University of Technology, Sydney

National Centre for Groundwater Management.

A hydrogeological investigation of the Natural Farming Sequence applied in the Bylong Valley at Tarwyn Park Property.

A thesis submitted by Paul Anderson in partial fulfilment of the requirements of the Master of Science degree in Hydrogeology and Groundwater Management, October 1997.

EXECUTIVE SUMMARY

This report summarises the work of the National Centre for Groundwater Management on the Natural Farming Sequence Project (NFS), Tarwyn Park, Bylong. The investigations described in this report are a summary of the field and office work conducted over the period March through June 1997 but including components of work carried out at all stages of the project.

The hydrogeological interpretation of the Tarwyn Park floodplain system is that it is a semi-confined surficial aquifer composed of unconsolidated alluvial sands and clays with relatively high transmissivity, moderate storage capacity and a moderate average throughflux of good quality irrigation water. The Tarwyn Park aquifer system contains a considerable volume of water in storage. Major components of the aquifer water appear to be precipitation and evapotranspiration. There is a small but significant component of recharge to the groundwater from the NFS canals for conveying water to the floodplain, comprising seepage though the contoured levees.

The computed values for hydraulic conductivity vary considerably as the floodplain lithology varies, however average values of between 25 m/day and 34 m/day approximate the value expected for silty sands.

Water quality is specifically affected by the composition and depth of the soil column forming the unsaturated zone. Water discharged from shallow bedrock and clay near the edges of the floodplain is significantly more saline than the water contained in the main zone of the floodplain. The water in the main floodplain alluvials is of good quality with low total dissolved solids and low concentration of nutrients such as nitrate and orthophosphate.

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1.0 INTRODUCTION

This report is the culmination of field work of the National Centre for Groundwater Management over the period to July 1996 to May 1997 in relation to the hydrogeological evaluation of the Syndicated Research and Development Project 17885/18p 'Natural Farming Sequence' (NFS) associated with the Department of Industry, Science and Technology, Canberra.

The contents of this report are a description of hydrogeological processes that are operating on the Tarwyn Park floodplain resulting in a high standard of water quality entering and leaving the system is good, and the effect of land salinity on the groundwater appear to be minimised.

2.0 PREVIOUS WORK

Previous work and pre-existing data concerning the project site at the time of writing consists of:

- Well completion data from the NSW Department of Land and Water Conservation date from 1920 to 1976, and comprise boremaster records, lithology logs, hydrochemical data, hydrographs and hydraulic testing data for 53 bores listed with the DLWC and located in the Bylong Valley.
- BT Corporate Finance Report 'Advance Eligibility Ruling Application Proposed R&D Project - "Natural Farming Sequence"(Reference 17885/18/01), 4 May 1994'.
- Australian Agricultural Research Pty Limited 'Natural Farming Sequence Commercialisation Plan, November 1994'.(AAR)
- Natural Farming Sequence Joint Venture Quarterly Report 1 (Period 1 July 1995 to 30 September 1995) October 1995.(NFSJVQR1)
- Report on Hydrogeological Investigation of Tarwyn Farm - Natural Farming Sequence: 24-30 December 1995. Roberta L Rice, Consultant, Geo-Ocean Horizons Pty Ltd.(Rice, 1995)

- Quarterly Report 'Hydrological Evaluation of the Natural Farming Sequence applied in the Bylong Valley associated with Tarwyn Park and Homeleigh Properties Phase 1: Data Acquisition and Preliminary Evaluation' NCGM, UTS, June 1996. (NCGMQR1)
- Report on Visit to Tarwyn Park, Bylong, 6 August 1996. Dr William A. Milne Home, NCGM, UTS.
- Quarterly Report 'Hydrological Evaluation of the Natural Farming Sequence applied in the Bylong Valley associated with Tarwyn Park and Homeleigh Properties Stages 2 and 3' NCGM, UTS, November 1996.(NCGMQR2)
- Quarterly Report 'Hydrological Evaluation of the Natural Farming Sequence applied in the Bylong Valley associated with Tarwyn Park and Homeleigh Properties Stages 4 and 5.' NCGM, UTS, May 1997.(NCGMQR3)

This list is by no means comprehensive and includes only those reports that deal with the hydrogeology of the Tarwyn Park - Bylong Valley. Hitherto, there have been hydrogeological studies by Rice (1996) and some data from a study commenced by Warren Overton in 1996.

3.0 BACKGROUND

'Tarwyn Park' is located in Upper Bylong, in the Bylong Valley area some 54 kilometres north of Rylstone, on the central Tablelands of N.S.W. (Figures 1a , 1b.). It is situated next to the Bylong River, which drains northwest toward the Goulbourn River. Throughout this report, the names Bylong River and Bylong Creek are used interchangeably.

'Tarwyn Park' was purchased by the researcher (Mr. Andrews) in 1974 in a degraded state. Gully erosion was reportedly over 6 metres in places, both dryland and irrigation salinity problems were extensive and productive vegetal cover was minimal.(pers.comm., Andrews, 1997; NFSJVQR1,1995.)

The researcher implemented 'Natural Farming Sequence'(NFS) from 1974 to 1979, making adjustments to surface water drainage (Rice, 1996; NFSJVQR1, 1995.) and diversification of vegetation on the floodplains surrounding Tarwyn Park (observations in Rice, 1996; Hanson, 1996) through a cause and effect methodology resulting in hydraulic loading and subsequent raising of the local water table (AAR, 1994; NFSJVQR1, 1995) and increase in the productivity without conventional irrigation.

As a result 'Tarwyn Park' has remained producing throughout the driest period on record in N.S.W. in 1982 and the wettest in 1987 (NFSJVQR1, 1995 (attach. C)).

The National Centre for Groundwater Management (NCGM) was contracted to conduct a 'hydrogeological evaluation of the Natural Farming Sequence applied in the Bylong Valley associated with Tarwyn Park and Homeleigh properties' under the terms outlined in the final research proposal prepared by NCGM for the NFS Joint Venture. The study was generally confined to the Tarwyn Park and Iron Tank floodplains, with the exception of periodical monitoring of the piezometers in the Homeleigh Property. These piezometers were dry throughout the period of the study.

Figure 1(c) shows the topography of Tarwyn Park and identifies points of reference used for the duration of this study.

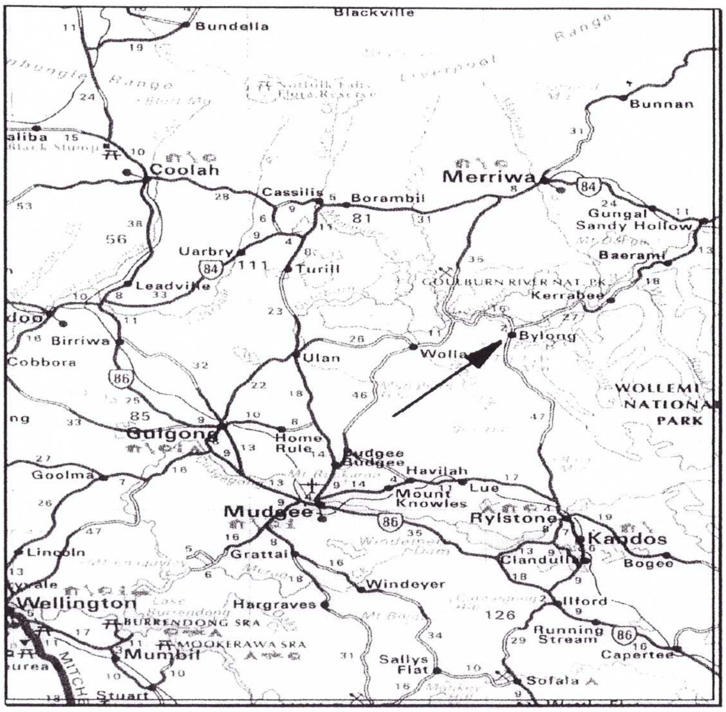


Figure 1a - Bylong Locality

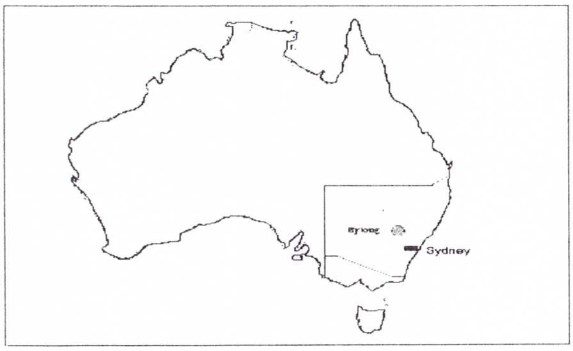


Figure 1b - Bylong Location

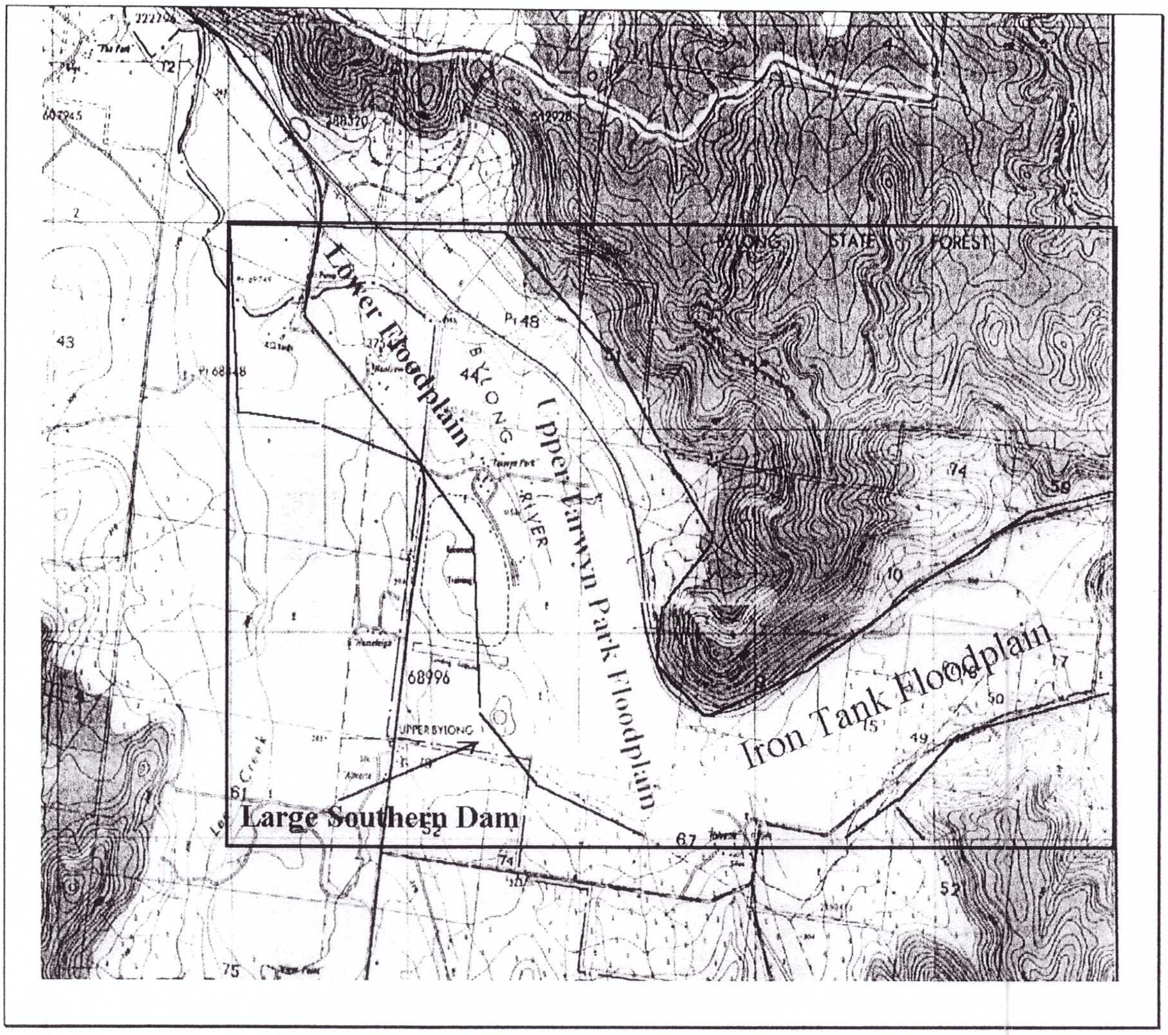


Figure 1 (c) - Study Area

3.1 Natural Farming Sequence - Conceptual Hydrogeological Model (Andrews, 1996)

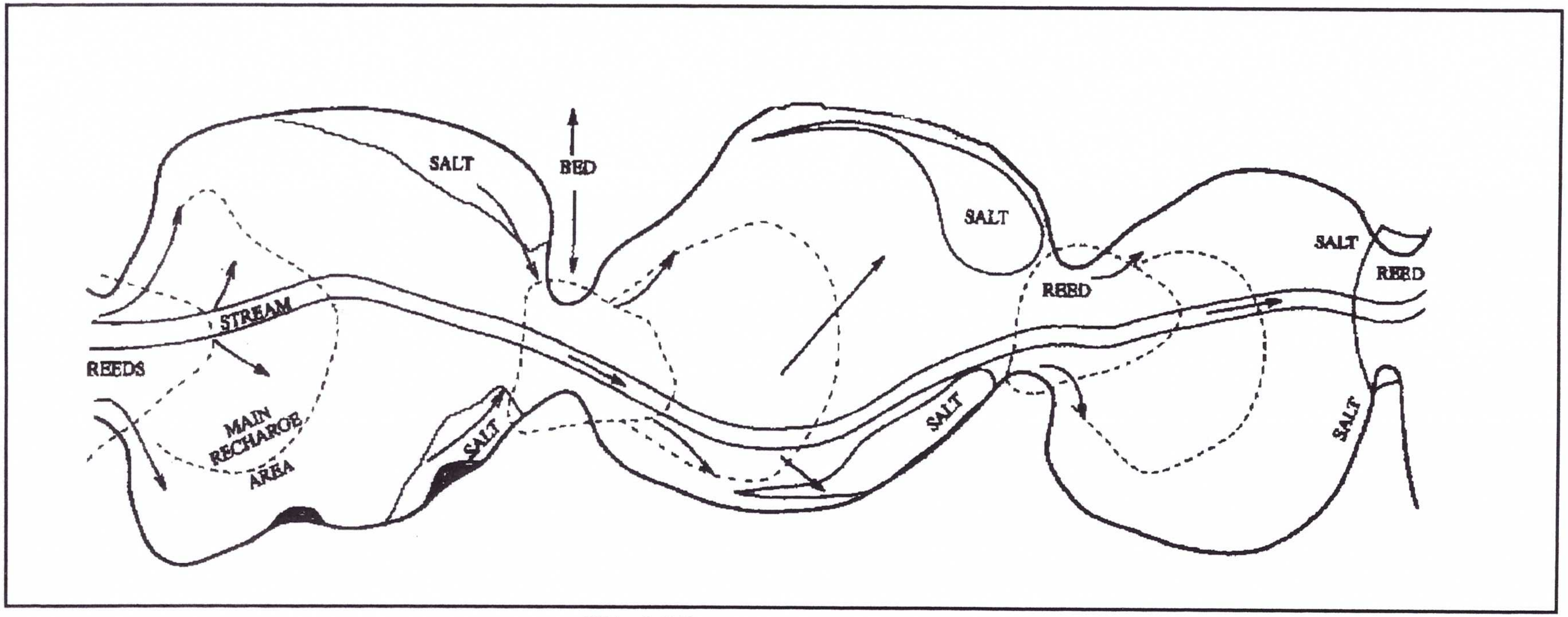
The conceptual models of NFS are presented in Figures 2 (a,b) derived from sketches by the researcher. Figure 2 (a) is a plan view of the conceptual model, showing the natural Australian river sequence as series of linked 'ponds', separated by narrow zones that may be geological or biological in origin. Salt accumulation would naturally occur in the relatively quiescent edges of the pond where the distance from the main flow has resulted in the deposition of silts and clays rather than sands. The depth to bedrock near the edges of the floodplain is shallow, and the artesian input from the rock is also quite saline, adding to the build up of salt. The main subsurface flow is via sand deposited by river and flood sequences. The water is of good quality due to the high throughflow and results in the gradual dilution of the salt over time. The system is kept in equilibrium by interaction of vegetation with the hydrological processes. As more sediment is deposited, and the valley infill is increased, wedges of soil, rich in salt are formed at the edges of the floodplain and are kept insitu (apart from slow dilution) by the hydraulic pressure of the main flow.

Reed beds and stilling ponds exist at the narrow zones, promoting the deposition, formation and stabilisation of silts and clay lenses. The relative position of these fertile zones makes them ideal for the distribution of nutrients in the form of decaying vegetal matter to other parts of the floodplain further downstream.

Besides seepage from shallow bedrock near the edges of the floodplain, the conceptual models assume little upward flow of deep groundwater from the bedrock. Thus the dominant hydrogeological processes influencing the floodplain production takes place within the unconsolidated sediments. The deposition of clay lenses of varying sizes results in perched water tables of good quality water derived from the recharge areas, and this water is thus made more available to the floodplain vegetation.

