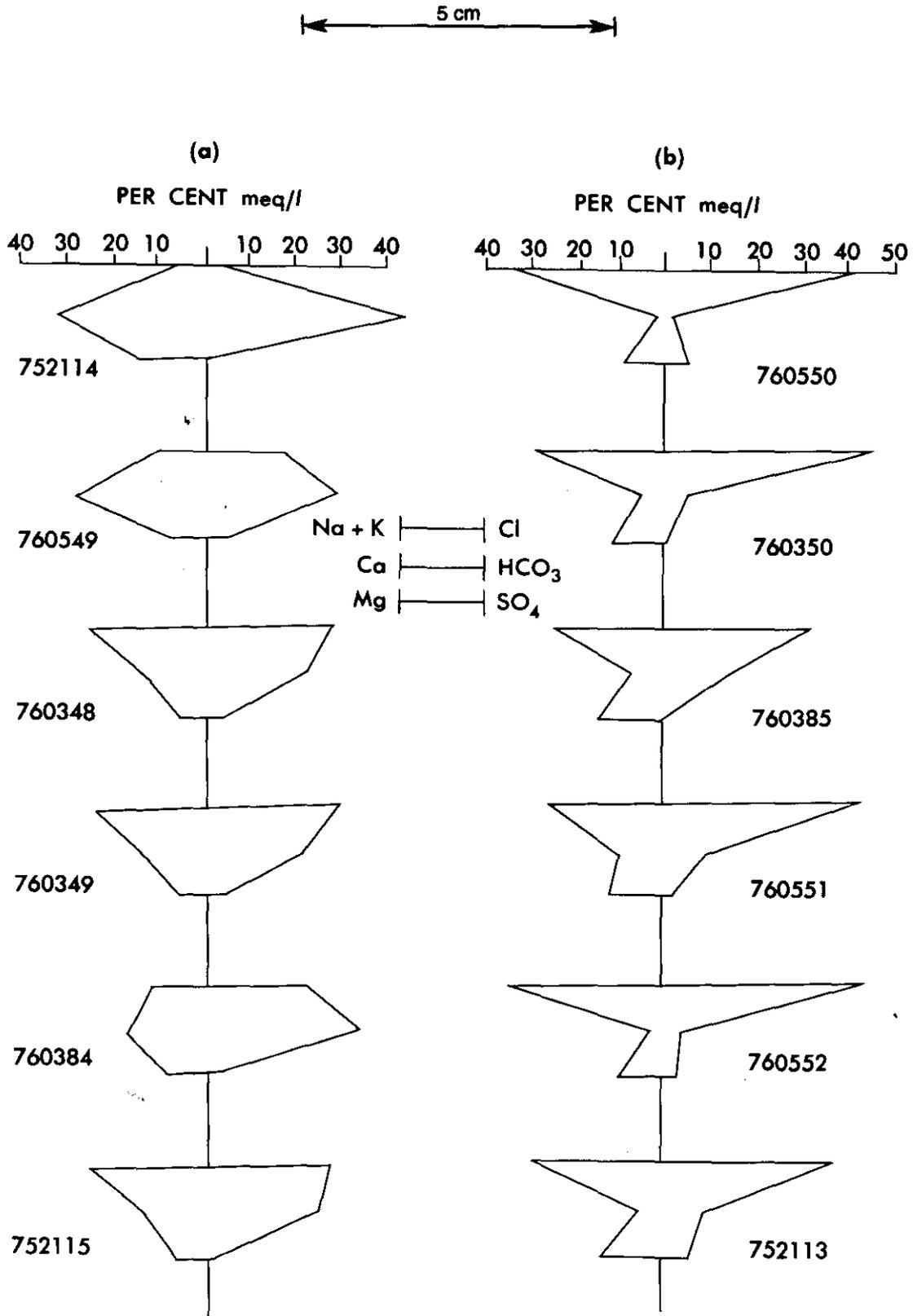


Figure 9. Chemical analyses of water from Quaternary (a) and Tertiary (b) sediments near Greens Beach, represented as Stiff diagrams. Registration numbers from Tables 4 and 5.

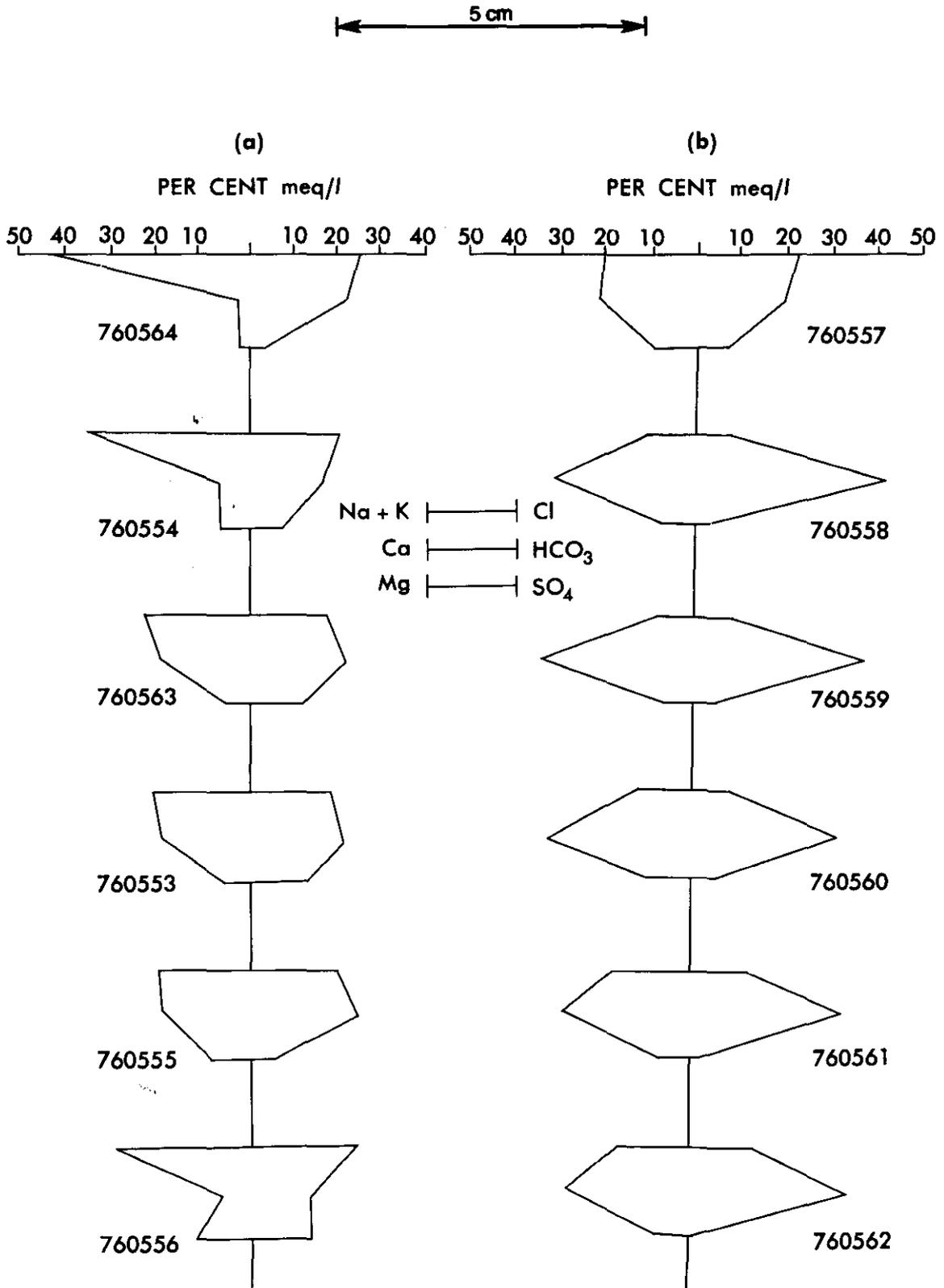


Figure 10. Chemical analyses of water in Quaternary sediments near Kelso, represented as Stiff diagrams. Registration numbers from Table 6.