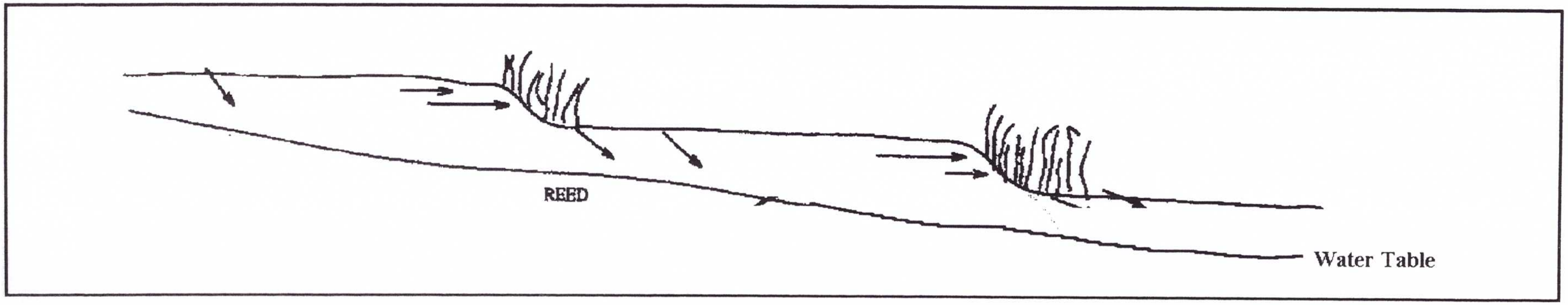
The high water table of the floodplain presents little danger of salinity problems, due to the dominantly good quality water in the system forced to the surface because of clay lenses and geomorphology. The absence of irrigation and dams means that the

AUSTRALIAN RIVER SEQUENCE



PLAN

Figure 2(a)



SIDE ELEVATION

Figure 2(b)

vegetation accesses the subsurface water naturally and major losses in the groundwater budget are from evapotranspiration through the floodplain vegetation and natural discharge to lower aquifers, rather than evaporation. With approximately one - half of all water used in NSW and Victoria being for pasture irrigation, subsurface water storage is a key component of the NFS.

Breakdown of this system will ultimately result in mobilisation of the insitu salt and salinisation of the river system. This is occurring in Australian river systems, to varying degrees, at present.

3.2 Natural Farming Sequence - Effects on the Tarwyn Park Floodplain

Tarwyn Park floodplain which forms part of the headwaters catchment of the Goulburn River system, can be described in terms of the NFS conceptual model with saline groundwater and seepages occurring along the edges of the floodplain and reed beds near the headlands. The headlands extend into the floodplain and are covered by a veneer of sediment overlying the weathered bedrock, forming clay barriers which may be augmented naturally by the accumulation of colloidal material. Geophysical surveys at two sites to investigate postulated clay barriers confirmed their presence (NCGMQR2) and the mineralogy is described in Section 8.2 of this report. The main difference from the natural condition of a floodplain is that the Bylong River is incised into the sediments instead of being raised above them. The occurrence of an incised river bed is typical of a degraded floodplain in the headwaters of an alluvial system. A floodplain in this condition is characterised by deep gullies and severe erosion. The Bylong Valley at Tarwyn Park fitted this description prior to the establishment of the NFS.

Plates 1, 2 and 3 are enlargements of aerial photographs taken respectively in May 1970, August 1982 and September 1992. The 1970 photograph (Plate 1) shows Tarwyn Park before the NFS was established. The floodplain downstream of Helvetia and in the vicinity of Tarwyn Park contains gullies, with the area north of Tarwyn Park showing a well developed, dendritic network of channels. The main channel of

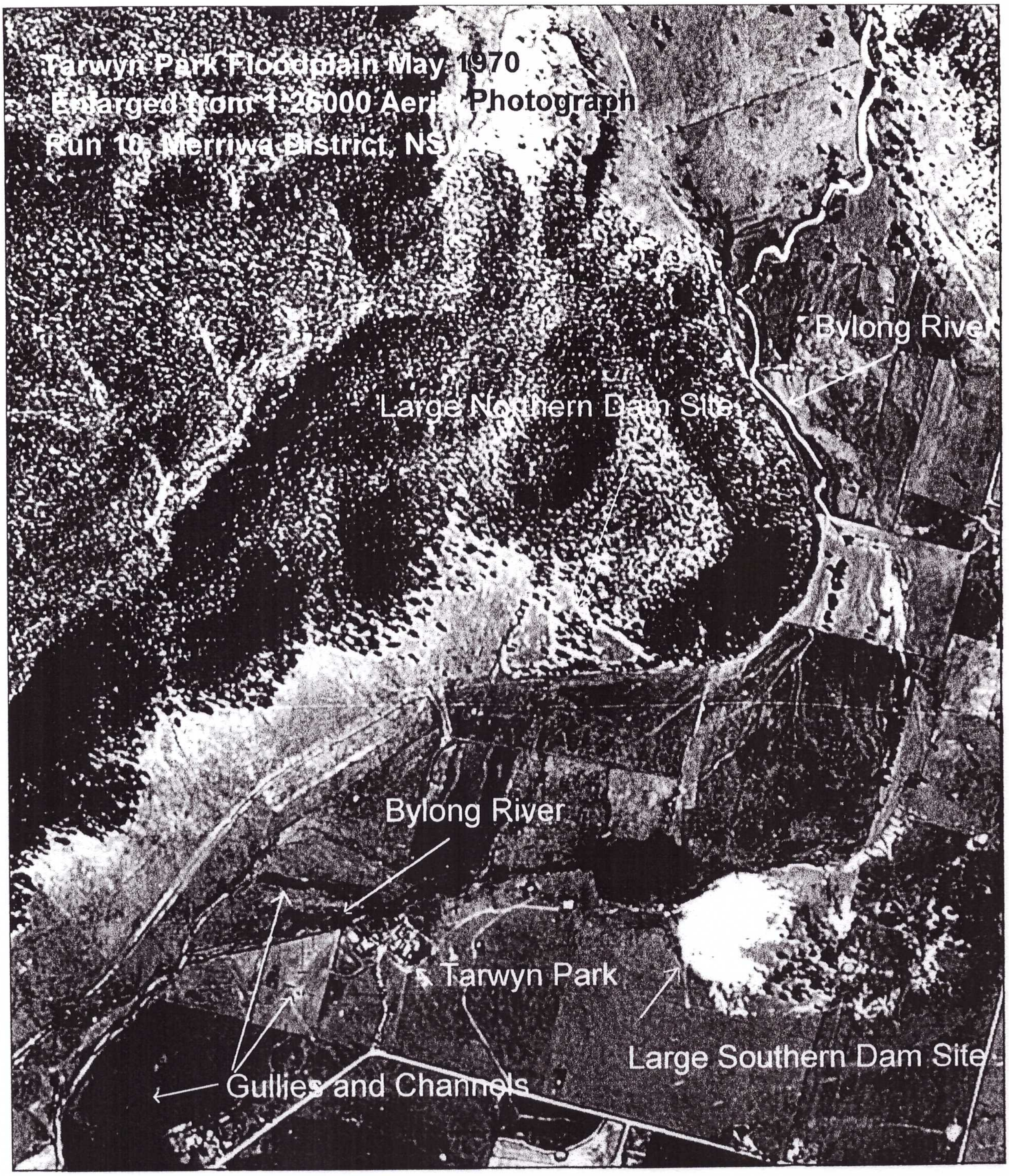


Plate 1 - Aerial Photo of the Tarwyn Park Floodplain May 1970

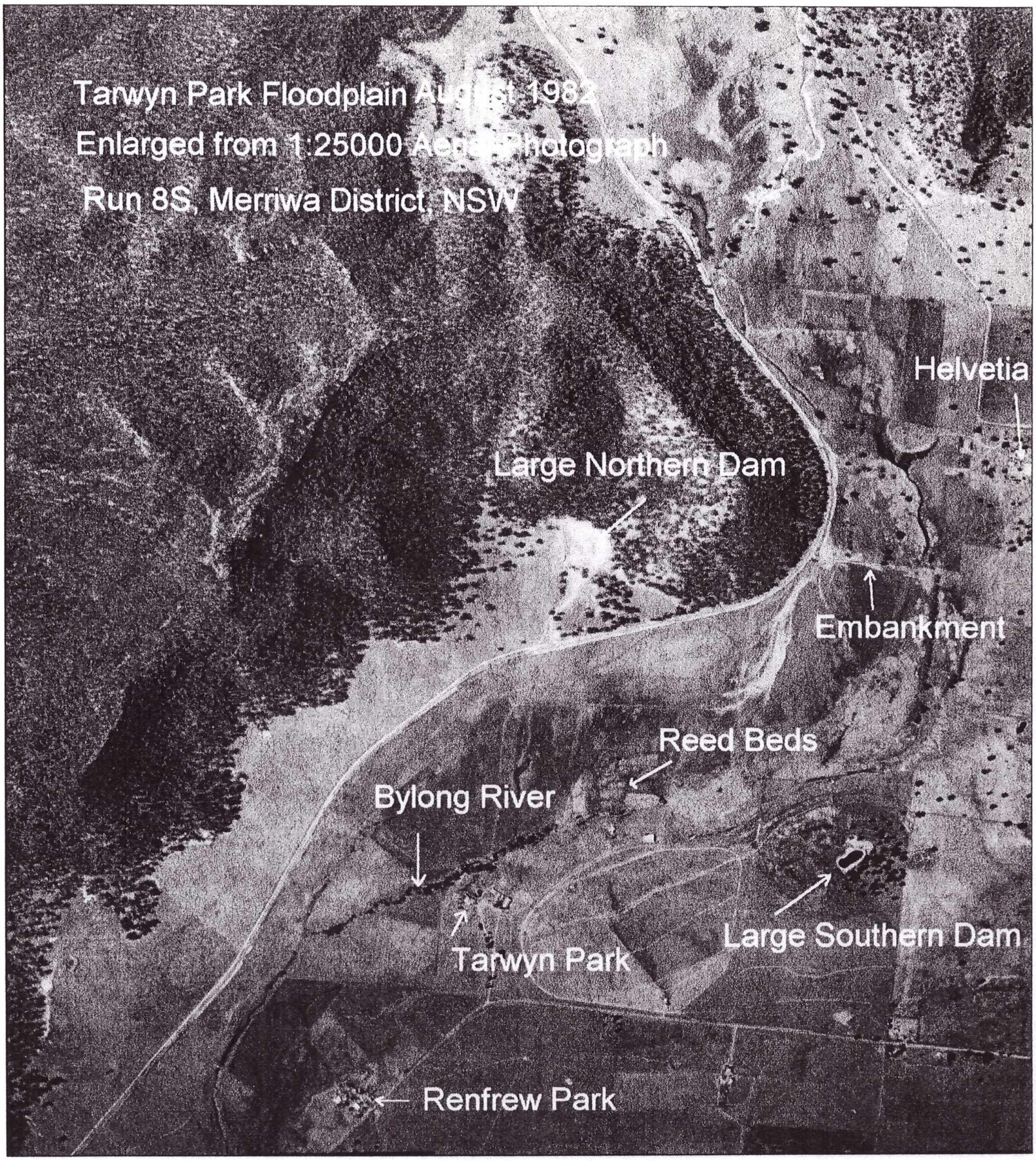


Plate 2 - Aerial Photo of the Tarwyn Park Floodplain August 1982

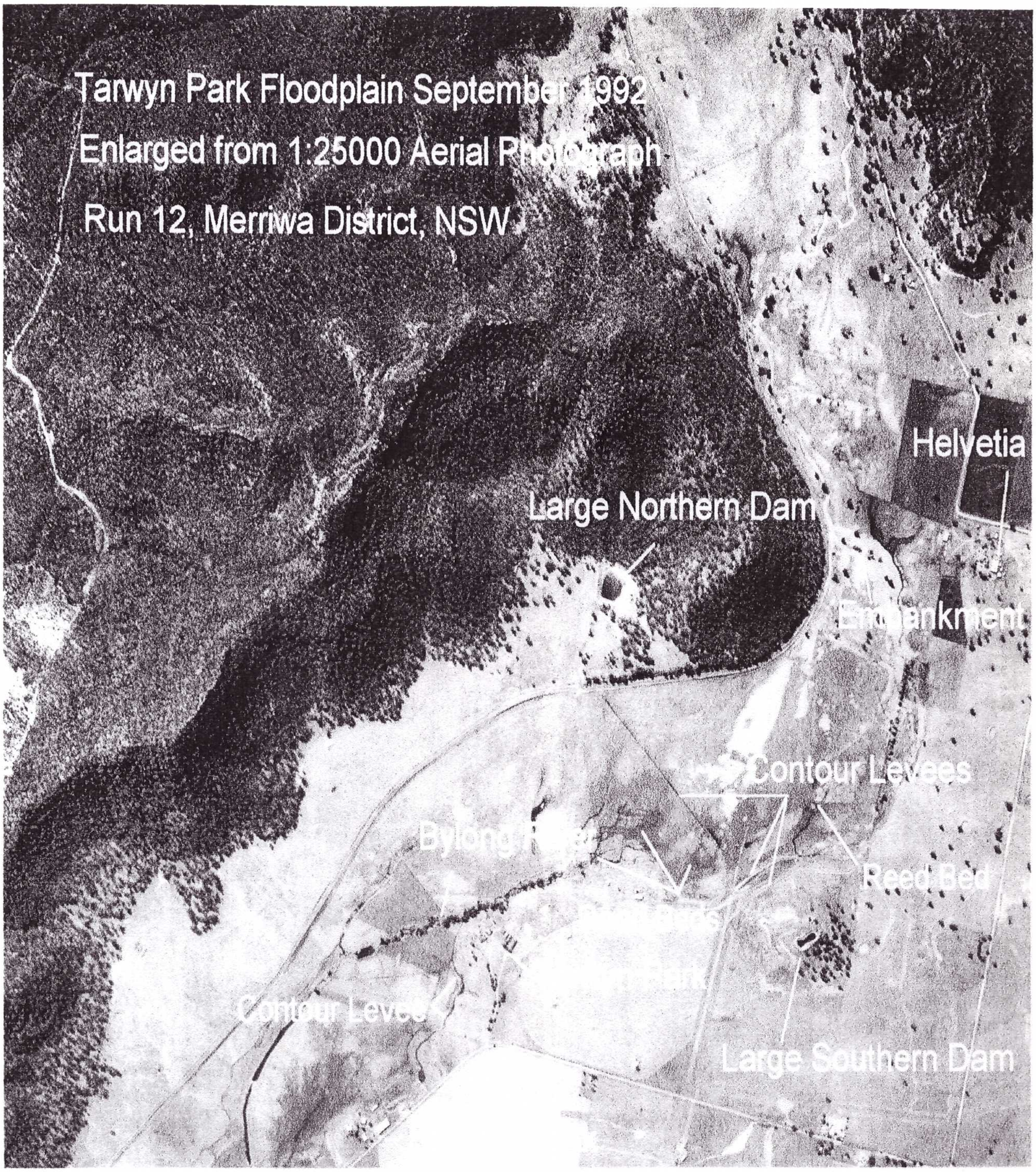


Plate 3 - Aerial Photo of the Tarwyn Park Floodplain September 1992

the Bylong River is relatively deeply incised into the floodplain and no trees are apparent on its banks.

In contrast to the pre-NFS condition, the 1982 photograph (Plate 2) and the 1992 photograph (Plate 3) show a high density of trees along the Bylong River north and east of Tarwyn Park. The course of the river is marked by a continuous belt of trees and shows no significant change in morphology, suggesting that it has been stabilised. Also the network of gullies is much less prominent. The reed beds have increased in area and show distinct drainage distributary channels. In addition, the 1992 photograph shows clearly the position of the NFS contour levees.

The levees near the large Southern Dam and Renfrew Park have the effect of raising the creek bed above the floodplain so that the natural condition of recharge to soil water and groundwater is achieved. This condition leads to an increase in the volume of good quality groundwater stored in the floodplain and available for use by plants. More detailed discussion of these effects is given in Sections 7.0 through 10.0 of this report.

The Bylong river serves as a drain for groundwater from the Tarwyn Park floodplain as its profile elevation is lower than the water table except at the northern end where the reverse condition occurs. This latter condition is typical of the Bylong Valley downstream of Tarwyn Park. For instance, immediately north of Tinkatong the channel of the Bylong River is incised to a depth of 4 to 5 metres below the general ground level and the static water level measured in a bore close to the river was some 6.5 metres below the ground level in April 1997. In contrast, groundwater levels are close to the ground surface in Tarwyn Park. These higher water levels may be attributed to recharge of the floodplain from the NFS contour levees with some retention of storage possibly due to the clay barriers. These hydrogeological observations of the Tarwyn Park floodplain are discussed in Sections 7.0, 8.0 and 9.0 of this report.

4.0 CLIMATE

The daily precipitation data measured at Tarwyn Park and evaporation measured at Scone during the period of the study are provided in Figure 3. The average monthly rainfall, average monthly mean daily pan evaporation and average monthly mean daily maximum temperature for the Bylong area are shown in Appendix A. The average yearly rainfall for the Bylong area for the period June 1968 to May 1996 is 606mm/year. These data indicate a moderately dry, temperate to sub-tropical system (NCGMQR1, 1996).

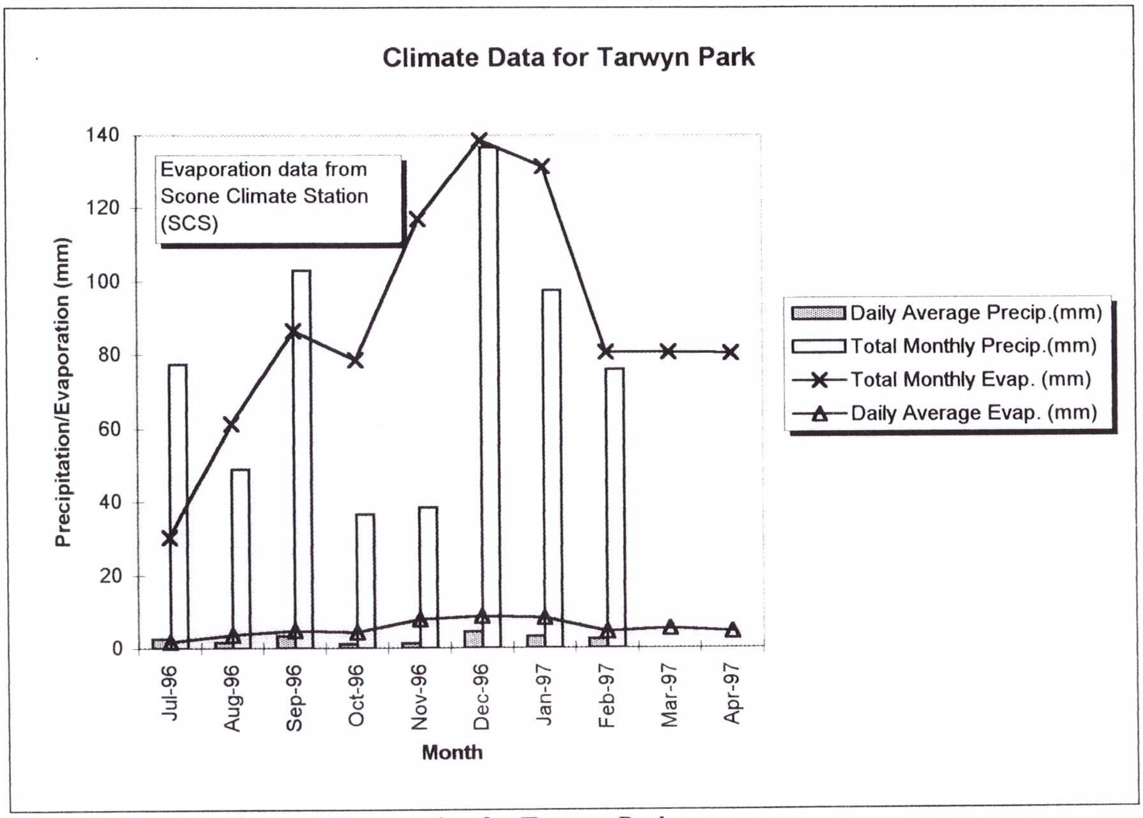


Figure 3. Precipitation and Evaporation for Tarwyn Park

The precipitation during the months from October to February is often caused by high rainfall intensity storm events. These events result in local flooding on some occasions (observations in Rice,1996; and NCGMQR3).

The evaporation data is based on daily pan evaporation values recorded at Scone Climate Station (SCS). It can be seen to follow the expected seasonal sinusoidal cycle (discussion in NCGMQR1,Section 4.1).

The total monthly evaporation is greater than the total monthly precipitation for approximately 75% of the year. This would indicate that surface storage of water for irrigation purposes in this area is not an optimal water management strategy. Generally, the high evaporation during the summer months of the study period substantially influences recharge of the surficial aquifer. This can be seen in relative water table measurements presented and discussed in Section 7.3.

Estimates of evapotranspiration from the evaporation data for the Tarwyn Park floodplains are included in Appendix A, and the impact on the water budget is discussed in Section 10.

5.0 LAND USE

The immediate area surrounding Tarwyn Park is used for the breeding of thoroughbred horses. In excess of 300 horses are kept on the property. Lucernes and oats are the dominant production crop grown on surrounding properties.

6.0 GEOLOGY OF THE AREA

The structural geology of the Tarwyn Park area was mapped by traverses across the face of the escarpments, mainly to the immediate north of the Tarwyn Park homestead. This was completed with two objectives in mind. Firstly to confirm the presence of major faults trending roughly northwest through the Bylong Valley that were tentatively identified by aerial photo interpretation (NCGMQR2, Figure 1) and secondly, to identify any other structural features that may have an effect on the hydrogeology.

Geologically, the Bylong Valley is situated on the western edge of the Sydney Basin near the boundary of the sandstones of the Narrabeen Group and siltstones and coals of the Singleton Coal Measures and proximal to the southwestern boundary of the Hunter Valley Dome Belt. Escarpments surrounding the catchment are composed of unmetamorphosed, graded, massive pebbly sandstones and fine sandstones dipping gently to moderately to the east. Isolated caps of Tertiary olivine basalt occur in the Bylong State Forest and in other locations, overlying the Hawkesbury Sandstone in areas of high elevation. Block jointing and some minor faulting is evident in the cliffs, possibly due to pressure unloading or due to their proximity to the Hunter Valley Dome Belt. Interbedded, laminated fine sands, siltstones, shales and coals occur near the base of the sandstone cliffs, possibly marking the boundary with the Singleton Coal Measures. These beds also dip shallowly to the east.

The joint system, most evident in the sandstone, is roughly orthogonal, with dominant trends as follows; $90^0/055^0$, $84^0W/162^0$, $25^0E/145^0$.There was no discernible movement sense on any of the fractures observed, nor was any evidence of major faulting seen in any of the traverses.

Due to the lack of regional metamorphism, the joints are possibly the result of erosional unloading and would not extend to any great depth. The hydrogeological effects would therefore be minimal. This confirms the observations made by Paul Tammetta on artesian recharge in the Tarwyn Park region (NCGMQR1, Section 4.3.3).

The Bylong Valley comprises mainly Quaternary gravel, sand, silt and clay, derived from the conglomerates, sandstones, shales, and nearby volcanics and form the unconsolidated sediments of the valley infill. Figure 4 is a smaller scale geological map taken from the Environmental Impact Statement on the Sandy Hollow - Ulan Railway Proposal (Longworth and Mackenzie Pty. Ltd., 1980).The important features of the Tarwyn Park geology shown on this map are the surrounding conglomerates which give rise to pebble layers in the soil profile where the conglomerates occur. The surrounding escarpments are shown as mostly sandstone and minor shale. The shales, siltstone and coals outcrop near the base of the sandstone escarpments in this area and

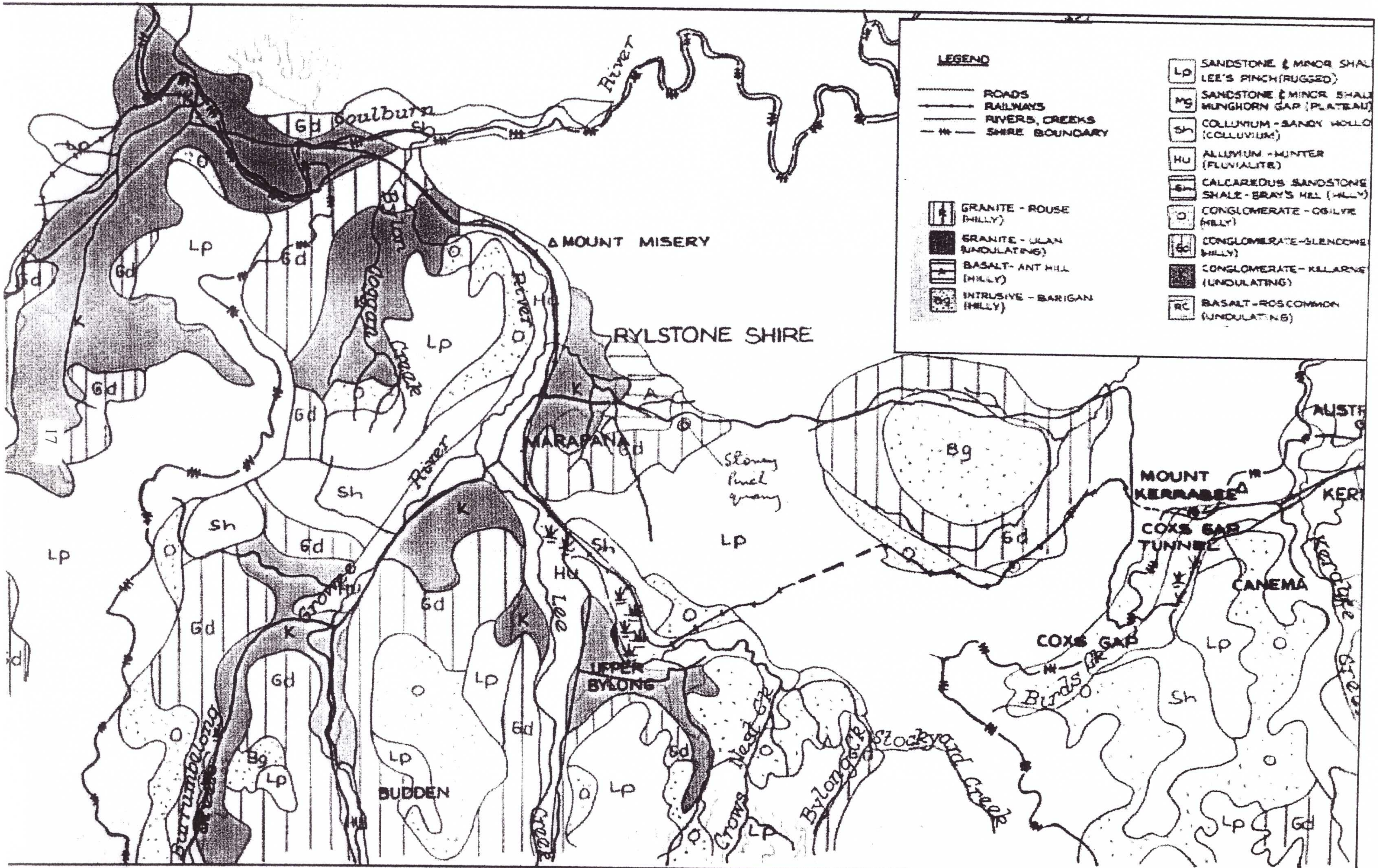


Figure 4 - Generalised Geology of the Bylong Area (modified from Longworth and Mackenzie 1980)

occur at shallow depth (~2 m) on the slopes surrounding the Tarwyn Park floodplain. The Figure 5(a) is a lithological cross - section from the canal stage at TPCA5 and TP3 showing the interbedded alluvial nature of the floodplain. Figures 5 (b) and (c), are schematic hydrogeological cross-sections based on available data such as bore and piezometer lithological logs, water table maps and DC geophysical surveying (NCGMQR2). The land surface elevation and the water table geometry in Figure 5 (c) showing the water table geometry is comparable to the conceptual side elevation drawn by the researcher shown in Figure 2 (a). Significant water table 'steps' in the suficial aquifer are present at TW6, between TW2 and TW1 and between IW5 and TP9. Section locations are shown in Figure 5(d).

It is interesting to note the wetlands notation included on the Longworth and Mackenzie map. This notation is included on older maps of the area and indicates the pristine state of the Tarwyn Park floodplain.

7.0 HYDROGEOLOGY

7.1 Piezometers

A total of 15 piezometers was installed in the floodplains. Their location is shown on Figure 5(d). A 70 millimetre hand auger was used to drill the holes to depths of about 2-3 metres (drilling of more than 1 or 2 metres below the water table was not possible with the hand auger due to caving). The lithology was recorded in logs and has been correlated (refer Figures 5(a) to (c)), although due to the shallow depths the usefulness of the section is limited. TP1 to TP5 were constructed of 50 millimetre PVC pipe with slots cut at approximately 1 centimetre spacing over 1 metre as a screen. The exterior of the screen was wrapped in a thin geotextile sock to prevent fine sediments from clogging the piezometer. On completion of the piezometer, gravel was packed around the screen and overlain by sand and bentonite clay pellets as a seal. The completion characteristics of each piezometer are provided in Table 1.

The three piezometers proximal to TW9 and TW10 were installed to provide further water quality information across the floodplain from the contour levees and the Large

Table 1 -Tarwyn Park Piezometer Installation

Piezo - TP1	50mm PVC pipe
Depth (cm)	Lithology
0	Topsoil, dark grey clay
30	sandy clay
60	pebbly sand
90	pebbly sand
110	pebbly sand
130	dark grey clay
140	dark grey clay
150	dark grey clay
180	dark grey clay
210	pebbly sand
260	pebbly sand
EOH	
Screen	180 to 260
	1cm spaced slots and geotextile

Piezo - TP2	50mm PVC pipe
Depth (cm)	Lithology
0	Topsoil, dark grey clay
50	sandy clay
80	pebbly sand
180	sand, minor clay
220	dark grey clay
260	sand
280	sand
EOH	
Screen	180 to 280
	1cm spaced slots and geotextiles

Piezo - TP3	50mm PVC pipe
Depth (cm)	Lithology
0	Topsoil, clayey sand
30	clay, minor sand
60	sand
90	dark grey clay
120	dark grey clay
150	dark grey clay
180	pebbly sand
210	pebbly sand
240	pebbly sand
270	pebbly sand
300	pebbly sand
310	clay, minor sand
330	pebbly sand
360	pebbly sand
390	clay, minor sand
400	pebbly sand
EOH	
Screen	300 to 400
	1cm spaced slots and geotextile

Piezo - TP4	50mm PVC pipe
Depth (cm)	Lithology
0	Topsoil, dark brown silt
50	dark brown silt
100	dark brown clay
150	dark brown clay
160	dark brown clay
200	sand, minor clay
280	light brown clay
340	weathered sandstone b'rock
EOH	
Screen	250 to 340
	1cm slots and geotextile

Piezo - TP5	50mm PVC Pipe
Depth (cm)	Lithology
0	light brown silty clay
20	dark grey clay
60	dark grey clay
80	gravel/light brown clay
90	dark grey brown clay
110	dark grey-black clay
135	dark grey black weathered shale
150	sand, minor clay
250	gravel/light brown clay
340	EOH
Screen	240 - 340
	1 cm slots and geotextile