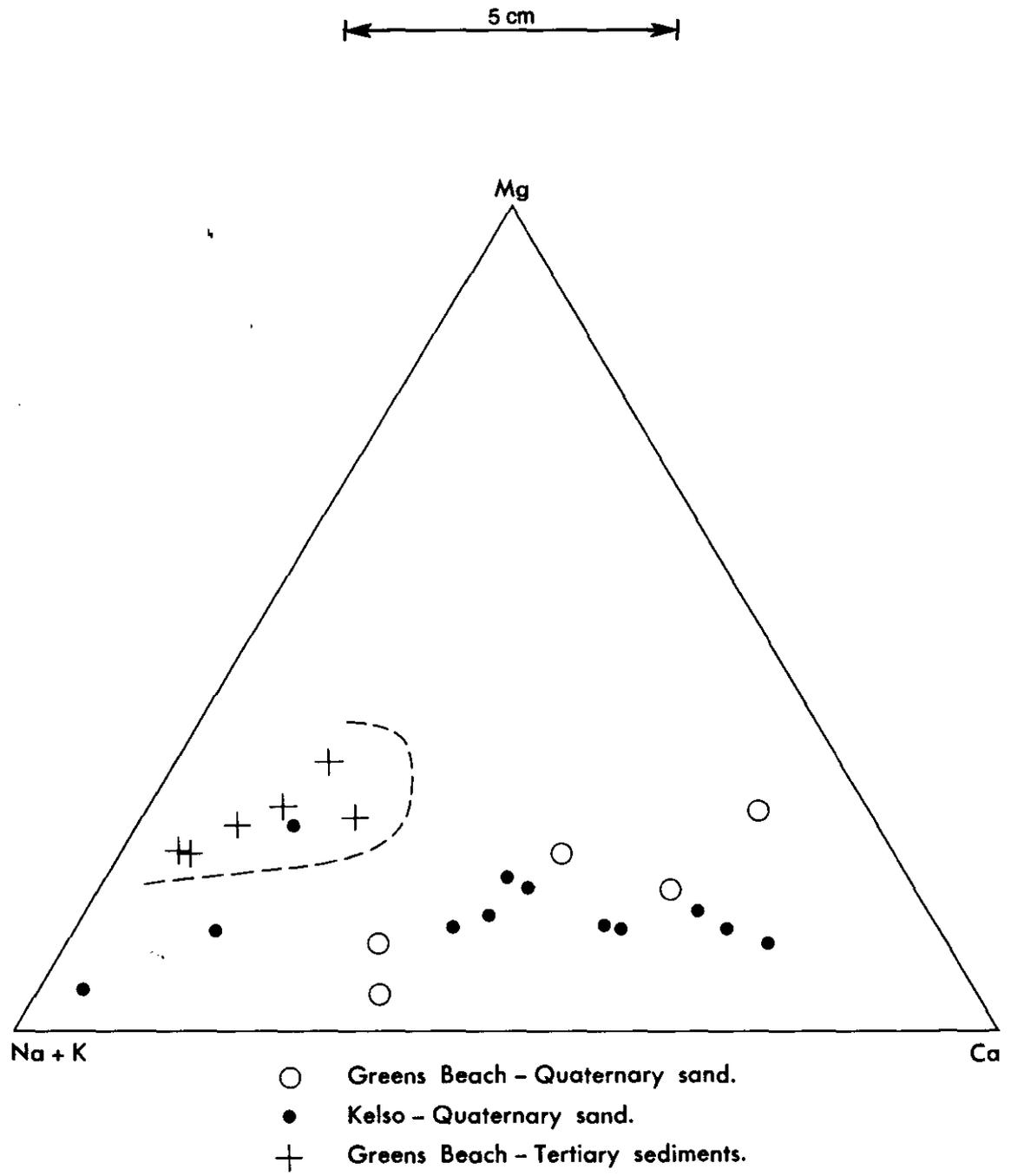


Figure 11. *Triangular diagram of water analyses from the Greens Beach-Kelso area, plotted as per cent cation meq/l.*

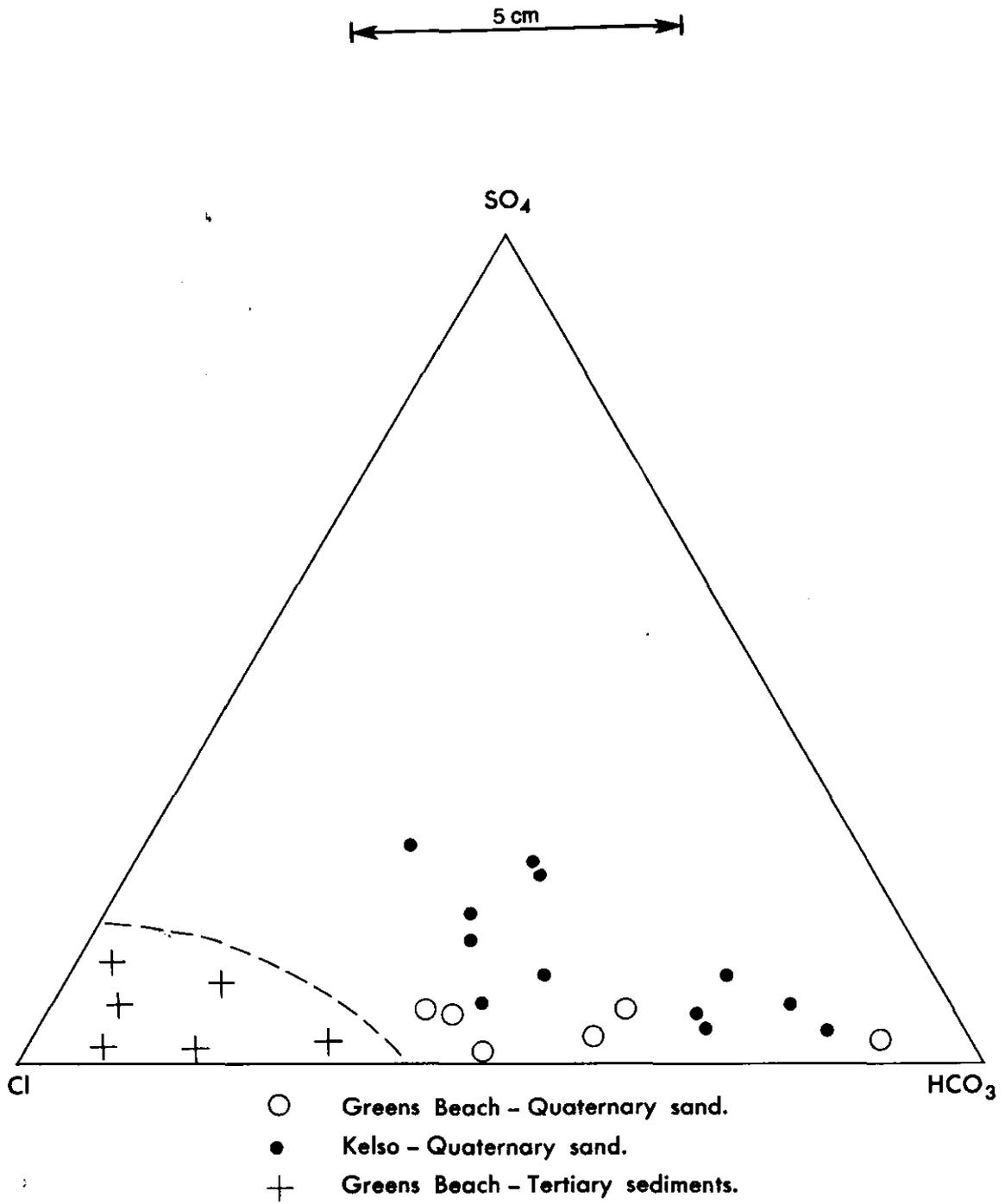


Figure 12. *Triangular diagram of water analyses from the Greens Beach-Kelso area, plotted as per cent anion meq/l.*

Table 4. CHEMICAL ANALYSES¹ OF WATER IN QUATERNARY SEDIMENTS AT GREENS BEACH

² Expressed as milligrams per litre mg/l, milligram equivalents per litre meq/l, and percentage milligram equivalents per litre % meq/l.