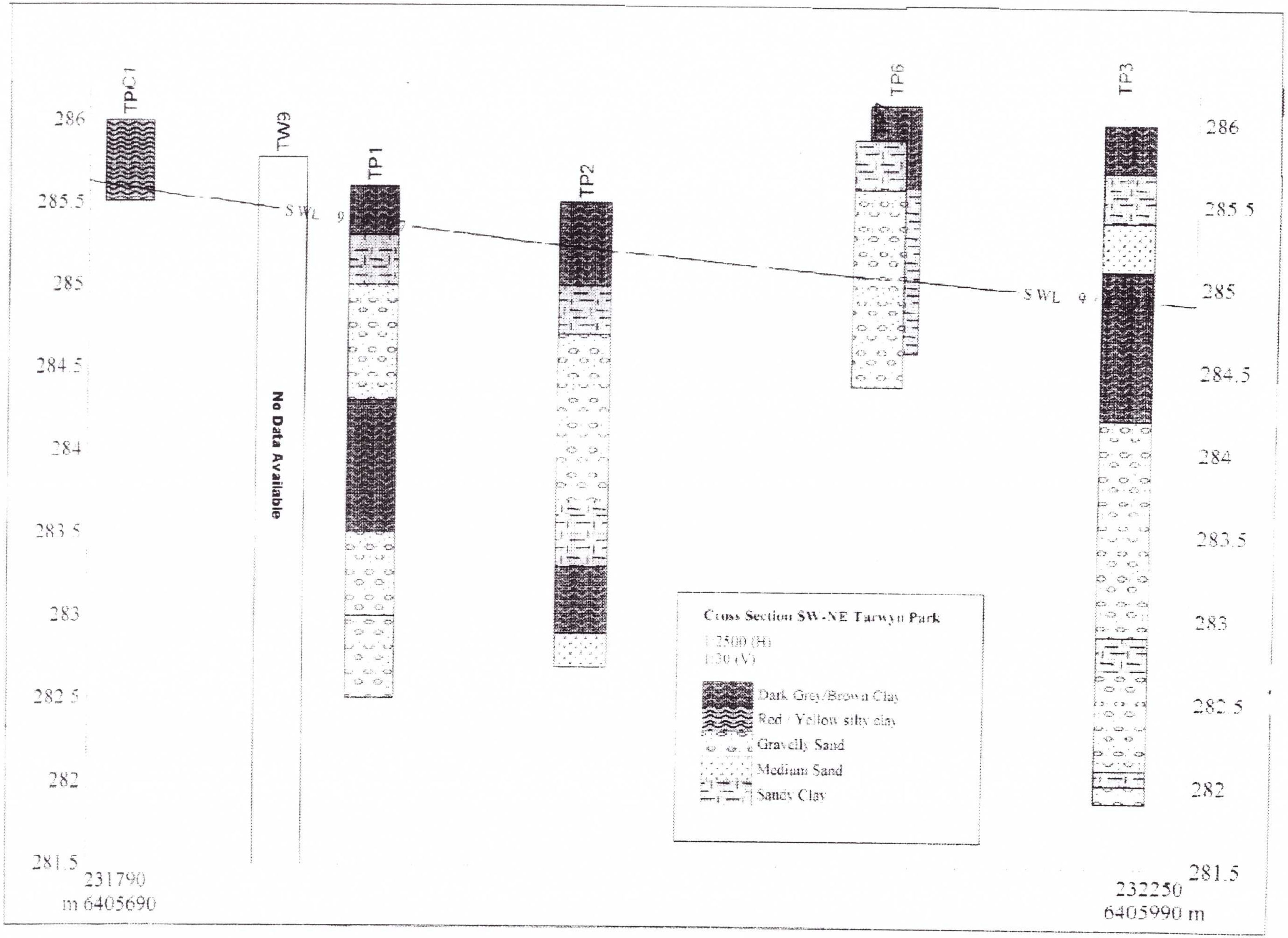


Figure 5(a) Hydrogeological Cross - Section Upper Tarwyn Park Floodplain

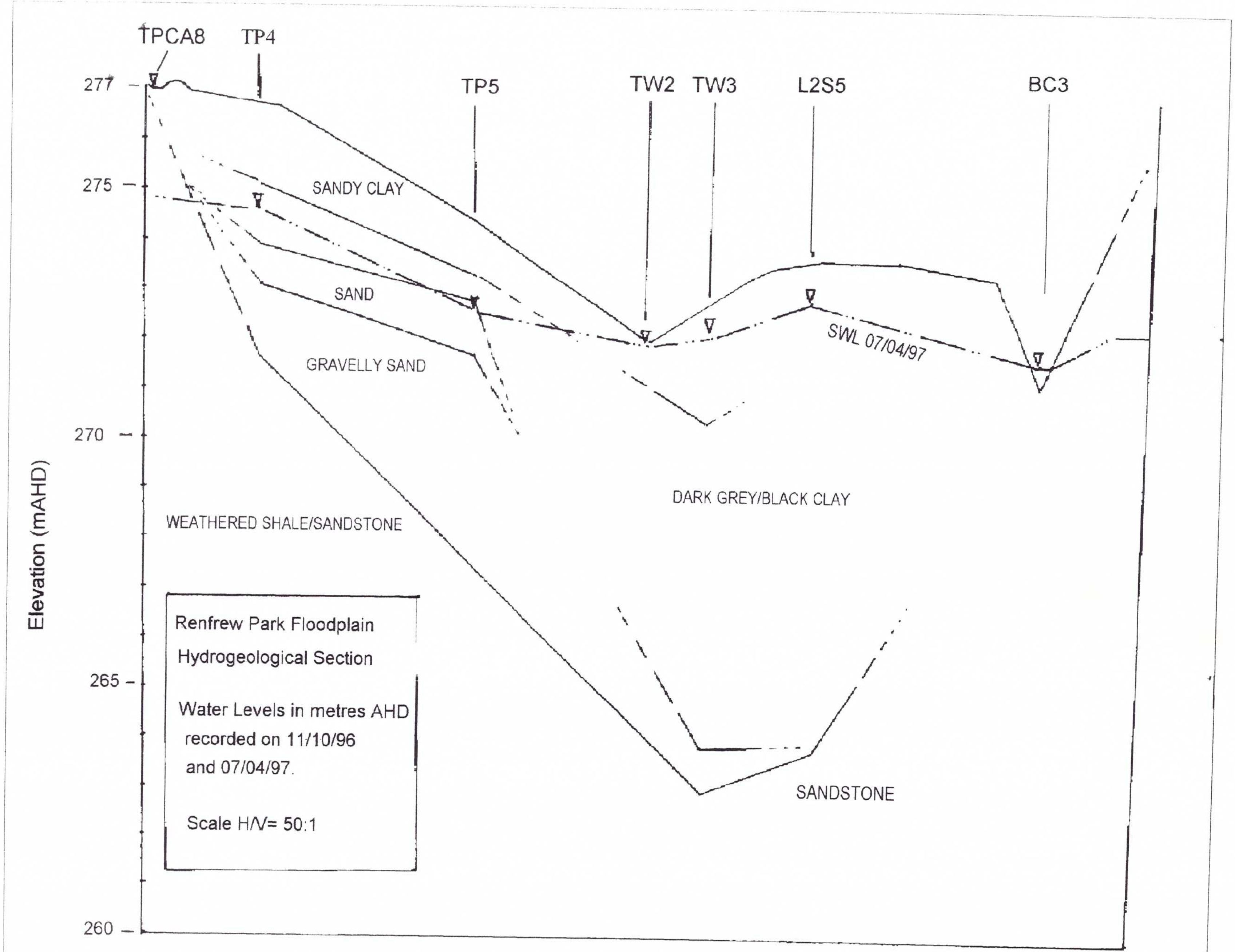


Figure 5(b) Hydrogeological Cross - Section Lower Tarwyn Park Floodplain

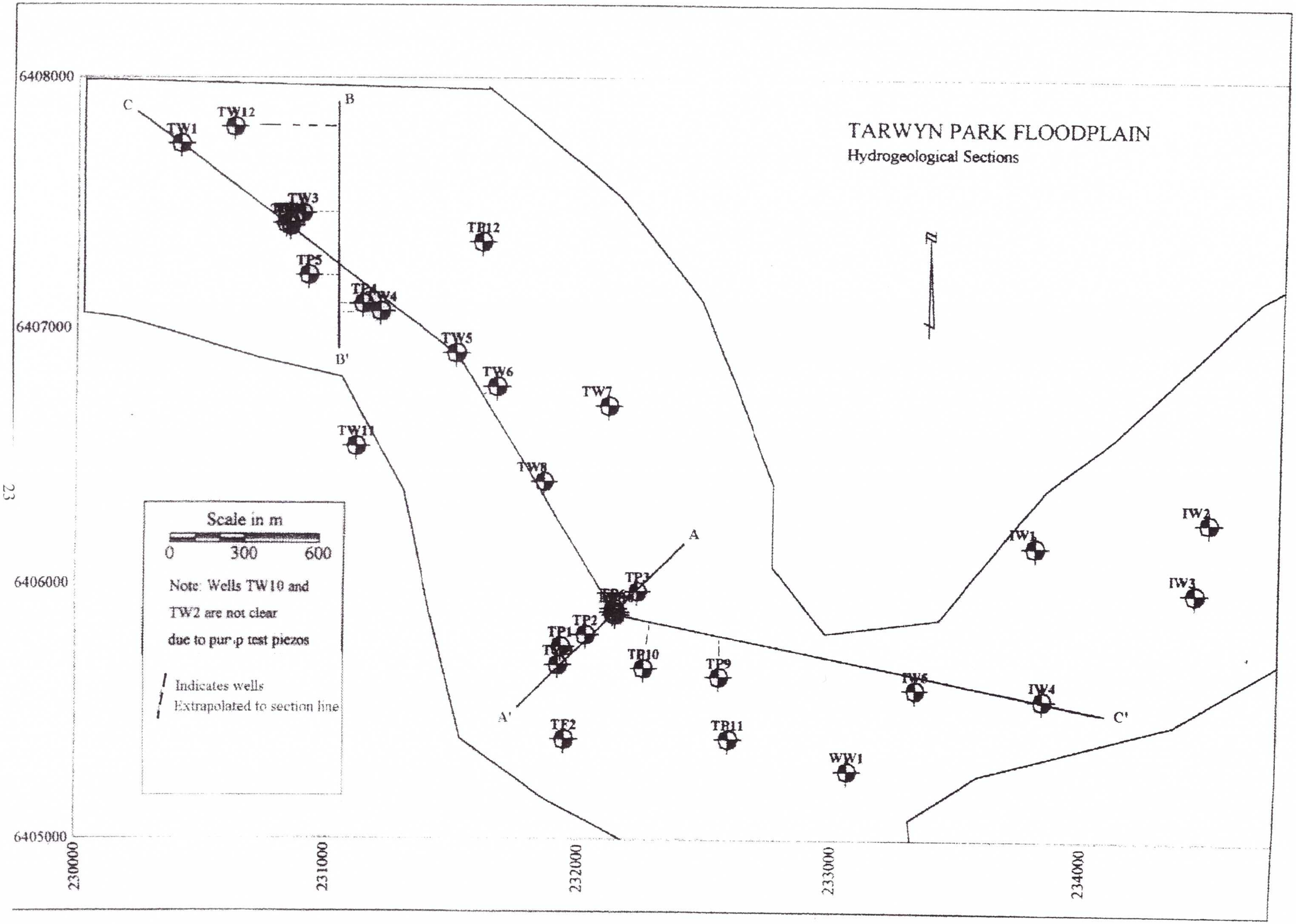


Figure 5(d) Cross - Section Plan Tarwyn Park

Southern Dam, an area highlighted by high salinity measurements (TF2, TW9). It was attempted to auger a hole between the dam and the contour levees but a layer of weathered rock was struck at a depth of 2 metres and prevented further drilling. The water table was not reached.

The two piezometers proximal to TW4 and TW2 were installed to provide water quality data on the groundwater below the contour levees at 'Renfrew Park', again due to high salinity measurements in that area.

Piezometers TP6 to TP8 were drilled to the water table only for the purpose of monitoring the imposed drawdown by pumping at TW10. They are not clearly shown on Figure 5 (d) due to their proximity to the well and to each other.

Piezometers TP9 to TP11 were installed on the upper Tarwyn Park floodplain to collect more data on the water table in that area. Piezometer TP12 was established on the eastern side of the floodplain across from the Tarwyn Park Homestead to determine water quality on that side.

Piezometers TP13 to TP15 were temporary piezometers installed to monitor drawdown imposed by pumping at TW2. Again, their position is not clear on Figure 5(d).
Lithological logs and completion characteristic were not recorded for piezometers TP6 to TP15. They are simply open stand-pipes designed to measure the water level on the floodplain.

7.2 Bore Information

Rice (1996) provides information on most of the relevant bores in the Tarwyn Park / Iron Tank aquifers in Appendix C to her report. The Department of Land and Water Conservation has bore completion and hydrogeochemical details on some bores in the Bylong Valley as presented in NCGMQR1 (1996), but only a few are on the Tarwyn Park floodplains. Further to these details, the coordinates of the relevant bores in

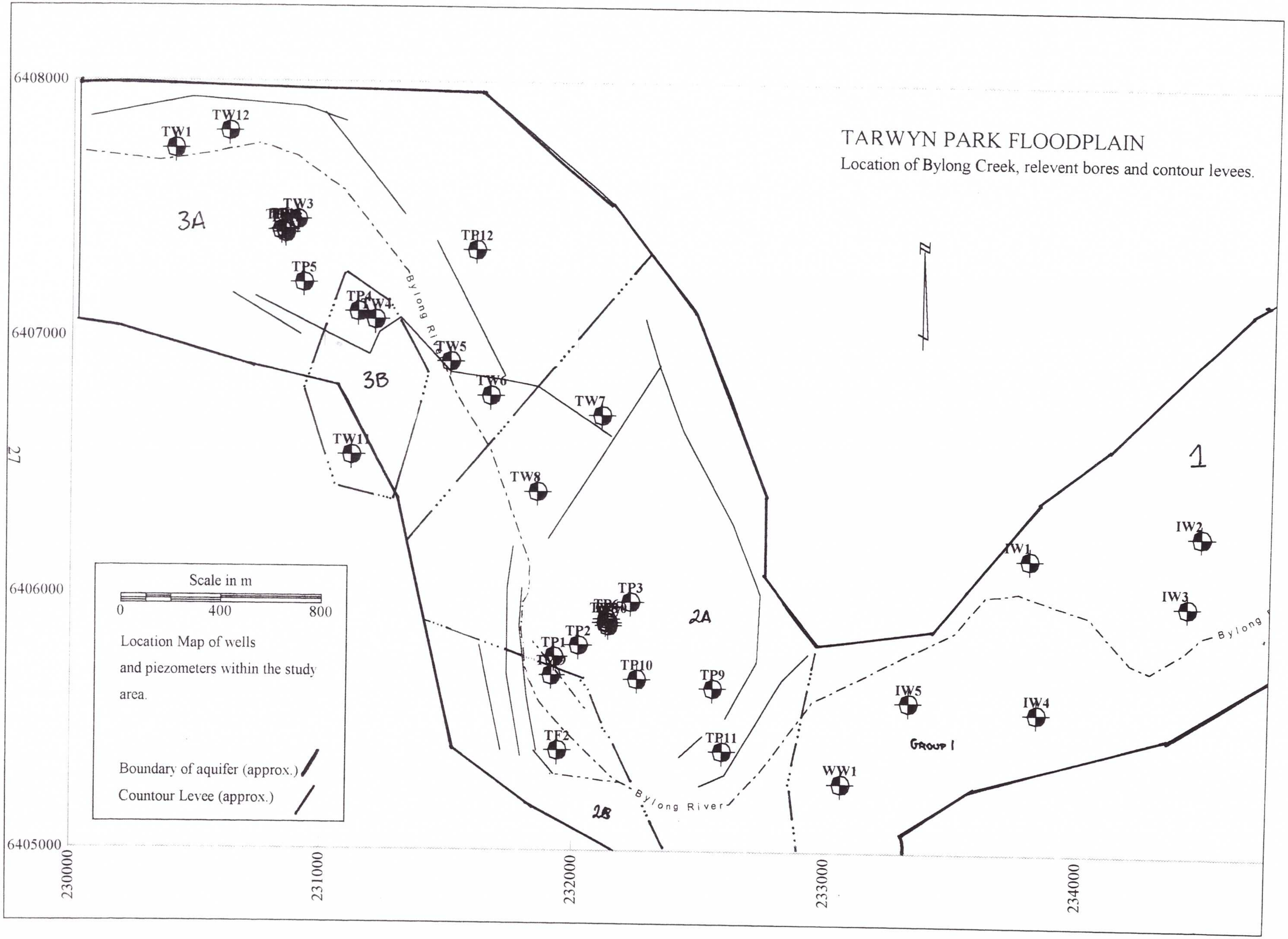
AMG and AHD are presented in Table 2. Most of the bores are large diameter (1.2 m) wells with concrete well heads and casing. Limited information on the screen construction and position are available. Older wells on the floodplain are of square cross-section, wood construction and range from 1 to 1.5 metre square.
The bores and piezometers are grouped according to their position on the floodplain as shown in Figure 6. The rationale behind the grouping is discussed in Section 8.

Wells IW1, IW2 and IW3 were not surveyed due to access problems. They are plotted on Figure 6 using (approximate) coordinates from the DLWC records.

STATION	EASTING (M)	NORTHING (M)	ELEVATION (M)	LOCATION COMMENTS
TP6	232128.6	6405906.2	286.1	pump test piezo near tw10
TP7	232136.6	6405880.2	285.9	pump test piezo near tw10
TP8	232125.2	6405891.3	286.2	pump test piezo near tw10
TP9	232552.3	6405636.2	288.9	temp piezo near large oak
TP10	232251.1	6405669.8	288.0	temp piezo 500m N of weir
TP11	232592.7	6405389.8	289.6	temp piezo under weir bank
TW12	230615.2	6407798.8	272.5	bore near tw1/water tank
BC1	230737.1	6407751.5	271.1	Bylong Creek (northrn end)
BC2	230883.5	6407703.8	271.6	Bylong Creek (northrn end)
BC3	231072.0	6407572.8	272.0	Bylong Creek (northrn end)
BC4	231325.4	6407258.5	274.8	Bylong Creek near tw4
BC5	231523.5	6406779.8	277.7	Bylong Creek near tp hmstd
BC6	231662.3	6406565.8	279.7	Bylong Creek near tp hmstd
TP12	231596.4	6407342.2	275.9	Temp piezo on E side fldpln
BC7	231824.4	6406115.9	283.4	Bylong Crk (near Stuarts house)
BC8	231811.3	6405849.9	284.9	Bylong Crk (near landing strip)
BC9	232048.8	6405552.8	286.1	Bylong Crk (near tw9/tf2)
WW1	233063.3	6405268.1	292.5	Wallings Well (lower one)
TP13	230842.5	6407404.0	272.7	Pump test piezo near tw2
TP14	230824.4	6407414.3	272.5	Pump test piezo near tw2
TP15	230838.1	6407418.3	272.7	Pump test piezo near tw2
NP1	231097.7	6406493.2	288.8	Newcastle plot N end of racetrk
TW11	231112.2	6406539.9	288.4	Well above tp hmstd (n end of rtrk)
TP1	231922.2	6405756.5	285.6	Piezo near tw9/tw10
TP2	232017.9	6405800.8	285.5	Piezo near tw9/tw10
TP3	232223.1	6405971.8	286.0	Piezo eastrn side of tw10
TPCA1	231900.6	6405467.3	287.3	Canal stn near tf2 - upper tp fldpln
TPCA2	231927.3	6405479.2	287.4	Canal stn near tf2 - upper tp fldpln
TPCA3	231899.2	6405514.8	286.5	Canal stn near tw9 - upper tp fldpln
TPCA4	231857.1	6405615.5	286.4	Canal stn near tw9 - upper tp fldpln
TPCA5	231807.0	6405702.0	286.0	Canal stn near tw9 - upper tp fldpln
TPCA6	231717.5	6405792.8	286.0	Canal stn near tw9 - upper tp fldpln
TP4	231134.5	6407098.1	276.2	Piezo near tw4- lower tp fldpln
TP5	230916.6	6407209.2	274.4	Piezo near Renfrew p-lower tp fldpln
TPCA7	231234.0	6406930.7	277.1	Canal stn near tw4 - lower tp fldpln
TPCA8	231136.8	6406966.6	277.0	Canal stn near tw4 - lower tp fldpln
TPCA9	231055.8	6407027.4	277.0	Canal stn near tw4 - lower tp fldpln
TPCA10	230976.0	6407089.5	277.1	Canal stn near renfrew p
TPCA11	230874.3	6407067.3	277.3	Canal stn near renfrew p
TPCA12	230794.0	6407160.4	276.9	Canal stn near renfrew p
TW1	230401.8	6407730.9	272.6	Well near bridge
TW2	230839.0	6407413.2	272.5	Well near renfrew park
TW3	230887.1	6407455.3	273.2	Well near renfrew park
TW4	231201.8	6407068.1	276.8	Well middle of lower tp fldpln (bush)
TW5	231499.3	6406906.4	278.7	Well e side of bylng crk near tp hstd
TW6	231659.2	6406774.4	279.2	Well e side of bylng crk near tp hstd
TW7	232105.2	640696.5	284.9	Well ne of TW6
TW8	231791.9	6406483.7	284.5	Well near Stuarts house
TW9	231912.5	6405683.6	285.8	Well near canal - upper tp fldpln
TW10	232136.7	6405892.5	286.3	Well middle of upper tp fldpln
TF2	231939.3	6405390.0	286.8	Piezo near canal - upper tp fldpln
IW4	233836.2	6405550.1	296.2	Well near iron tnk homestead
IW5	233328.7	6405588.4	292.5	Well above weir - lower iron tnk fldpln

Abbreviations: tp = Tarwyn Park; iron tnk = Iron Tank; renfrew p = Renfrew Park; n=north, e=east, w=west, s=south.

Table 2. Coordinates of relevant bores



TARWYN PARK FLOODPLAIN
Location of Bylong Creek, relevent bores and contour levees.
6408000
6407000
6406000
6405000
230000
231000
232000
233000
234000
3A
3B
2A
2B
1
Group I
Bylong River
Bylong Creek
TW1
TW12
TW3
TP5
TP4
TW4
TW5
TW6
TW7
TW8
TW11
TP12
TP1
TP2
TP3
TP9
TP10
TP11
TF2
WW1
IW1
IW2
IW3
IW4
IW5
Scale in m
0
400
800
Location Map of wells
and piezometers within the study
area.
Boundary of aquifer (approx.)
Countour Levee (approx.)

7.3 Groundwater Hydrographs

Figures 7, 8, and 9 show hydrographs plotted against the precipitation from August 1996 to February 1997 which indicate particularly large response to rainfall event in wells in the northern part of the project area (Group 3A,B). The rate of increase of well TW1 is twice that of wells TW9 and TW10. This relatively large increase in water level is probably a result of several factors. Primarily, the topography of the area from TW2 to TW1 is relatively flat with less than 20 cm fall over 550 metres, and a corresponding low groundwater hydraulic gradient. Secondly, according to the researcher, a clay barrier has formed at this location, forcing water to the surface and also impeding groundwater flow. Geophysics (NCGMQR1) and auguring in the area has confirmed the dominantly clay lithology present. Thirdly, the main surface water discharge zones have been artificially impeded by the road placement across the lower floodplain. This has the effect that in high flow times, the surface water tends to pool behind the culvert under the bridge in the road, probably enhancing recharge and stimulating the formation of a reed bed. TW1, near the sandy creek bed, is also the focus of surface and groundwater flow from the Tarwyn Park floodplain and would be expected to have a much larger groundwater accession due to the recharge event. Although devoid of a large number of data measurements, the plots show a large increasing water level after the rainfall event which may indicate recharge from surface flooding in that area. Surface flooding was evident after 71 millimetres of rain fell on the 29 and 30 September 1996.

The water table response to the rainfall event in September 1996 shows an overall rise in the level of the majority of wells measured. However a similar (77 mm) rainfall event in December 1996 actually resulted in a slight drop in some water of the levels measured. The total evaporation exceeds the total rainfall for December 1996 (Figure 3.) but not for September 1996. It should be noted that while the evaporation data is from Scone, the measurements for precipitation were recorded at Bylong and as such, they cannot be compared with reliability. In the absence of lateral recharge, the observed groundwater recession may be due to aquifer discharge rather than evaporation.

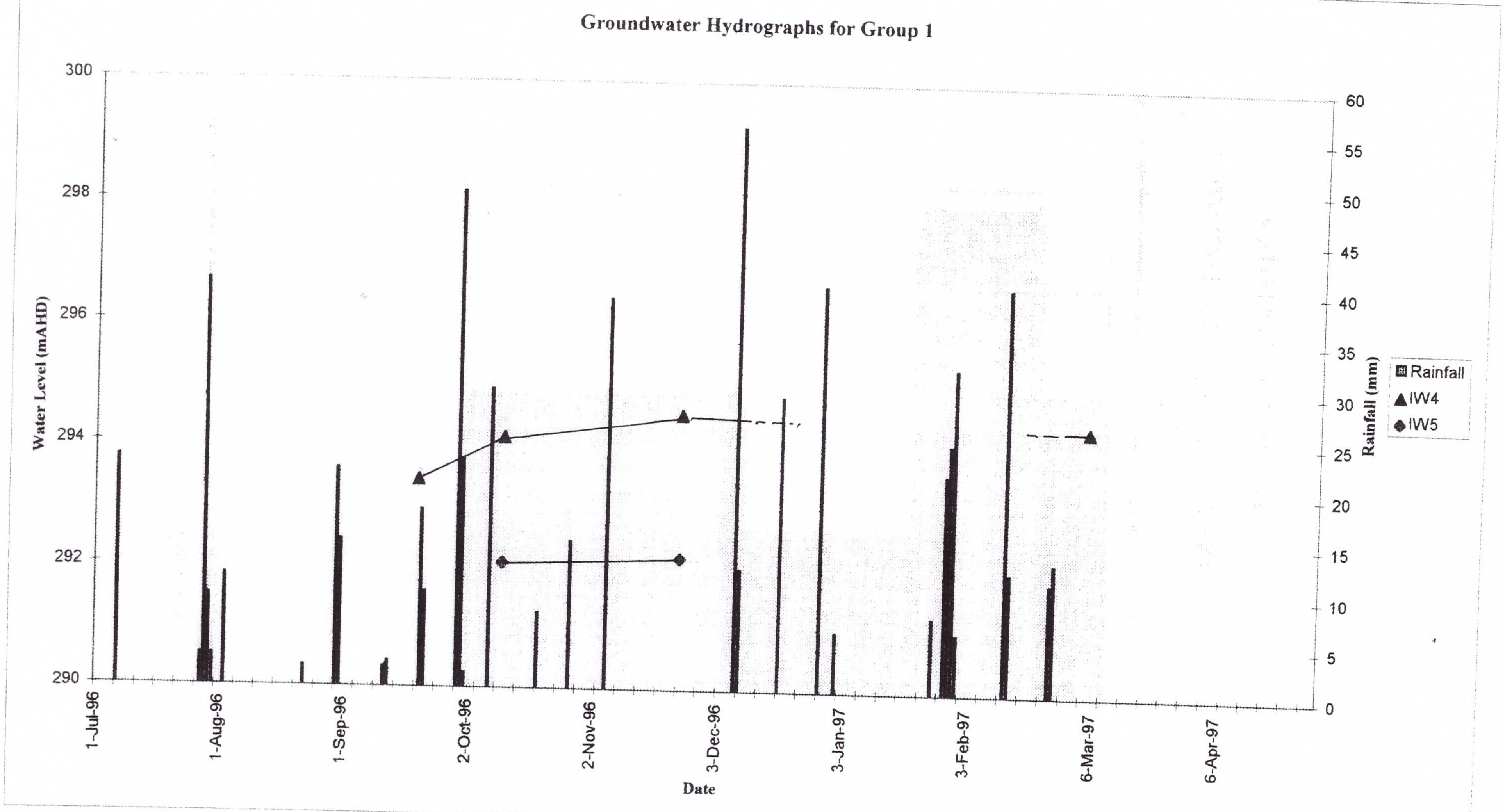


Figure 7. Groundwater Hydrographs for Group 1

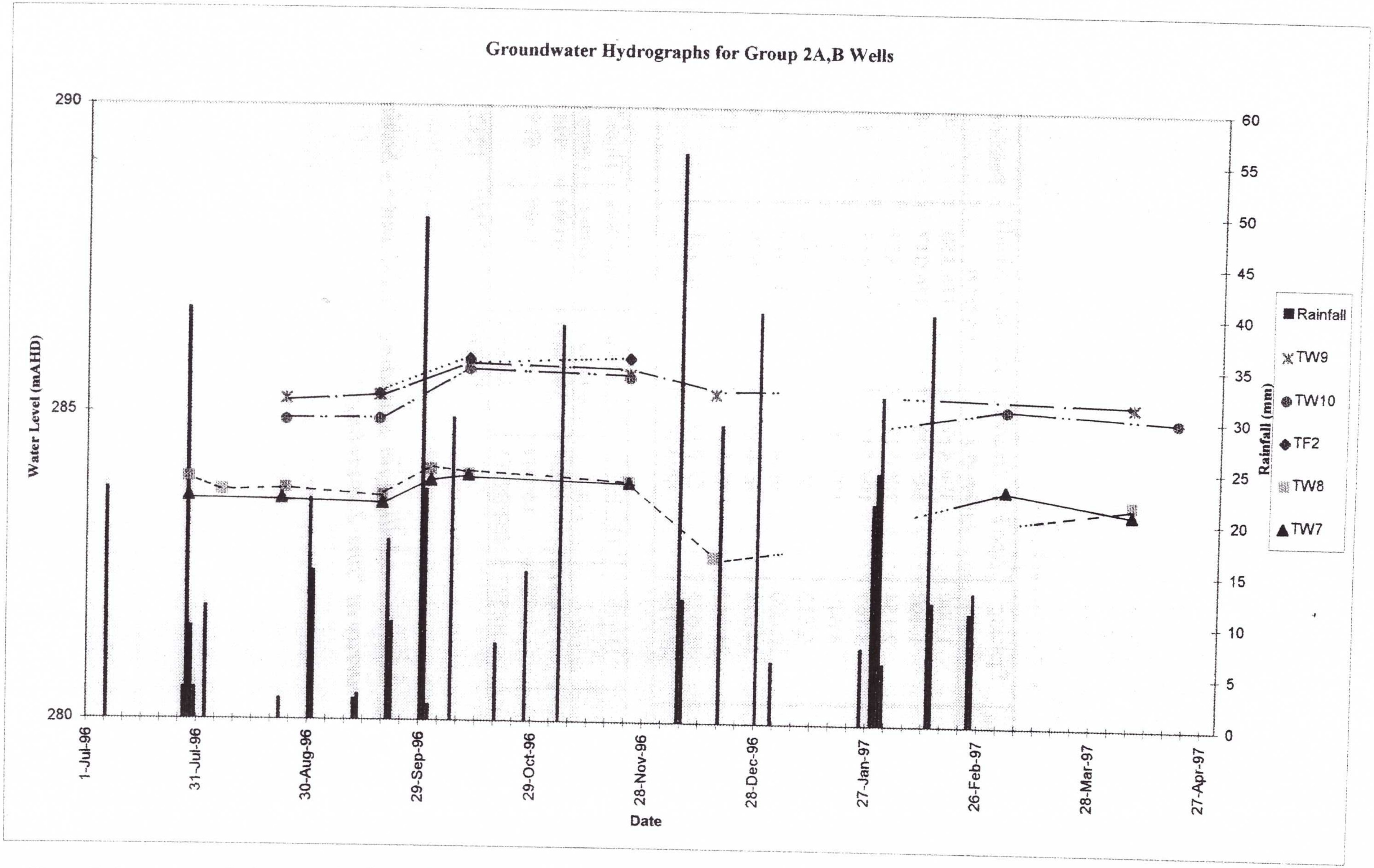


Figure 8. Groundwater Hydrographs for Group 2

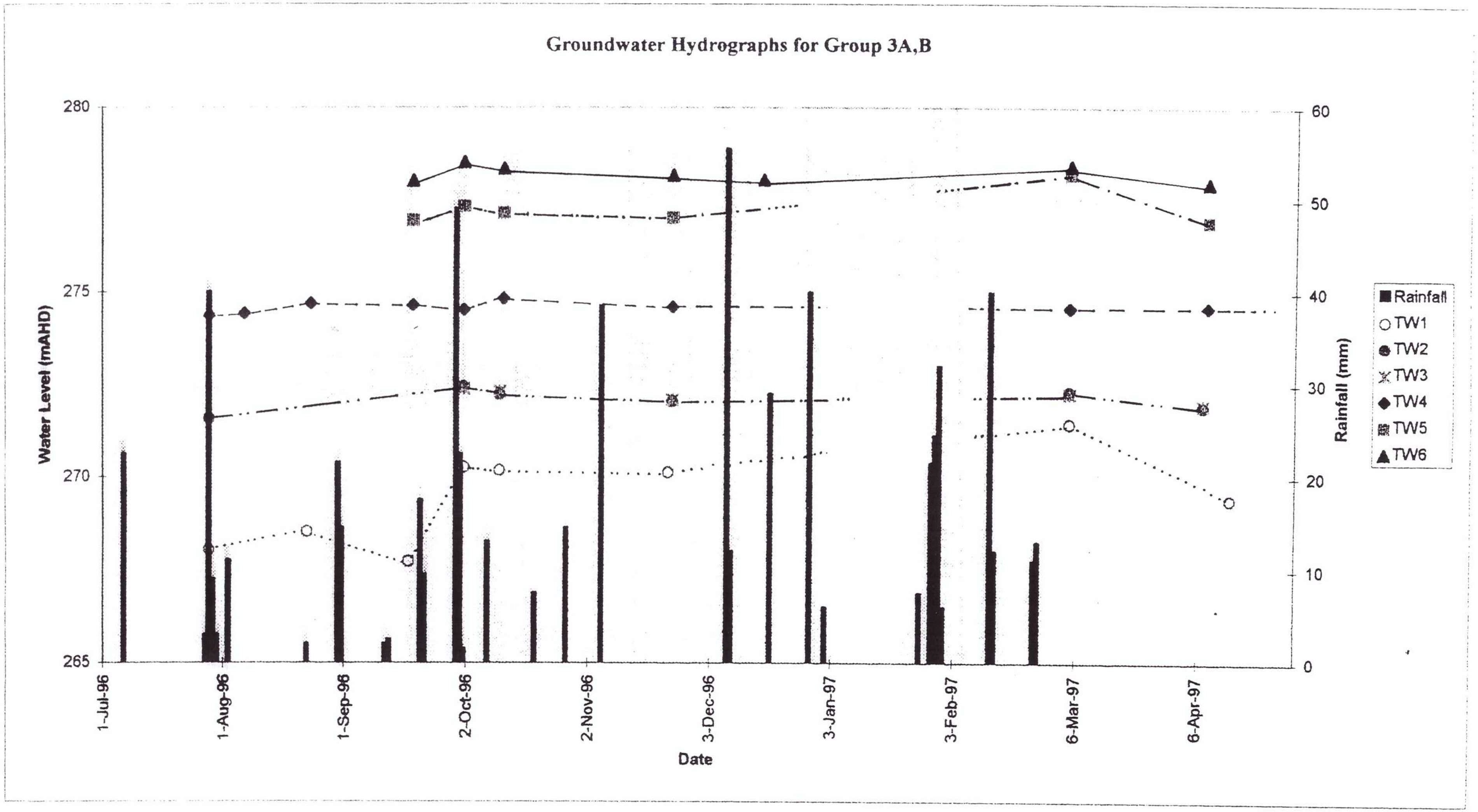


Figure 9. Groundwater Hydrographs for Group 3

Figures 10 through 14 are the recorded well hydrographs presented relative to the measured base of the Bylong River and contour levees. They show which areas of the floodplain aquifer are subject to recharge and discharge and the changes that take place over the period of study. Figure 15 shows the section lines A to E, roughly perpendicular to the main flow direction, onto which the recorded data from nearby wells is projected. It is clear that for most of the floodplain aquifer, and for most of the period of the study, the groundwater is discharging into the Bylong River. However, the water table at TW1 is below the level of the creek bed for periods of lower rainfall and appears to be recharged by the creek at this point. This may indicate an increase in the hydraulic gradient near to TW1 or a water table 'step' down to a lower aquifer as discussed in Section 6 and shown in Figure 5(c). The water 'steps' are less pronounced in a dry period as shown in Figure 5(c), however the changes in the water table gradient are still noticeable and are interpreted as water being forced over clay barriers present near locations IW5, TW8 and TW2. The chaotic nature of the operating pump at TW2 means that the measured water level may have been influenced substantially.

The water level recorded at TW10 during a dry spell such as August and September 1996 is below the elevation of the bed of the Bylong River and much lower than the level recorded in TW9. Flow would therefore be in a direction toward the centre of the floodplain in a dry period. This flow direction is reversed during high rainfall, toward the edge of the floodplain. This can be seen more clearly in Figures 16 and 17, which demonstrate the change in net flow between the three wells on the upper Tarwyn Park floodplain after a 71 mm rainfall event. The implication is that in this upper area at least, recharge is from the central part of the floodplain. This pattern of recharge is emphasised in Figure 2(a) of the conceptual model of NFS and discussed in Section 3.2, where it is noted that recharge of the aquifer occurs from the more sandy parts of the floodplain.