Constituent	752114 ² 15/12/75 ³			760549 6/4/76			760348 24/2/76		
	mg/l	meq/l	% meq/l	mg/l	meq/l	% meq/l	mg/l	meq/l	% meq/l
Silica (SiO ₂)	5	-	-	<5	±	-	8	-	-
Iron (Fe)	0.4	0.01	0.07	0.2	0.00	0.0	<0.1	0.0	0.0
Calcium (Ca)	84	4.19	32.4	95	4.74	29.1	76	3.79	14.8
Magnesium (Mg)	22	1.81	14.0	17	1.40	8.6	22	1.81	7.1
Sodium (Na)	16	0.70	5.41	45	1.96	12.0	160	6.96	27.1
Potassium (K)	2.0	0.05	0.39	2.4	0.06	0.37	8	0.20	0.78
Bicarbonate (HCO ₃)	340	5.57	43.1	290	4.76	29.2	330	5.41	21.1
Sulphate (SO ₄)	<5	<0.1	<0.8	29	0.61	3.7	35	0.73	2.84
Chloride (Cl)	21	0.59	4.56	95	2.66	16.3	240	6.77	26.4
Total dissolved solids	360	12.9		540	16.3		730	25.7	
Permanent hardness (as CaCO ₃)	20			67			10		
Temporary hardness (as CaCO ₃)	280			240			270		
Alkalinity (as CaCO ₃)	280			240			270		
pH		8.0			7.5			7.5	
% difference of anion and cation equivalents ⁴		5			1			0.6	
Per cent Sodium ⁵		11			25			56	
Sodium adsorption ratio ⁶		0.4			1.1			4.2	

752114. Well, Greens Beach caravan park, [787517]

760549. Well, Greens Beach caravan park, [787517]

760348. Pump test, proline Hole 1 [789516], 50 minutes after pump started.

1. Analyses by Department of Mines Laboratory, Launceston.

2. Department of Mines registered number.

3. Sample collection date.

4. An indication of the accuracy of the analysis. Should approach zero if all major species have been determined.

Calculated: $100 \times (\text{difference of cation and anion meq/l}) \div \text{Total meq/l}$.

5. Per cent Sodium = $100 \times (\text{Na} + \text{K}) / (\text{Na} + \text{K} + \text{Ca} + \text{Mg})$ (meq/l).

6. S.A.R. = $\text{Na} / \sqrt{(\text{Ca} + \text{Mg}) / 2}$ (meq/l).

24-23

20/11/76

Table 4. (continued)

Constituent	760349 ² 24/2/76 ³			760384 26/2/76			752115 17/12/75		
	mg/l	meq/l	% meq/l	mg/l	meq/l	% meq/l	mg/l	meq/l	% meq/l
Silica (SiO ₂)	10	-	-	13	-	-	3	-	-
Iron (Fe)	<0.1	0.0	0.0	<0.1	0.00	0.0	0.1	0.00	0.0
Calcium (Ca)	82	4.09	14.6	60	2.99	19.4	70	3.49	15.1
Magnesium (Mg)	24	1.97	7.04	18	1.48	9.6	24	1.97	8.53
Sodium (Na)	170	7.39	26.4	50	2.18	14.2	140	6.09	26.4
Potassium (K)	8	0.20	0.71	3.1	0.08	0.52	3.5	0.09	0.4
Bicarbonate (HCO ₃)	340	5.57	19.9	305	5.00	32.5	330	5.41	23.4
Sulphate (SO ₄)	42	0.87	3.11	13	0.27	1.8	5	0.11	0.5
Chloride (Cl)	280	7.90	28.2	120	3.36	21.8	210	5.88	25.5
Total dissolved solids	800	28.0		480	15.4		670	23.1	
Permanent hardness (as CaCO ₃)	24			} 220			5		
Temporary hardness (as CaCO ₃)	280						270		
Alkalinity (as CaCO ₃)	280			250			270		
pH		7.6			7.4			8.2	
% difference of anion and cation equivalents ⁴		2.5			12			1	
Per cent Sodium ⁵		56			33			53	
Sodium adsorption ratio ⁶		4.2			1.5			3.7	

760349. Pump test, proline Hole 1, 400 minutes after pump started.

760384. Pump test, proline Hole 5 [794518], 60 minutes after pump started. Al <0.2 mg/l.

752115. Lagoon in sand dunes, [795520].

24-24

24/46

Table 5. CHEMICAL ANALYSES OF WATER IN TERTIARY SEDIMENTS NEAR GREENS BEACH

Constituent	760550 7/4/76			760350 25/2/76			760385 25/2/76		
	mg/l	meq/l	% meq/l	mg/l	meq/l	% meq/l	mg/l	meq/l	% meq/l
Silica (SiO ₂)	30	-	-	29	-	-	76	-	-
Iron (Fe)	3.5	0.13	0.38	0.9	0.03	0.32	8.6	0.31	4.90
Calcium (Ca)	18	0.90	2.67	15	0.75	4.86	13	0.65	6.93
Magnesium (Mg)	44	3.61	10.7	21	1.73	11.2	17	1.40	14.9
Sodium (Na)	270	11.8	34.9	110	4.79	31.1	50	2.18	23.2
Potassium (K)	4.3	0.11	0.29	4	0.10	0.65	2	0.05	0.53
Bicarbonate (HCO ₃)	42	0.69	2.0	41	0.67	4.35	94	1.54	16.4
Sulphate (SO ₄)	95	2.00	5.9	<5	<0.1	<0.65	<5	<0.1	<0.1
Chloride (Cl)	520	14.6	43.2	260	7.33	47.6	110	3.10	33.0
Total dissolved solids	1210	33.8		520	15.4		350	9.23	
Permanent hardness (as CaCO ₃)	190			90					
Temporary hardness (as CaCO ₃)	34			33					
Alkalinity (as CaCO ₃)	34			33					
pH		6.6			6.0			6.2	
% difference of anion and cation equivalents		2			4			0.5	
Per cent Sodium		72			66			52	
S.A.R.		7.8			4.3			2.1	

760550. Pump test, proline Hole 3 [785510], 5 minutes after pump started. Al = 9 mg/l.
 760350. Pump test, proline Hole 15 [770504], 10 minutes after pump started. Al = 1.3 mg/l.
 760385. Pump test, proline Hole 16 [778504], 35 minutes after pump started. Al = 1.5 mg/l.

24-25

05/40

Table 5. (continued)

Constituent	760551 7/4/76			760552 6/4/76			752113 15/12/76		
	mg/l	meq/l	% meq/l	mg/l	meq/l	% meq/l	mg/l	meq/l	% meq/l
Silica (SiO ₂)	15	-	-	14	-	-	10	-	-
Iron (Fe)	3.7	0.13	0.87	6.9	0.25	2.40	1	0.05	0.27
Calcium (Ca)	30	1.50	10.1	6.2	0.31	2.98	24	1.20	6.58
Magnesium (Mg)	23	1.89	12.7	13	1.07	10.3	30	2.47	13.6
Sodium (Na)	85	3.70	24.8	80	3.48	33.5	120	5.22	28.6
Potassium (K)	2.2	0.06	0.4	2.5	0.06	0.58	6.9	0.18	0.99
Bicarbonate (HCO ₃)	83	1.36	9.1	23	0.38	3.65	91	1.49	8.17
Sulphate (SO ₄)	<5	<0.11	0.7	16	0.34	3.27	41	0.85	4.66
Chloride (Cl)	220	6.16	41.3	160	4.48	43.1	240	6.77	37.4
Total dissolved solids	580	14.9			10.4		660	18.23	
Permanent hardness (as CaCO ₃)	100						110		
Temporary hardness (as CaCO ₃)	68						75		
Alkalinity (as CaCO ₃)	68						75		
pH		6.4			5.6			6.8	
% difference of anion and cation equivalents		2			1			1	
Per cent Sodium		53			72			59	
S.A.R.		2.8			4.2			3.9	