The water table maps at 19 September 1996, 11 October 1996 and 14 April 1997 are shown in Figures 18, 19 and 20. These maps are relatively interpretive due to the

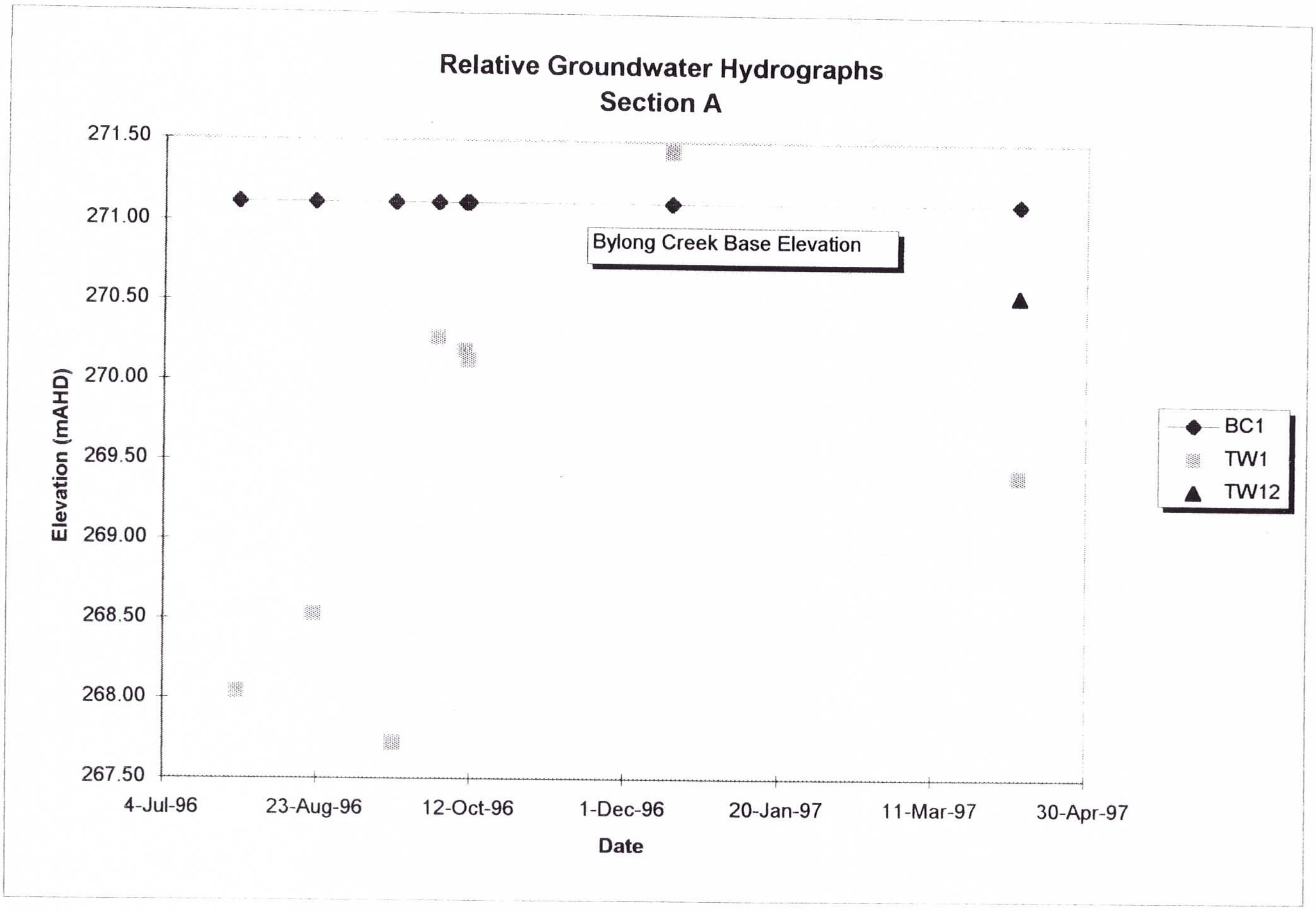


Figure 10. Relative Water Levels Section A

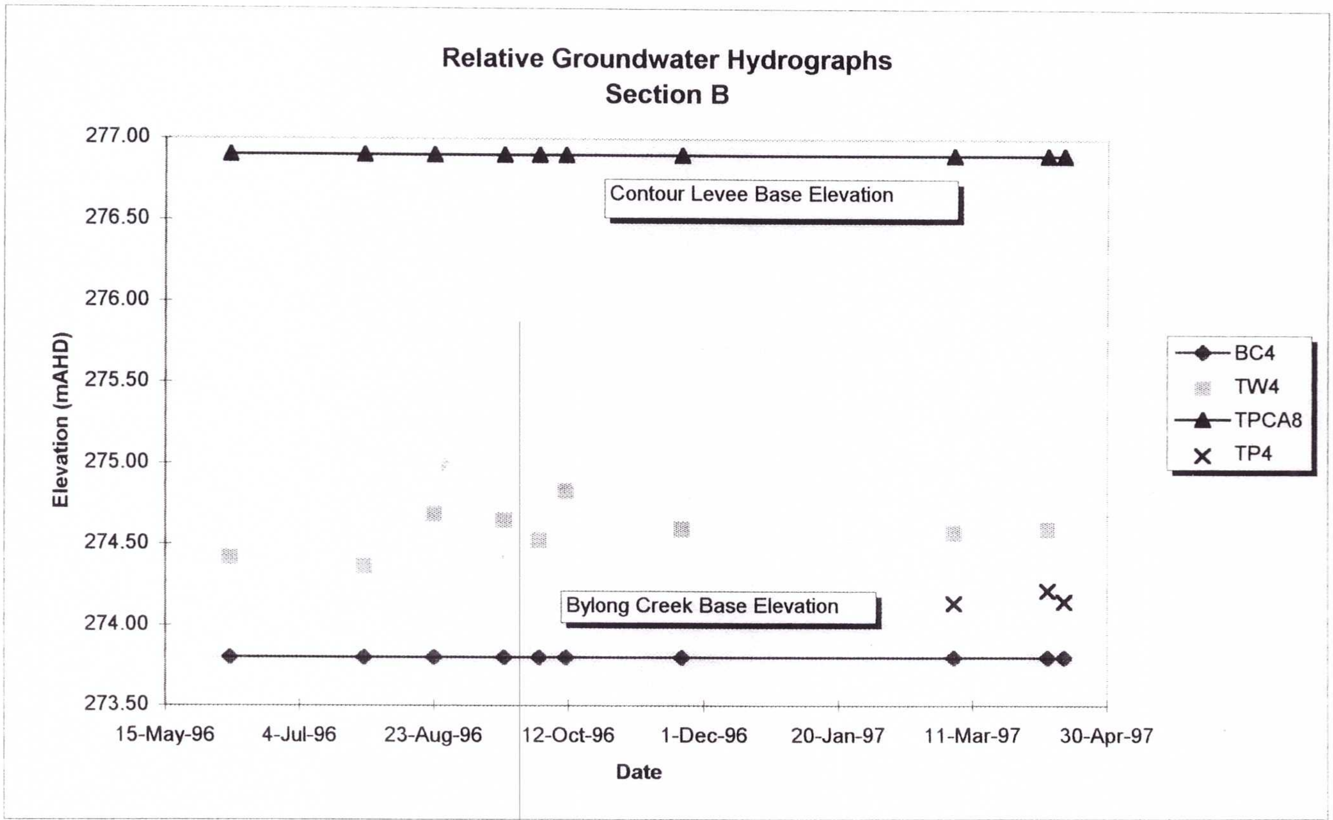


Figure 11. Relative Water Levels Section B

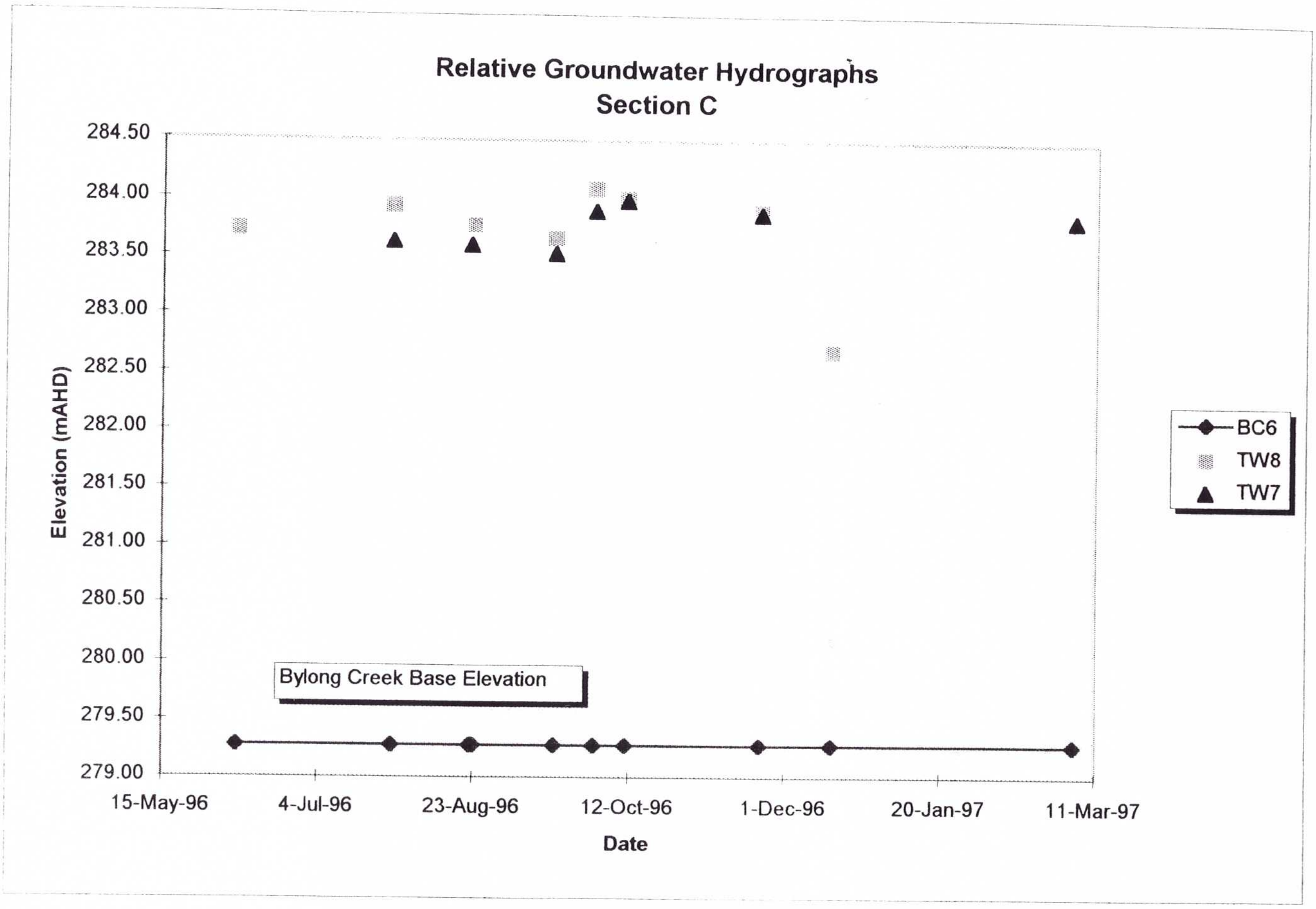


Figure 12. Relative Water Levels Section C

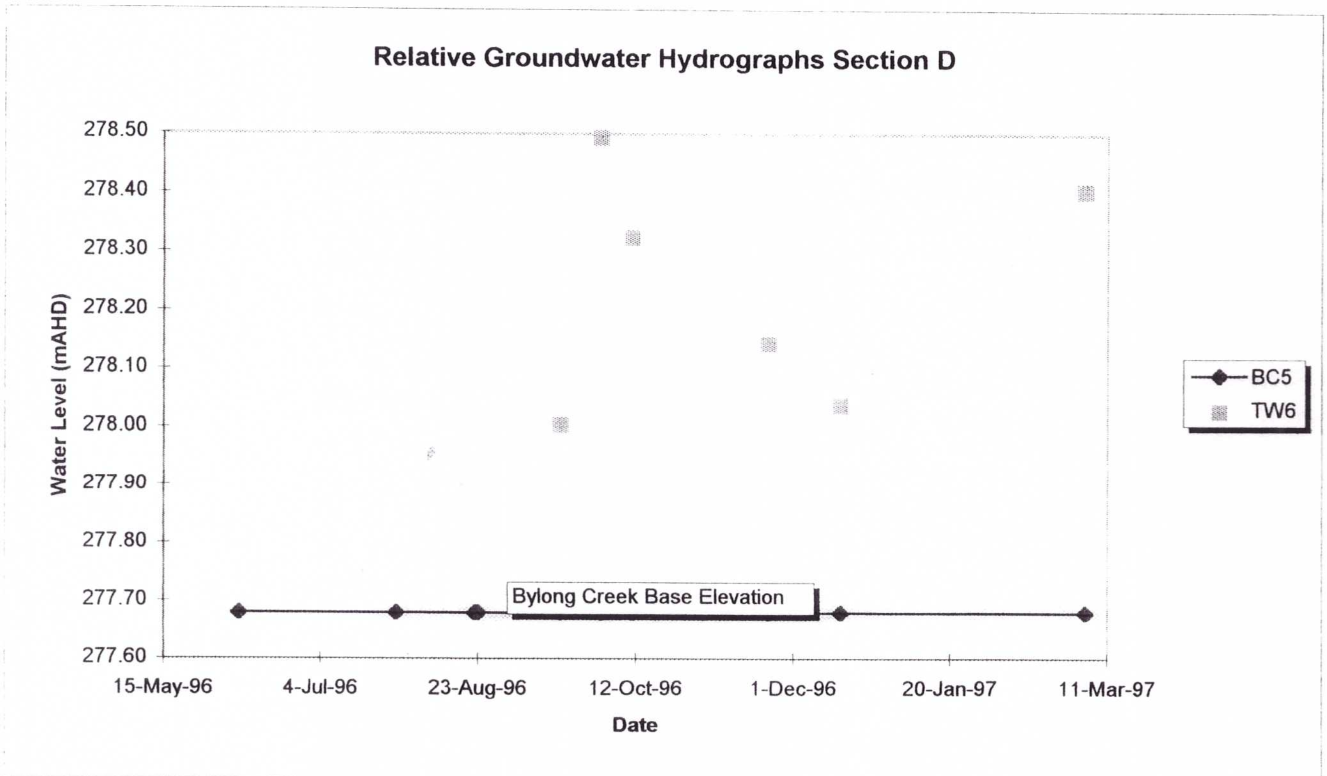


Figure 13. Relative Water Levels Section D

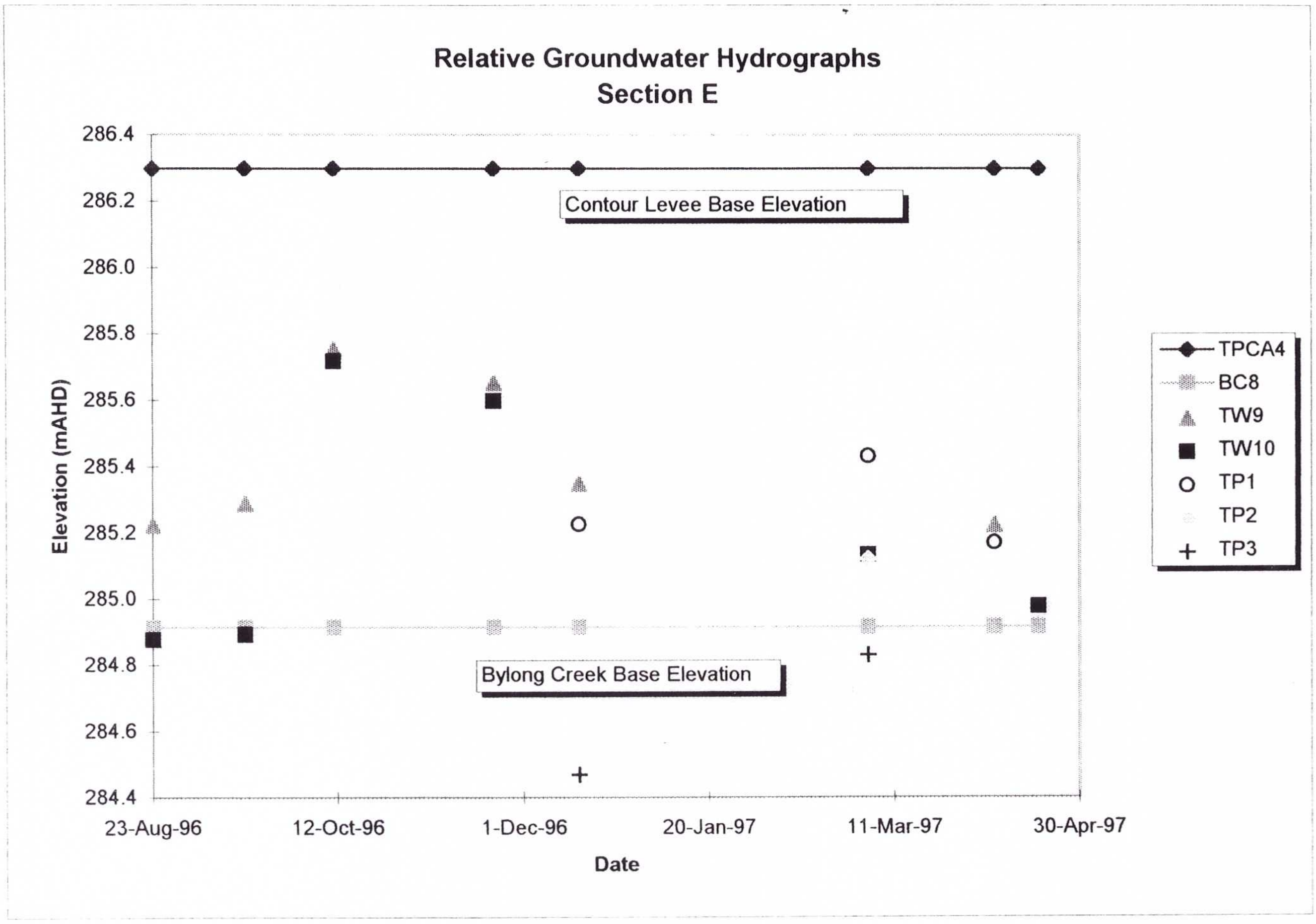


Figure 14. Relative Water Levels Section E

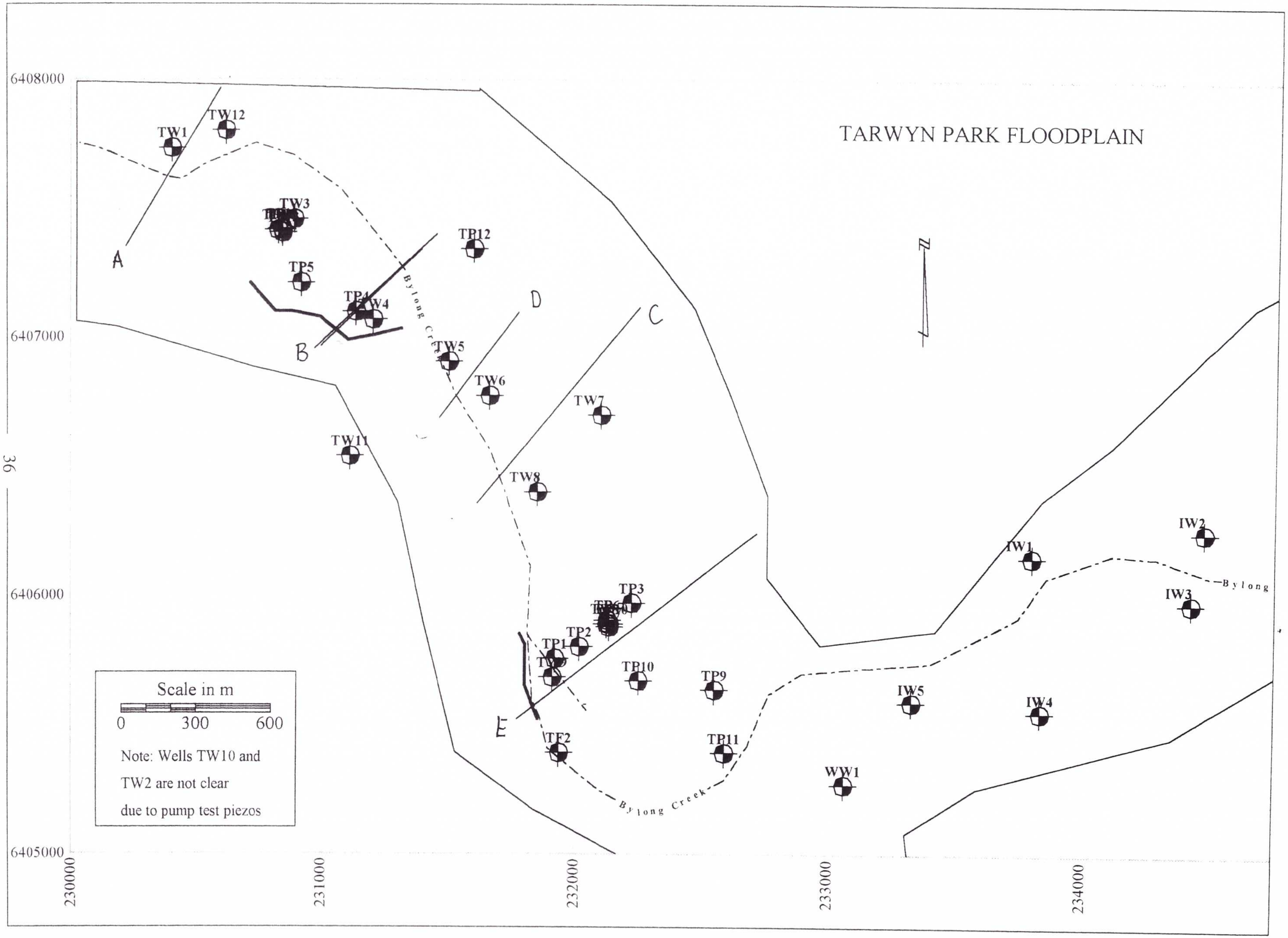


Figure 15. Plan for Hydrograph Sections

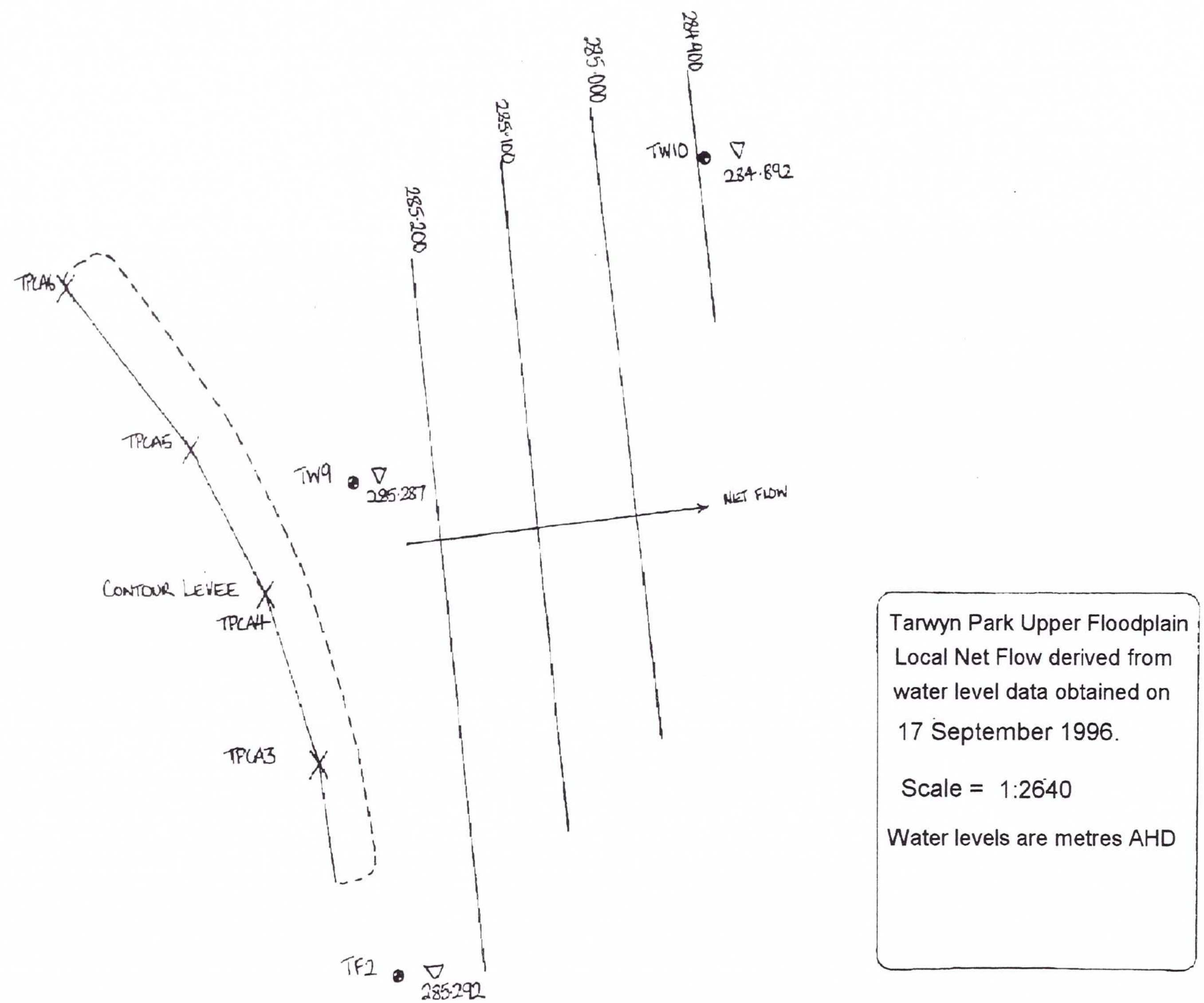


Figure 16. Local Flow for Upper Tarwyn Park Floodplain

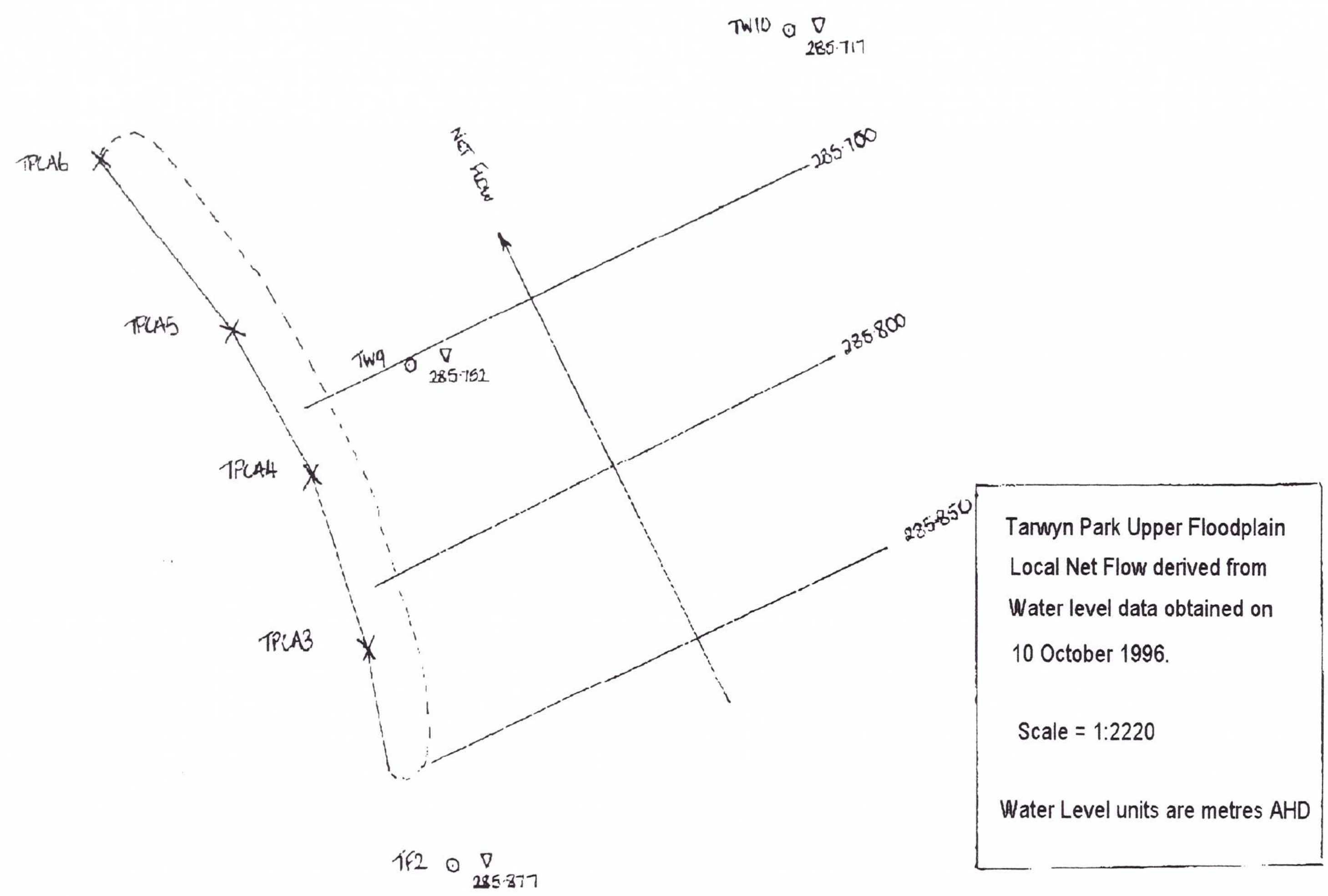


Figure 17. Local Flow for Upper Tarwyn Park Floodplain

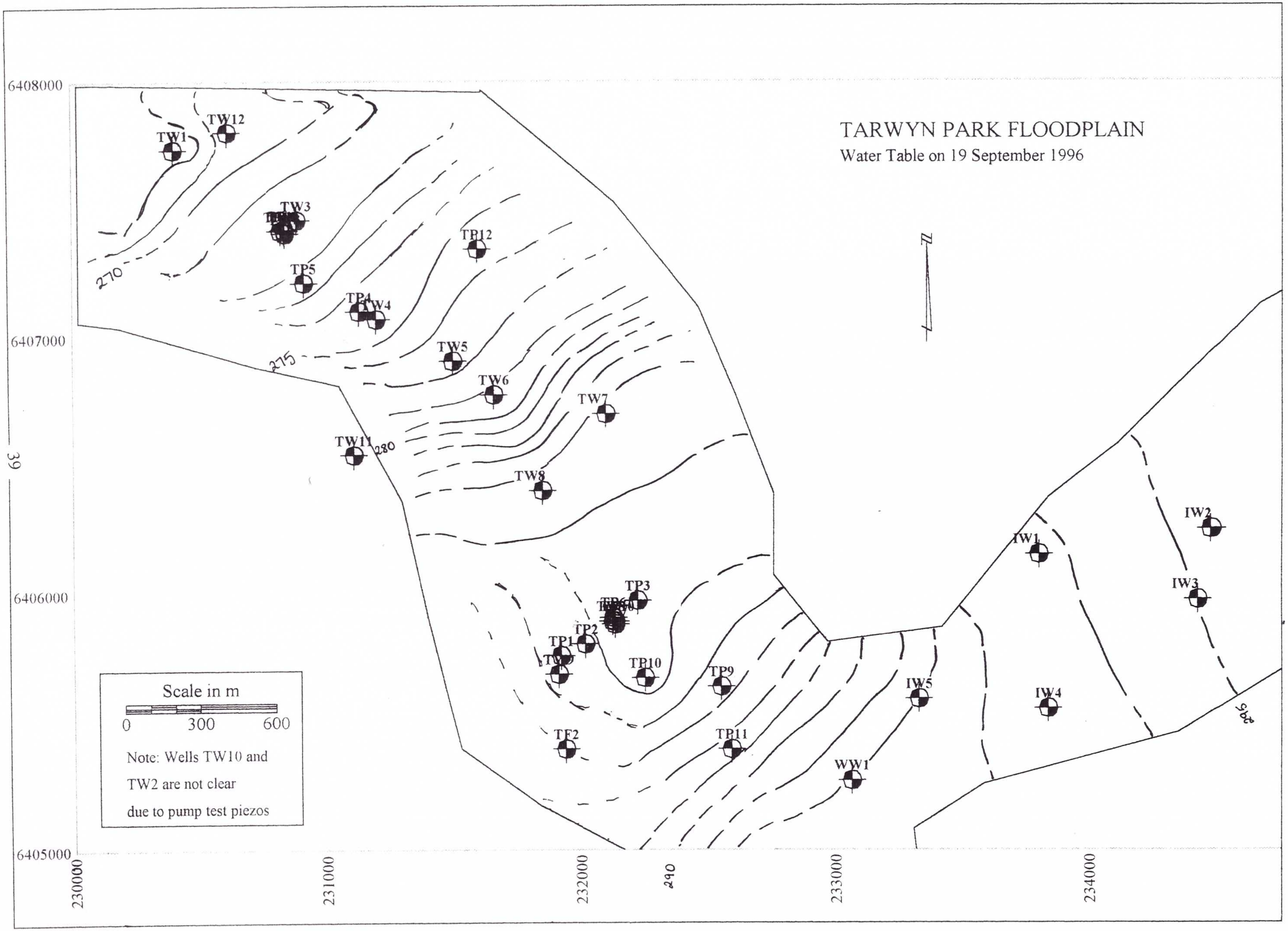


Figure 18. Tarwyn Park Water Table 19 September 1996

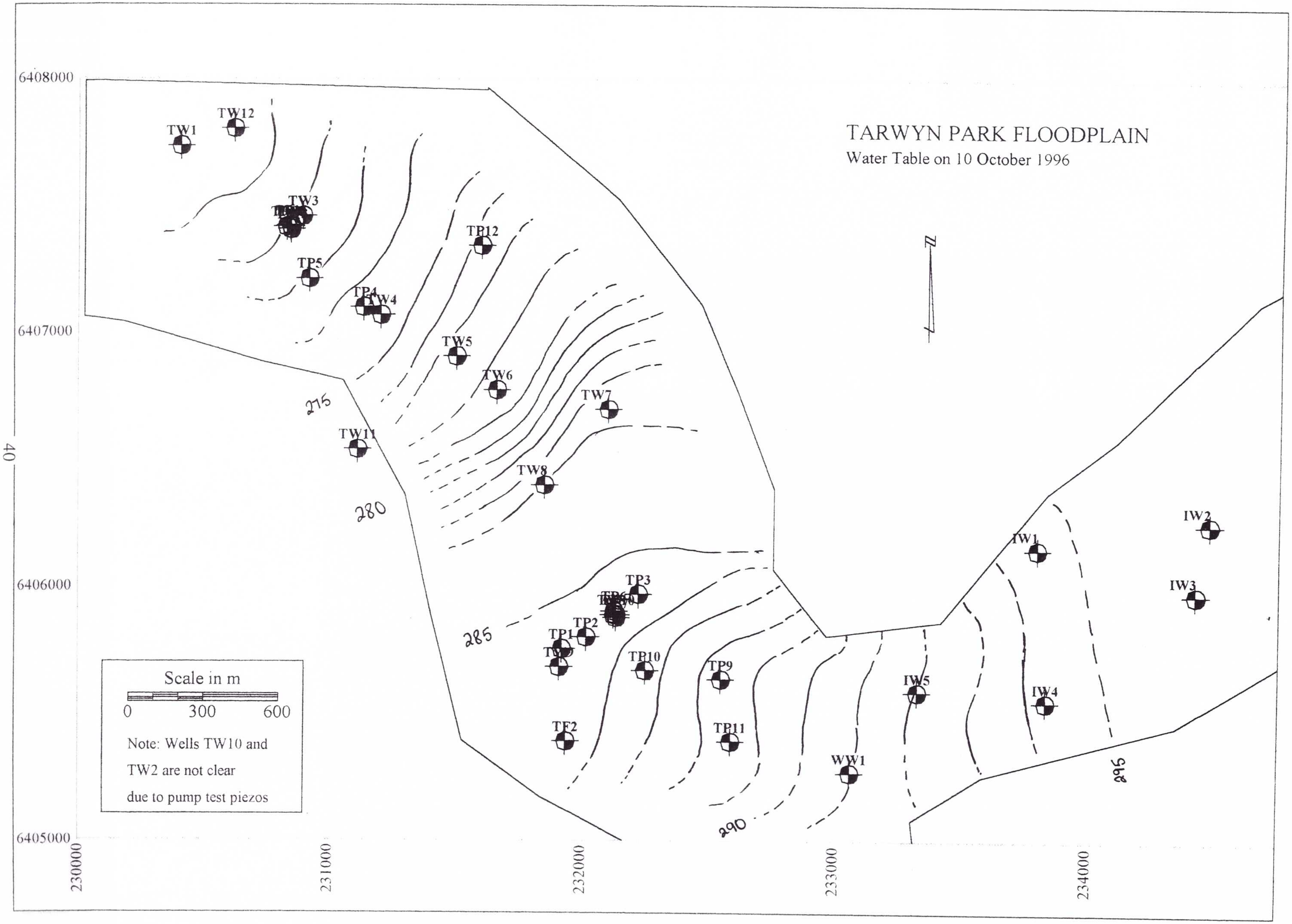


Figure 19. Tarwyn Park Water Table 10 October 1996

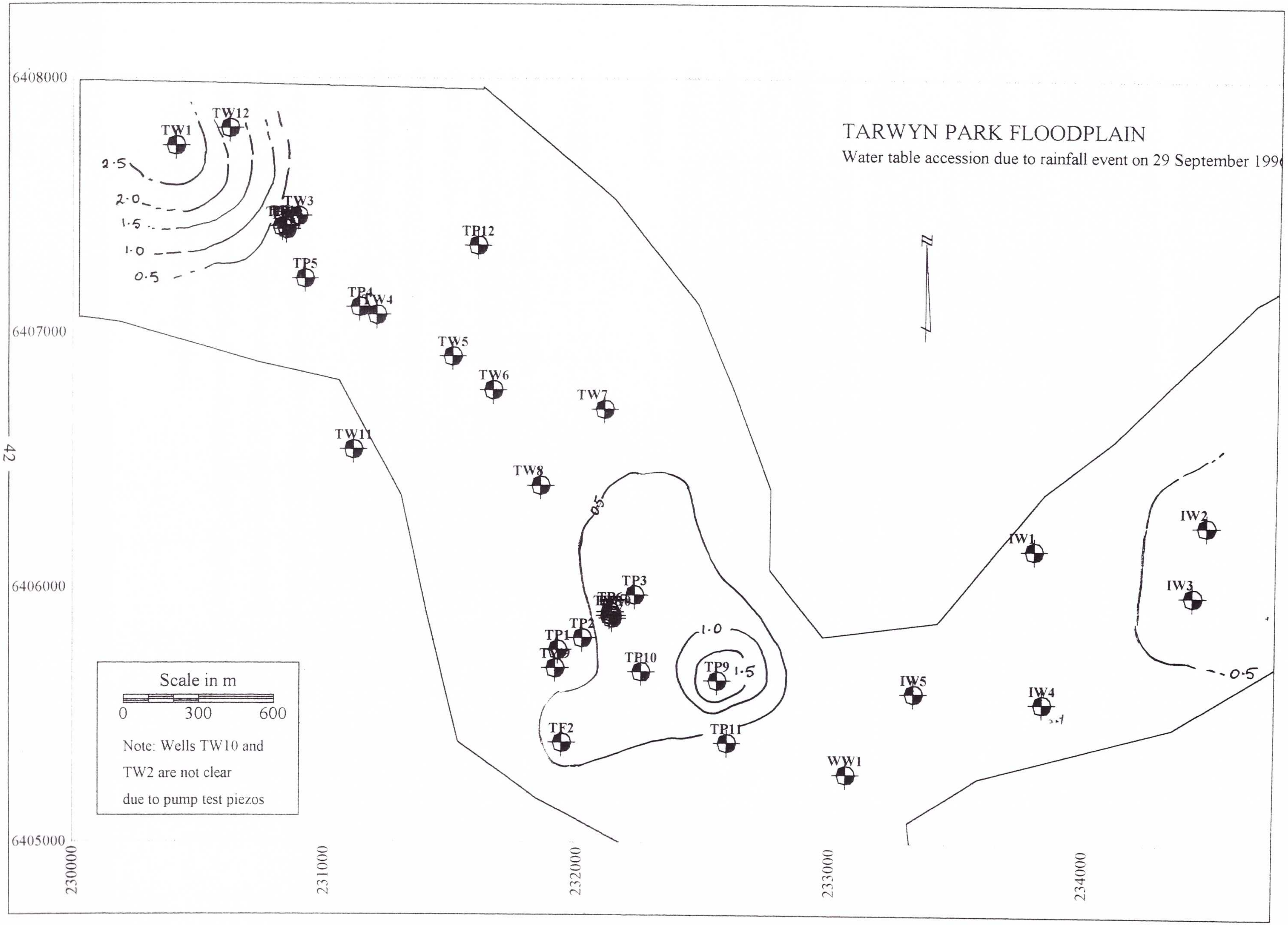


Figure 21. Groundwater Difference from 19 Sep to 10 Oct 1996

Resistivity data has been evaluated using RINVERT^{R}, a software package designed by Mr Noel Merrick at the NCGM. Initial multi-layer models of the floodplain stratigraphy have been generated and correlated into geoelectric sections (Appendix F) across the floodplain at Tarwyn Park. These sections show an approximately 2 metre thick, semi-continuous sandy layer at depths ranging from 0.5 to 1.5 metres. Weathered bedrock occurs as a relatively flat surface between 14 and 19 metres depth. A thick, low resistivity unit underlying the sandy layer is interpreted to be a saturated sandy/clay layer. Increases in groundwater salinity can be seen to occur along Line 1, reflected in the decreases in resistivity in correlated units. In Lines 4 and 5 the soundings show a dominantly low resistivity clay lithology, confirming the presence of a clay barrier in the lower Tarwyn Park floodplain. The output data from RINVERT^{R} is included in Appendix F.

7.5 Estimation of Hydraulic Parameters of the Floodplains

The data and analysis for two pump tests run on wells in the project area are shown in Appendix C. The determined aquifer parameters are averaged from the values computed for each observation piezometer and the large diameters wells. The upper Tarwyn Park floodplain (TW10) has a transmissivity (T) of 404 m^2 / day and a storativity S of 0.08, which approximates a hydraulic conductivity of 29 m/day over the average aquifer thickness of 14 meters.

The lower Tarwyn Park floodplain (Lister Well) has a transmissivity of 344 m^2/day and a hydraulic conductivity of 34 m/day over an aquifer thickness of 10 metres.

Sediment samples were taken from piezometers TP6, TP7 and TP8 to analyse the physical properties of the aquifer. The grainsize analysis of the three locations are included in Appendix C. Considering their relative proximity, the samples show marked differences in grainsize which emphasises the variable nature of the aquifer as a whole. This variability makes gaining a sufficiently representative sample through statistical analysis of a large number of random samples difficult and quite beyond the scope of this project. Instead, a broad generalisation may be used, considering the nature of the samples taken seems to indicate the range of variability of the aquifer. Discussion with the researcher and independent observations support this.

The grains are generally quartz-felspathic, sub-rounded to sub-angular, and sub-spherical to spherical in shape in the coarser fractions and platy alumina-silicates in the finer fraction.

Combining the average aquifer thickness of the upper and lower Tarwyn Park floodplains yields a mean thickness of 11.5 m. Average porosity values for the aquifer can be computed from the grainsize distribution data of samples from TP8, TP7 and TP6 using the program SOILPROP (output and graphs are also included in Appendix C). The saturated water content of the sample is estimated from knowledge of the bulk density and the moisture retention curve, yielding an average porosity of 0.37 (ignoring trapped gas). At an average aquifer width of 500 m, the average subsurface lateral flow velocities of groundwater are then estimated at 0.5 m/day.