760551. Pump test, proline Hole 19 [801508], 60 minutes after pump started. Al = 7.1 mg/l.

760552. Pump test, proline Hole 20 [792506], 25 minutes after pump started. Al = 13 mg/l.

752113. Spring in Tertiary sediments, Greens Beach [783514]. Al <0.2 mg/l.

24-26

26/46

Table 6. CHEMICAL ANALYSES OF WATER IN QUATERNARY SEDIMENTS AT KELSO

Constituent	760564(1) * 5/4/76			760554(2) 5/4/76			760563(3) 5/4/76		
	mg/l	meq/l	% meq/l	mg/l	meq/l	% meq/l	mg/l	meq/l	% meq/l
Silica (SiO ₂)	25	-	-	18	-	-	8.0	-	-
Iron (Fe)	<0.1	0.0	0.0	<0.1	0.0	0.0	<0.1	0.0	0.0
Calcium (Ca)	18	0.90	2.0	83	4.14	6.90	130	6.49	19.7
Magnesium (Mg)	12	0.99	2.2	43	3.53	5.88	27	2.22	6.73
Sodium (Na)	460	20.0	44.7	480	20.9	34.8	180	7.83	23.7
Potassium (K)	11	0.28	0.63	30	0.77	1.28	16	0.41	1.24
Bicarbonate (HCO ₃)	610	10.0	22.4	610	10.0	16.7	420	6.89	20.9
Sulphate (SO ₄)	77	1.62	3.6	230	4.83	8.05	170	3.57	10.8
Chloride (Cl)	390	10.9	24.4	420	11.8	19.7	200	5.6	17.0
Total dissolved solids	1320	44.7		1770	60.0		1050	33.0	
Permanent hardness (as CaCO ₃)	nil			nil			95		
Temporary hardness (as CaCO ₃)	94			380			340		
Alkalinity (as CaCO ₃)	500			500			340		
pH		8.0			7.9			7.5	
% difference of anion and cation equivalents		0.8			4.5			2.7	
Per cent Sodium		91			74			49	
S.A.R.		21			11			3.8	

*Numbers in brackets correspond to those in Appendix 2.

760564. Well at Kelso. J.S. Beams owner. [827495] Al <0.2 mg/l.
 760554. Well at Kelso. H.B. Roberts owner. [823498] Al <0.2 mg/l.
 760563. Well at Kelso. A. Milner owner. [823498] Al <0.2 mg/l.

24-27

27/46

Table 6. (continued)

Constituent	760553(4) 5/4/76			760555(5) 6/4/76			760556(7) 6/4/76		
	mg/l	meq/l	% meq/l	mg/l	meq/l	% meq/l	mg/l	meq/l	% meq/l
Silica (SiO ₂)	<5	-	-	10	-	-	6.0	-	-
Iron (Fe)	<0.1	0.0	0.0	<0.1	0.0	0.0	0.5	0.02	0.03
Calcium (Ca)	100	4.99	19.7	105	5.24	20.4	88	4.39	7.43
Magnesium (Mg)	22	1.81	7.15	30	2.47	9.61	93	7.64	12.9
Sodium (Na)	120	5.22	20.6	120	5.22	20.3	400	17.4	29.4
Potassium (K)	10	0.26	1.03	5.7	0.15	0.58	30	0.77	1.3
Bicarbonate (HCO ₃)	330	5.41	21.4	380	6.23	24.2	480	7.87	13.3
Sulphate (SO ₄)	150	3.15	12.5	62	1.30	5.06	360	7.56	12.8
Chloride (Cl)	160	4.48	17.7	180	5.04	19.6	480	13.4	22.7
Total dissolved solids	750	25.3		770	25.7		1790	59.1	
Permanent hardness (as CaCO ₃)	70			75			210		
Temporary hardness (as CaCO ₃)	270			310			390		
Alkalinity (as CaCO ₃)	270			310			390		
pH		7.5			7.7			7.7	
% difference of anion and cation equivalents		3.0			2.0			2.3	
Per cent Sodium		45			41			60	
S.A.R.		2.8			2.7			7.1	

760553. Well at Kelso. T. Mason owner. [823498] Al <0.2 mg/l.
 760555. Well at Kelso. J. Gimpl owner. [823499] Al <0.2 mg/l.
 760556. Well at Kelso. R. Smith owner. [823500] Al <0.2 mg/l.

24-28

28/46

Table 6. (continued)

Constituents	760557 (8) 6/4/76			760558 (9) 6/4/76			760559 (16) 6/4/76		
	mg/l	meq/l	% meq/l	mg/l	meq/l	% meq/l	mg/l	meq/l	% meq/l
Silica (SiO ₂)	16	-	-	7.2	-	-	9.0	-	-
Iron (Fe)	0.2	0.01	0.0	<0.1	0.0	0.0	<0.1	0.0	0.0
Calcium (Ca)	120	5.99	21.3	76	3.79	31.2	83	4.14	33.8
Magnesium (Mg)	31	2.55	9.1	9.3	0.76	6.25	7.8	0.64	5.22
Sodium (Na)	120	5.32	18.9	25	1.11	9.13	23	1.02	8.33
Potassium (K)	6.8	0.17	0.6	3.3	0.08	0.66	1.2	0.03	0.25
Bicarbonate (HCO ₃)	340	5.58	19.8	320	5.25	43.2	300	4.92	40.2
Sulphate (SO ₄)	100	2.10	7.46	13	0.27	2.22	22	0.46	3.76
Chloride (Cl)	230	6.44	22.9	32	0.90	7.4	37	1.04	8.49
Total dissolved solids	940	28.2		360	12.2		390	12.3	
Permanent hardness (as CaCO ₃)	150			nil			nil		
Temporary hardness (as CaCO ₃)	280			230			240		
Alkalinity (as CaCO ₃)	280			260			250		
pH		7.9			7.9			7.7	
% difference of anion and cation equivalents		0.3			5.6			4.8	
Per cent Sodium		39			21			18	
S.A.R.		2.6			0.74			0.66	

760557. Well at Kelso. G. Bealey owner. [823501]. Al <0.2 mg/l.
 760558. Well at Kelso. H. Schell owner. [822502]. Al <0.2 mg/l.
 760559. Well at Kelso. K. Banfield owner. [822502]. Al <0.2 mg/l.

24-29

9/1/68

Table 6. (continued)

Constituents	760560 (17) 6/4/76			760561 (21) 7/4/76			760562 (22) 7/4/76		
	mg/l	meq/l	% meq/l	mg/l	meq/l	% meq/l	mg/l	meq/l	% meq/l
Silica (SiO ₂)	11	-	-	11	-	-	14	-	-
Iron (Fe)	<0.1	0.0	0.0	0.2	0.01	0.0	<0.1	0.0	0.0
Calcium (Ca)	100	4.99	32.1	78	3.89	27.6	93	4.64	26.7
Magnesium (Mg)	15	1.23	7.91	11	0.90	6.39	14	1.15	6.62
Sodium (Na)	35	1.55	9.97	48	2.13	15.1	61	2.71	15.6
Potassium (K)	13	0.33	2.12	4.1	0.10	0.71	3.4	0.09	0.52
Bicarbonate (HCO ₃)	310	5.08	32.7	290	4.76	33.8	370	6.07	34.9
Sulphate (SO ₄)	38	0.80	5.14	20	0.42	2.98	17	0.36	2.07
Chloride (Cl)	56	1.57	10.1	67	1.88	13.4	84	2.35	13.5
Total dissolved solids	620	15.6		420	14.1		490	17.4	
Permanent hardness (as CaCO ₃)	61			nil			nil		
Temporary hardness (as CaCO ₃)	250			240			290		
Alkalinity (as CaCO ₃)	250			240			300		
pH		7.3			7.9			7.9	
% difference of anion and cation equivalents		4.2			0.2			1.1	
Per cent Sodium		23			32			33	
S.A.R.		0.88			1.4			2.5	

760560. Well at Kelso. J. Whybrow owner. [822505]. Al <0.2 mg/l.

760561. Well at Kelso. W. Goer owner. [821506]. Al <0.2 mg/l.

760562. Well at Kelso. E. Cornish owner. [821506]. Al <0.2 mg/l.

24-30

30/46

Table 7. FACTORS AFFECTING THE ACCEPTABILITY OF DOMESTIC WATER SUPPLIES*

Parameter†	Undesirable effects	Recommended level (mg/l)
Alkalinity (as CaCO ₃)	Gastro-intestinal irritation	30-500
Hardness	Encrustations on fittings, utensils. (Physiological effect uncertain).	100 (rarely up to 500)
pH	Sour taste; corrosion of fittings.	6.5-9.0
Sodium (Na)		270
Iron (Fe)	Unpleasant taste; brown staining.	0.3
Magnesium (Mg)	Taste; contributes to hardness; gastro-intestinal irritation.	30-150
Calcium (Ca)	Kidney disease; contributes to hardness.	<200
Chloride (Cl)	Taste; corrosion.	200-600
Sulphate (SO ₄)	Gastro-intestinal irritation in presence of Mg and Na.	<250
H ₂ S	Taste and odour.	Undetectable

*Adapted from Hart (1974).

†Other factors such as colour and turbidity are self explanatory.

Physical and chemical aspects of the groundwater at Kelso and Greens Beach are described in Table 8 as acceptable (✓), doubtful, or unacceptable (X).

Table 8. ACCEPTABILITY OF THE GROUNDWATER AT GREENS BEACH AND KELSO

Parameter	GREENS BEACH AREA		KELSO
	Quaternary sediments	Tertiary sediments	
Colour	✓	✓	✓
Turbidity	✓	X	✓
Alkalinity	✓	✓	✓
Hardness	doubtful ¹	✓	X
pH	✓	X	✓
Na	✓	✓	✓
Fe	✓	X ³	✓
Mg	✓	✓	✓
Ca	✓	✓	✓
Cl	✓	✓	✓
SO ₄	✓	✓	✓
H ₂ S	X ²	X ²	✓

¹Mainly temporary. ²Easily removed by aeration. ³Exceedingly high.

The groundwater in the Quaternary sediments at Greens Beach (area 3) is considered suitable for human consumption despite its hardness and the presence of H₂S. The hardness is mainly temporary and is probably at a level acceptable to most people. In fact, an inverse relationship has been found between hardness and cardiovascular disease (Hart, 1974). The main problem

with this water is that it may cause encrustation on cooling coils and domestic equipment, unless the hardness-producing constituents are removed by ion-exchange softeners.

Any detectable level of H₂S in water is objectionable, but the gas is easily removed by simple aeration, either at the site of pumping, at a reservoir, or at a later stage in the reticulated supply.

The Tertiary water is unacceptable on three counts: its corrosively low pH, high iron content, and turbidity. Turbidity is caused by fine suspended clay particles. Extended pumping may in many cases reduce this factor to acceptable levels (e.g. proline hole 16, table 2).

Water in the Kelso area is too hard for drinking purposes unless it is treated beforehand.

Acceptability of the groundwater for agricultural use

Many factors affect the suitability of irrigation water, including total dissolved solids and their relative proportions, soil type and frequency of irrigation. The nature of the soil is critical since it determines the degree to which dissolved salts precipitate in the root zone of plants. The same water applied successfully to one soil may be undesirable in another. Thus the suitability of the groundwater at Kelso and Greens Beach for agricultural and gardening purposes as depicted in Figures 13 and 14 should be regarded as approximate only. Boundaries between acceptability fields are gradual and the sandy porous soils in the area are more tolerant than most to deleterious constituents.

With few exceptions, all the groundwater is suitable for agricultural purposes.

CONCLUSIONS

The area investigated contains large amounts of groundwater. The resource lies at shallow depth and is easily extractable by simple and economic methods.

The most favourable area in terms of accessibility and water quality is the aeolian and marine deposits east of the caravan park at Greens Beach. Reserves are estimated at 1.5 x 10⁶ m³ of water. Yearly recharge is of the same order as the projected annual residential requirement of 250 000 m³. Simple aeration may be needed to remove dissolved H₂S, and although the water is expected to be acceptable for human consumption, primary treatment may be required to remove hardness. It is generally acceptable for gardening uses.

RECOMMENDATIONS

The groundwater should be extracted by spear bores spaced in a radial arrangement around a single central pump*, jetted to a depth of at least 7 m, and spaced no closer than 10 m apart. Twelve to fifteen spears pumping continuously at about 30 l/min will provide 250 000 m³/year. However, this amount of water will not be required immediately. A small battery of perhaps six spears should be installed initially, and the system can readily be expanded if required.

The most favourable site for a spear bore installation is in the

*The town of Currie, King Island obtains most of its domestic water supplies from a similar arrangement.

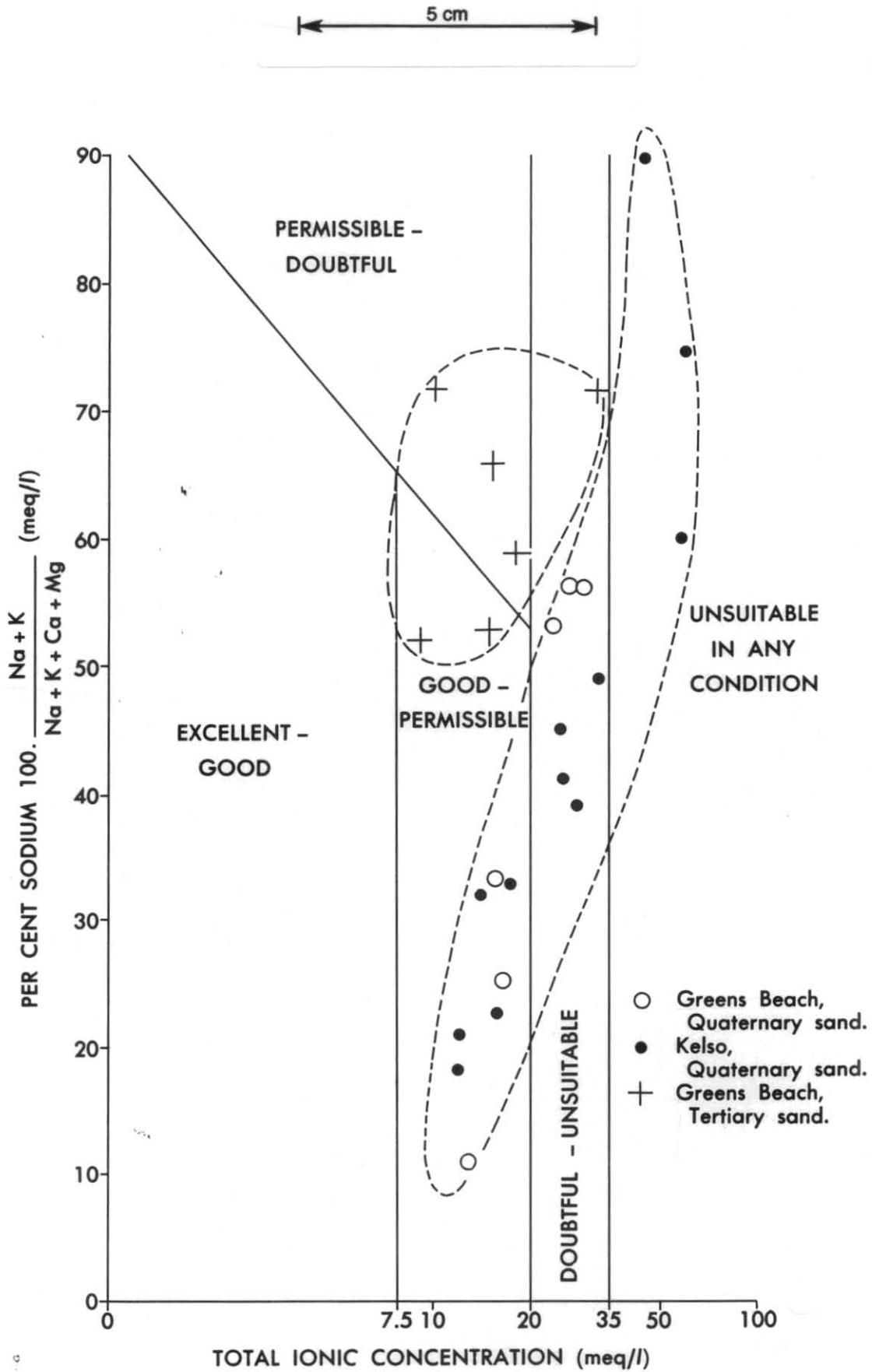


Figure 13. Suitability of groundwater for agricultural use. Per cent sodium criterion.