The SOILPROP program also generates pressure and permeability relationships the unsaturated zone based on parametric models developed by Brooks and Corey (1964) and van Genuchten (1980). These models use the predictable variation of soil hydraulic properties with particle size distribution to estimate their parameters. Both sets of water curves show a pressure head extends to the surface elevation for the samples TP6, TP7 and TP8.

7.6 Discussion

Observations and testing of the aquifer has confirmed the initial supposition by Tammetta (NCGMQR1) that the main aquifer is surficial and composed of alluvial sands, gravels and clays thinly covering and bounded by sandstone and shale bedrock. The system is dominated by recharge from precipitation and upper aquifers with a minor component of artificial recharge from the contour levees. The average water level is approximately 1 metre but is highly variable spacially as well as temporally especially after precipitation where perched water tables occur in places where subsurface clay lenses may exist (TW8). The aquifer appears to vary from unconfined on the Iron Tank and upper Tarwyn Park floodplains to semi-confined on the lower paddocks. The unsaturated zone of the aquifer extends to surface elevation, with the irreducible moisture content of the soil above the water table not reached. The lithology of the floodplain aquifer is highly variable.

The position of reed beds on the Tarwyn Park floodplain near TW8 and IW5, and the corresponding high water table at these locations in both wet and dry periods shown in Figure 5(c) suggest that recharge takes place, probably due to a ponding of surface water behind weirs constructed at these locations. The reed beds may have the effect of stabilising these locations as continuous recharge zones of good quality water, preventing erosion and degradation.

The hydrogeological dynamics of the Tarwyn Park floodplain system as outlined in Section 3.1, 3.2 and this Section describe a sequence of recharge and discharge zones that appear to be consistent with NFS theory.

8.0 HYDROGEOCHEMISTRY

8.1 Water Quality

The sample locations and water quality parameters measured in the field are listed in Appendix B. Interpretation of all chemical analyses to date is provided below.
Water samples have been collected on the following dates:

a) 28, 29 December 1995 (Rice, 1996)

b) 21, 22, 23 August 1996

c) 22, 23, 24 September 1996

d) 10, 11 October 1996

e) 22, 23, 24 November 1996

f) 8, 9 May 1997

A total of 43 surface and groundwater samples have now been analysed and reported by the Water Environmental Laboratory at Arncliffe.

The samples were labelled according to the following format [Location/ Sample #./Sample #. at location]. Thus sample TW10/18/3 was the 18th sample taken from the beginning of the project and the 3rd sample taken from well TW10.

Generally, the analyses show minimal temporal and spatial variation in major ion content from the recharge area to the bottom of Tarwyn Park with the exception of wells TF2, TW9,TP12 and to a lesser extent TW4.

Possible major sources of phosphate and nitrate on the Tarwyn Park property are confined to runoff from artificial organic mulch, waste from the horses, natural vegetation and soil. This is reflected in the low nutrient values measured in the surface and groundwater. Analysis results of total nitrogen and total phosphorous from the project area are shown in Table 3. Generally, phosphorus (as orthophosphate) is the limiting nutrient in freshwater aquatic systems. That is, if all phosphorus is used, plant growth will cease, no matter how much nitrogen is available Although levels of 0.08 to 0.10 mg/l orthophosphate may trigger periodic blooms, long-term eutrophication will usually be prevented if total phosphorus levels and orthophosphate levels are below 0.5 mg/l and 0.05 mg/l, respectively (Dunne and Leopold, 1978). Relatively high nitrogen and phosphorous value can be seen in the water in well TW1, however a septic odour was noticed in the well, possibly a dead animal. The quality becomes good when sampled in November. Other relatively high phosphorous values were measured in wells TW10 and TW9. All wells are of large diameter and subject to surface contamination. With this in mind and referring to the Figures on pages D11 and D12 in Appendix D, no significant difference can be noted in the PO4 in the groundwater after rain.

Dec-95	TW1	TW2	TW8	TW10	TS3	TS4	IW1	IW3	IW4	
Ntot(mg/l)	1.4	0.75	0.4	3.6	0.95	2.2	9.9	3.7	0.4	
Ptot(mg/l)	0.11	0.035	0.045	0.335	0.105	0.38	1.26	0.06	0.025	