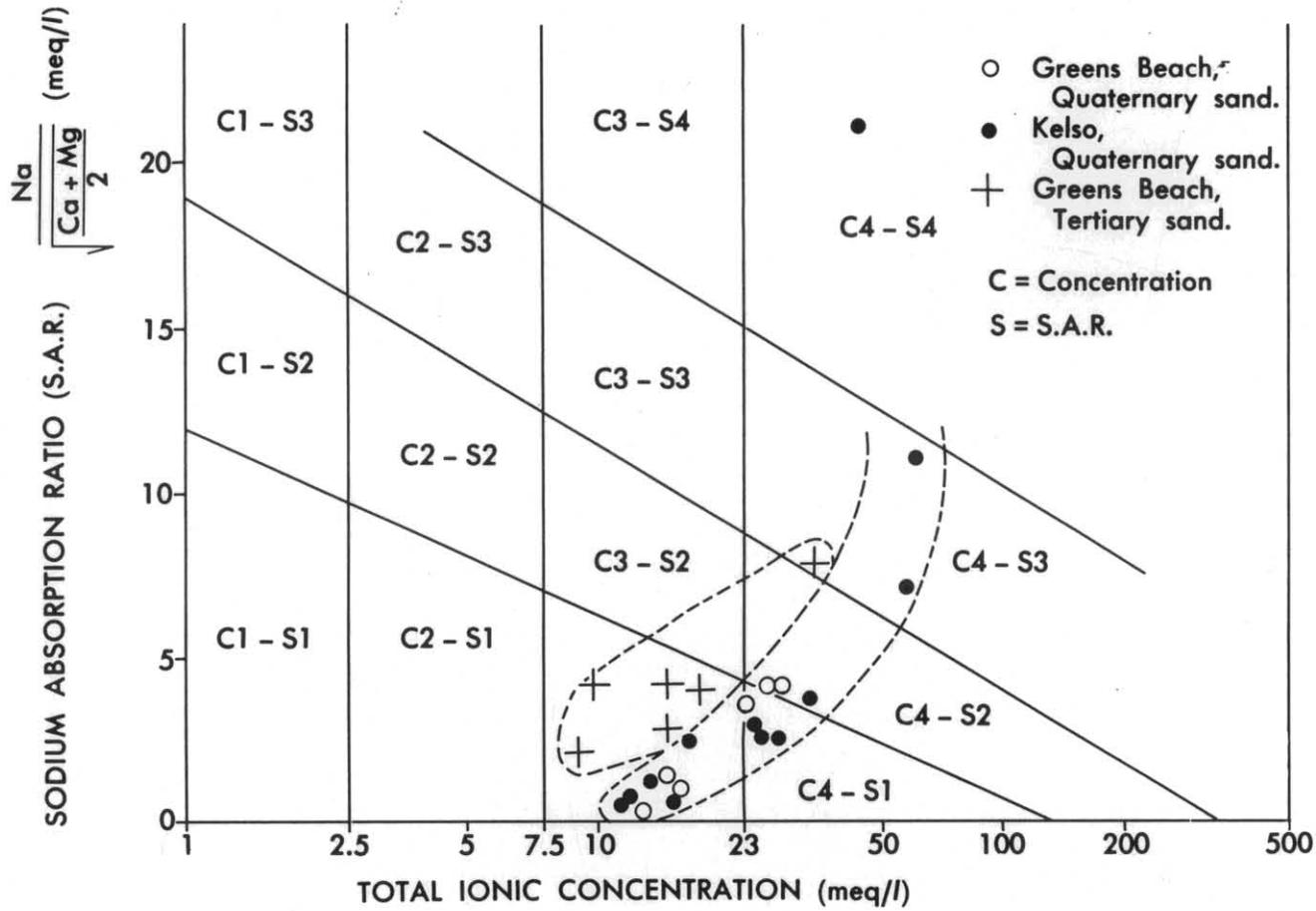
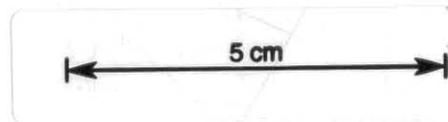


Figure 14. Suitability of groundwater for agricultural use. SAR criterion.



vicinity of proline Hole 5 where the aquifer appears to be free of clayey material and has been shown to yield up to 40 l/min to a single spear. The site should be at least 150 m inland from high water mark.

Ideally, the extracted groundwater should be pumped directly to a small reservoir, preferably on the northern flank of Wentworth Hill, and then reticulated for domestic use. The reservoir provides a convenient place for aeration to be carried out, and effectively levels out the demand of peak seasonal or daily requirements.

REFERENCES

- CROMER, W.C. 1974. Groundwater prospects, Greens Beach. *Unpubl.Rep.Dep. Mines Tasm.* 1974/32.
- CROMER, W.C. 1976. Hydrology of Seven Mile Beach. *Unpubl.Rep.Dep.Mines Tasm.* 1976/10.
- GEE, R.D.; LEGGE, P.J. 1971. Geological atlas 1 mile series. Zone 7 sheet 30 (8215N). Beaconsfield. *Department of Mines, Tasmania.*
- HART, B.T. 1974. A compilation of Australian water quality criteria. *Aust. Wat.Res.Council Tech.pap.* 7.
- SUTHERLAND, F.L. 1971. The geology and petrology of the Tertiary volcanic rocks of the Tamar Trough, northern Tasmania. *Rec.Qn Vict.Mus.* 36.

[14 May 1976]

APPENDIX 1

Geological logs of proline holes in the Greens Beach-Kelso area.

Locations are shown in Figure 2. All depths are in metres.

Hole 1. [789516]

- 0-2.0 Buff medium-fine grained Holocene aeolian quartz sand. Contains small fragmented shell particles, including sponge spicules and gastropods.
- 2.0-3.7 Buff-brown medium-grained marine quartz sand. Increased shell content.
- 3.7-9.0 Grey medium-grained marine quartz sand. Small gastropods and bivalves present. Grain size and shell content decreases after 7 m.
- 9.0-9.2 Sticky green-brown clay containing rounded quartzite pebbles (up to 5 cm) and wood fragments.
- 9.2-10.0 Brown carbonaceous clays. Wood and charcoal fragments common.
- 10.0-11.0 Coarse-grained shelly quartz sand containing rounded quartzite pebbles (up to 3 cm).

Hole 2. [789514]

- 0-9.6 Thin (less than 0.7 m) veneer of medium-fine grained buff Holocene aeolian quartz sand overlying fawn-buff medium-grained shelly marine quartz sand. After 4 m, a colour change to grey-yellow quartz sand. Shell content increases.
- 9.6-14.6 Interbedded green-blue clay, and rounded quartzite gravels (containing pebbles up to 6 cm in diameter).

Hole 3. [785510]

- 0-1.0 Medium-grained grey-brown slightly clayey Tertiary quartz sand.
- 1.0-2.0 Sandy blue-yellow clay.
- 2.0-9.0 Clayey medium-grained brown quartz sand.
- 9.0-15.0 Medium-grained grey-brown quartz sand; slightly clayey; some partly cemented dark brown sandy fragments.

Hole 4. [797514]

- 0-14.6 Slightly clayey medium-fine grained brown Quaternary quartz sand. Colour becomes greyer and clay content increases near 2 m. Shell fragments absent above 4 m. Rare rounded quartzite pebbles present near 4-5 m, becoming more common with depth; sand approaches a fine quartzite grit (clay is probably absent) in interval 12-14.6 m.

Hole 5. [794518]

- 0-3.7 Yellow-buff medium-fine grained Holocene aeolian quartz sand; small gastropod, bivalve and sponge spicule fragments present. CaCO₃ concretions at water table. Grain size increases slightly near 2.7 m.
- 3.7-11.0 Grey medium-grained shelly marine quartz sand, containing occasional rounded quartzite pebbles and increased shell content near 10 m.
- 11.0-14.6 Clean fine angular quartzite and quartz grit; fragments up to 1 cm in diameter. Shells absent.

Hole 6. [799522]

- 0-3.0 Yellow-buff medium-fine grained Holocene aeolian quartz sand. Grain size and shell content increases slightly after one metre.
- 3.0-5.0 Grey medium-grained shelly marine quartz sand, becoming greyer, more shelly and coarser below 4.3 m. Small amounts of well-rounded yellow-white quartzite pebbles up to one centimetre across. Grades into grey sandy grit near 5 m.
- 5.0-5.2 Sticky blue-green clay.
- 5.2- Drilling hard. Probably Tertiary basalt.

Hole 7. [803518]

- 0-1.0 Medium-fine grained dark yellow-brown Holocene aeolian quartz sand.
- 1.0-4.0 Coarser-grained shelly quartz sand.
- 4.0- Solid bottom. Probably Tertiary basalt.

Hole 8. [807516]

- 0-1.3 Fine-grained buff Holocene aeolian quartz sand. Hard shelly and quartz pebble band at 1.3 m.
- 1.3-2.3 Green shelly clay.
- 2.3- Solid bottom. Probably Tertiary basalt.

Hole 9. [808514]

- 0-0.3 Buff quartz-pebble sand.
- 0.3-1.0 Mottled yellow-brown clay containing basalt pebbles.
- 1.0- Tertiary basalt.

Hole 10. [810511]

- 0-1.1 Very fine silt overlying clay containing basalt fragments.
- 1.1- Tertiary basalt.

Hole 11. [812508]

- 0-1.1 Mottled grey-brown sandy clay.
- 1.1- Tertiary basalt.

Hole 12. [808506]

- 0-0.3 Medium-fine buff-grey organic quartz sand.
- 0.3-1.0 Mottled yellow, brown and grey sandy clay.
- 1.0-1.3 Grey-brown clayey sand.
- 1.3-2.0 Mottled clay containing rounded quartzite and weathered basalt pebbles. Some relict textures present.
- 2.0-2.5 Very sandy yellow-brown clay containing rounded quartzite and basalt pebbles.
- 2.5- Tertiary basalt.

Hole 13. [809501]

- 0-0.3 Grey sandy A1 soil horizon.
- 0.3-2.0 Yellow-brown sandy clay.
- 2.0-3.0 Medium-grained slightly clayey quartz sand containing rounded quartzite pebbles (up to 5 cm). Clay content increases with depth.

Hole 13. (continued)

- 3.0-11.0 Clayey yellow quartz-pebble sand becoming coarser with depth, and containing angular coarse sand-size quartzite fragments.
- 11.0-12.2 Grey-green clay containing quartz and basalt gravel horizons and wood fragments.
- 12.2-14.0 Grey clayey sand with quartzite pebbles (up to 5 cm).
- 14.0- Vesicular Tertiary basalt.

Hole 14. [764508]

- 0-4.6 Dark brown-grey clayey quartz sand, becoming sandier near 4.6 m.
- 4.6-6.4 Grey-green stiff clay containing relict textures of Jurassic dolerite.

Hole 15. [770504]

- 0-0.2 Dark yellow-brown sandy and organic A1 horizon.
- 0.2-1.0 Dark yellow-brown sandy clay.
- 1.0-2.0 Bright yellow-brown sticky sandy clay grading at 2 m into very sticky clayey quartz sand.
- 2.0-2.3 Sticky pale grey clayey quartz sand.
- 2.3-6.4 Pale yellow-brown clayey quartz sand containing grit-sized angular quartzite and dolerite fragments. Distinct colour change at about 4 m, together with decrease in clay content, to produce grey-brown medium-grained slightly clayey quartz sand. Small shell and charcoal fragments present; as well as small amounts of quartzite grit. Sand poorly sorted, moderately rounded.
- 6.4-10.4 Sticky dark green clayey quartz sand with rare rounded quartzite pebbles (up to one centimetre).
- 10.4-11.0 Relatively consolidated pale grey clayey quartz sand; high percentage of rock fragments. Probably weathered Precambrian(?) basement.

Hole 16. [778504]

- 0-0.2 Dark brown partly calcareous and sandy A1 horizon.
- 0.2-1.0 Yellow-brown clayey soil profile.
- 1.0-3.0 Dark yellow-brown sticky sandy clay.
- 3.0-12.8 Grey medium-fine grained slightly clayey sand.
- 13.8-14.6 Stiff grey-brown-orange sandy clay.

Hole 17. [805502]

- 0-1.3 Pale grey-brown medium-grained gritty Tertiary quartz sand.
- 1.3-2.3 Dark brown medium-grained slightly clayey quartz sand; becoming more orange in colour near 2.3 m.
- 2.3-3.1 Clayey grey-pale green quartz sand. Possibly contains quartzite pebbles.
- 3.1-3.2 Sticky dark green mottled and textured clay with angular fragments of fine-grained dark grey and unweathered Tertiary basalt. Clay may be weathered basalt. Drilling hard; stopped at 3.2 m by basalt.

Hole 18. [798512]

- 0-0.5 Brown-black sandy A1 horizon.
- 0.5-1.0 Dull yellow-brown sandy A2 horizon.
- 1.0-1.5 Iron-stained clayey quartz sand.

Hole 18. (continued)

- 1.5-2.5 Coarse quartz gravel; well rounded pebbles up to 5 cm.
- 2.5-3.0 Dark brown-black coarse angular quartz sand and fine gravel.
- 3.0-4.0 No recovery.
- 4.0-5.0 Coarse-grained quartz sand.
- 5.0-5.5 Drilling hard. Clay?
- 5.5-6.5 Coarse-grained and gritty angular quartz sand.
- 6.5-7.3 Quartzite gravel.
- 7.3-10.7 Angular quartz sand.
- 10.7-11.6 Quartzite gravel.
- 11.6- Hard drilling. Green, blue and grey clay containing rounded quartzite and dolerite(?) pebbles. Relict textures present in clay. Weathered basement.

Hole 19. [801508]

- 0-6.1 Brown and yellow quartz sand; well-rounded quartzite pebbles at 6 m.
- 6.1-7.3 Weathered Tertiary basalt.
- 7.3- Tertiary basalt.

Hole 20. [791506]

- 0-0.2 Brown-black organic and sandy A1 horizon.
- 0.2-6.0 Brown-greyish yellow, in places clayey, quartz sand.
- 6.0-6.3 Green-grey very sandy clay.
- 6.3-14.6 Quartz sand.

Hole 21. [777507]

- 0-1.7 Dull yellow-brown quartz sand.
- 1.7-10.7 Olive green-grey sandy clay and clays.

Hole 22. [772509]

- 0.1-0.6 Fine-grained light grey quartz sand.
- 0.6-11.0 Dull yellow-brown quartz sand.
- 11.0- Brown clayey sand; coarse in places; well cemented, with rare dolerite pebbles.

Hole 23. [778498]

- 0-3.0 Dark brown quartz sand.
- 3.0-11.0 Dull yellow-orange medium-grained quartz sand.
- 11.0- Sandy grey and blue and green clay.

Hole 24. [760500]

- 0-1.0 Dark black-brown silty A1 horizon.
- 1.0-2.4 Clayey sand.
- 2.4-3.7 Mottled grey and white plastic clay.
- 3.7-8.3 Mottled brown, yellow and white sandy clay; well rounded quartzite pebbles struck at 5.5 m.

Hole 25. [770497]

- 0-4.0 Medium-grained quartz sand.
- 4.0-5.5 Grey clayey sand.
- 5.5-9.2 Grey quartz sand.

Hole 26. [774496]

- 0-6.4 Grey clayey quartz sand; clay content increases near 6 m.
- 6.4-10.1 Clay at 7.5 m; predominantly medium-coarse grained clayey sand containing grit-sized angular quartzite fragments.

Hole 27. [782492]

- 0-0.5 Dark grey-brown silty Al horizon.
- 0.5-3.7 Yellow-brown clay.
- 3.7-12.0 Grey medium-coarse grained quartz sand, becoming brown/yellow after 7 m. Grey sandy clay present at 9.5 m.

Hole 28. [775525]

- 0-1.5 Grey, yellow and brown fine-grained quartz sand.
- 1.5-2.0 Yellow-brown and in placed mottled, sandy clay.
- 2.0- Hard drilling. Probably dolerite.

Hole 29. [771525]

- 0-3.7 Brown mottled sandy clay.
- 3.7- Jurassic dolerite.

Hole 30. [768529]

- 0-1.0 Brownish-grey quartz sand.
- 1.0-2.0 Yellow-brown mottled clayey sand.
- 2.0-5.5 Bright yellow-brown aeolian quartz sand.
- 5.5- Solid bottom.

APPENDIX 2

Wells in the Kelso area.

	Owner	Grid ref- erence ¹	Date dug	Depth (m)	Standing water level ² (m)	Quality (mg/l TDS ³)
1	J.S. Beams	827493	1970	4.3	3.1	1000
2	H.B. Roberts	824498	n.d.	2.1	1.5	1150
3	A. Milner	824498	n.d.	1.8	1.1	800
4	T. Mason	823498	n.d.	1.4	0.8	450
5	J. Gimpl	823499	n.d.	2.4	1.4	550
6	T.E. Parkinson	823499	n.d.	2.3	n.d.	n.d.
7	R. Smith	823500	n.d.	2.6	1.3	1500
8	G. Bealey	823501	pre 1900	2.7	2.1	600
9	H. Schell	822502	1968	2.4	1.8	250
10	B. Moy	822502	n.d.	3.1	2.1	n.d.
11	K.C. Herbett	822502	n.d.	2.4	2.0	75
12	J.A. Dunn	822502	n.d.	2.1	1.5	300
13	G. Stewart	822502	n.d.	n.d.	n.d.	n.d.
14	R.L. Eadie	822503	n.d.	2.6	2.0	360
15	B. Malvern	822503	n.d.	2.6	2.0	250
16	K. Banfield	822503	1975	2.9	2.2	250
17	J. Whybrow	822505	c.1956	3.1	2.1	400
18	A. Black	822505	1976	2.0	n.d.	n.d.
19	B. Butler	822505	1976	2.4	2.1	n.d.

Approximate safe yield (l/min)	Status	Geology	Remarks
10	Operating	0.1 m: sand, 1-1.5 m clay. 1.5-4.3 m: weathered basalt.	Concrete liners, 1.3 m in diameter; domestic and gardening purposes, excluding drinking.
3	Operating	0-2.1 m: sand, 2.1 m basalt.	General gardening purposes; concrete liners 1.3 m dia.
<5	Disused	0-1.8 m: sand, 1.8 m weathered basalt.	General gardening purposes.
10	Operating	0-1.4 m shelly sand.	General gardening purposes.
10	Operating	0-2.4 m: shelly sand, green shelly clay, 2.4 m basalt.	General gardening purposes. Concrete lined, 1.3 m diameter; drawdown 0.3 m after 10 minutes at 35 l/min.
n.d.	Abandoned	0-2.3 m: brown sand, shelly clay.	Hole collapsed during excavation.
n.d.	Operating	n.d.	General gardening purposes; high TSS ⁴ : steel lined 0.6 m diameter.
n.d.	Disused	n.d.	Concrete lined 2 m diameter, high TSS. Probably bottomed in basalt.
5	Operating	0-2.4 m: brown-yellow sand.	General gardening purposes.
n.d.	Operating	n.d.	Concrete lined, 1.5 m dia; sandy bottom. General gardening and domestic uses, excluding drinking.
n.d.	Operating	0-2.4 m: sand.	General gardening purposes; concrete lined 1.4 m diameter. Probably diluted by rain-water.
n.d.	Operating	0-2.1 m: sand.	Concrete lined, 1.3 m dia.
n.d.	Operating	n.d.	Well secured.
<5	Operating	0-2.6 m: sand	Concrete lined, 1.3 m dia. Gardening purposes.
n.d.	Operating	0-2.6 m: sand	Concrete lined, 1.3 m dia. Gardening purposes.
n.d.	Operating	0-2.9 m: sand.	Concrete lined tank 2 m ² with well at base.
n.d.	Operating	0-3.1 m: sand	
n.d.	Operating	0-2.0 m: sand; shells at base.	
n.d.	Operating	0-2.4 m: sand; shells at base.	

	Owner	Grid ref- erence ¹	Date dug	Depth (m)	Standing water level ² (m)	Quality (mg/l TDS ³)
20	G. O'Brien	822506	1976	3.1	2.4	420
21	W. Goer	821506	c.1960	2.2	2.0	420
22	E. Cornish	821506	1970	2.6	2.4	450
23	n.d.	819509	n.d.	n.d.	n.d.	n.d.
24	J. Squires	816498	c.1900	4.6	3.4	200
25	Comm. of Aust.	817494	c.1940	7.0	1.7	6500
26	J. Squires	825493	c.1870	6.1	3.1	300
27	L. Reid	823488	1968	3.1	1.5	150
28	V. Saboonskas	823488	1966	3.4	2.3	100

Approximate safe yield (l/min)	Status	Geology	Remarks
n.d.	Operating	0-3.1 m: sand; 3.1 m wood fragments.	Concrete lined 1.3 m diameter; gardening purposes.
n.d.	Operating	n.d.	Gardening purposes.
n.d.	Disused	0-2.6 m: sand	
n.d.	n.d.	n.d.	Well secured.
5-10	Disused	0-4.6 m: basalt boulders.	Occasionally used for gard- ening purposes; unlined 3 m diameter.
n.d.	Disused	n.d.	Timber lined, 1.3 m diameter; occasionally used for cattle.
n.d.	Abandoned	0-6.1 m: basalt boulder beds.	Unlined, 2.4 m diameter; solid basalt at base.
n.d.	Operating	0-3.2 m: sand	
n.d.	Abandoned	0-3.4 m: sand.	

Notes:

¹All localities lie within the AMG 100 km square DQ.

²As of April 1976. Owners of wells generally state
that water levels rise to ground level during winter.

³Measured by portable conductivity meter in the field.

⁴TSS = Total suspended solids.

n.d. = Not determined.

APPENDIX 3

Wells in the Greens Beach area.

	Owner	Grid ref- erence ¹	Date dug	Depth (m)	Standing water level ² (m)	Quality (mg/l TDS ³)
1	Beaconsfield Council	786515	1974	3	2	440
2	Edwards	783514	n.d.	1.3	0.6	n.d.
3	McGee	788512	n.d.	4.3	2.9	n.d.
4	Thorn	783514	c.1956	2.5	0.5	6000
5	Shaw	782514	n.d.	n.d.	n.d.	n.d.
6	n.d.	780523	n.d.	n.d.	n.d.	n.d.

Approximate safe yield (l/min)	Status	Geology	Remarks
12-15	Operating	0-3 m Quaternary aeolian and marine sand.	Concrete lined, 1.3 m dia. Supplies toilets in caravan park. TDS = 370 mg/l in April 1974. Water apparently contains small amounts of faecal coliforms.
n.d.	Operating		Apparently supplements council supply to caravan park.
n.d.	Operating	0-1 m sand; 1-4.3 m dolerite boulders and clay.	Concrete, 1.3 m diameter; gardening purposes. Water table rises to surface during wet months.
n.d.	Operating	0-2.5 m white sand.	Also supplements council supply to caravan park. General gardening uses.
n.d.	n.d.	n.d.	Owner absent; well not located.
n.d.	n.d.	n.d.	Well secured; owner absent.

Notes:

¹All localities lie within the AMG 100 km square DQ.

²As of April 1976. Water levels fluctuate annually.

³Measured by portable conductivity metre in the field.

n.d. = Not determined.