N:P	13	21	9	11	9	6	8	62	16	
Aug-96	TW1	TW4	TW7	TW8	TW10	TW9	TF2	TS1	TS2	TS3
PO4(mg/)	0.345	0.045	0.04	0.025	0.125	0.075	0.045	0.025	0.085	0.015
Ntot(mg/l)	9.2	0.65	0.35	0.3	0.8	3.4	2.3	1.3	2.7	0.25
Ptot(mg/l)	0.78	0.13	0.05	0.035	0.17	0.9	0.15	0.065	0.38	0.025
N:P	12	5	7	9	5	4	15	20	7	10
Sep-96	TF2	TW10	TW1	TW9	TW7	TW8	TW6	TW5	TW4	IW4
PO4(mg/)	0.065	0.075	0.46	0.19	0.04	0.025	0.05	0.02	0.06	0.02
Ntot(mg/l)	1.3	0.95	9.3	1.8	0.25	0.3	0.15	0.35	0.5	0.6
Ptot(mg/l)	0.105	0.08	0.615	0.42	0.055	0.035	0.05	0.08	0.08	0.045
N:P	12	12	15	4	5	9	3	4	6	13
Oct-96	TW10	TW9	TF2	IS6	TS8	TS9				
PO4(mg/)	0.25	0.435	0.03	0.015	0.075	0.02				
Ntot(mg/l)	2.4	3.4	2.3	0.2	1.1	1.3				
Ptot(mg/l)	0.29	0.96	0.4	0.03	0.105	0.06				
N:P	8	4	6	7	10	22				
Nov-96	TW1	TF2	TW9	TW10	IW3	IW2	TW4	TS10		
PO4(mg/)	0.05	0.015	0.065	0.175	0.02	0.01	0.06	0.04		
Ntot(mg/l)	1.1	1.2	4.2	1.5	0.75	0.45	0.75	1		
Ptot(mg/l)	0.08	0.14	1.02	0.27	0.065	0.08	0.15	0.08		
N:P	14	9	4	6	12	6	5	13		

Table 3 - Total Nitrogen (Ntot), Total Phosphorous (Ptot) and Orthophosphate (PO4)

All analyses showed a relatively high HCO3- content.

Sample analyses were grouped for graphical presentation to show areal and time-related chemical trends (Figure 6.). Group 1 is defined for the purposes of this study as the intake zone of the Tarwyn Park system located at the Iron Tank floodplain. It may be reasonably assumed that the groundwater and surface water have not been influenced by any modification of Mr. Andrews, such as the installation of contour levees or planned mulch deposition. Piper trilinear plots, Wilcox diagrams and Schoeller plots are provided with a brief discussion in Appendix D.

Group 2 is the area bounded by the constructed weir below the Iron Tank Floodplain and TW8 near the Tarwyn Park Floodplain. Group 3 extends from TW8 to the bridge near TW1. Groups 2 and 3 have been subdivided into Groups 2A, 2B and 3A, 3B due to disproportionately high hydrochemical influence from wells close to the edges of the floodplain.

A statistical analysis of the reported chemical data has not been attempted, however miscellaneous checks such as anion - cation balances, Total Dissolved Solids (TDS) checks and ion ratios are applied in the programs WATEVAL and HYDROWIN. Of the 43 sample analyses received all resulted in ion imbalances of less than 5% except TW10/9/2 (7.74%), TF2/8/2 (6.96%), TW4/16/2 (6.00%), TW4/27/1 (5.86%), TW1/1/1 (5.21%), IW3 (5.20%), IW3/25/1 (5.08%) and TF2/20/3 (5.00%).

Group 1 (IW1, IW2, IW3, IW4, IS6)

The pH values of the samples taken in the Group 1 area range from 6.9 to 7.8 over the period September 1996 to December 1996, with an average pH of 7.35 and a standard deviation of 0.39. The water is therefore in the alkaline half of the pH scale.

The Electrical Conductivity (EC) of the Group 1 samples varies between 157μS and 499μS with an average value of 304μS. This level of conductance falls within the medium-salinity water (C2) classification of irrigation water. (USDA Handbook No.60).

Group 2A (TW10, TW8, TW7)

The pH values of the samples taken in the Group 2A area range from 7.2 to 8.1 over the period August 1996 to December 1996, with an average value of 7.75 and a standard deviation of 0.27.

The Electrical Conductivity (EC) of the Group 2A samples varies between 395μS and 783μS with an average value of 634μS and a standard deviation of 115μS. This level of conductance falls within the medium-salinity water (C2) classification of irrigation water. (USDA Handbook No.60).

Group 2B (TF2, TW9)

The pH values of the samples taken in the Group 2B area range from 7.2 to 8.2 over the period August 1996 to December 1996, with an average value of 7.69 and a standard deviation of 0.34.

The Electrical Conductivity (EC) of the Group 2B samples varies between 627μS and 3610μS with an average value of 1539μS and a standard deviation of 1030μS. This level of conductance falls within the high-salinity water (C3) classification of irrigation water. (USDA Handbook No.60).

Group 3A (TW6, TW5, TW3, TW2, TW1)

The pH values of the samples taken in the Group 3A area range from 7.6 to 8.0 over the period August 1996 to December 1996, with an average value of 7.81 and a standard deviation of 0.14.

The Electrical Conductivity (EC) of the Group 3A samples varies between 482μS and 987μS with an average value of 775μS and a standard deviation of 179μS. This level of conductance falls within the high-salinity water (C3) classification of irrigation water. (USDA Handbook No.60).

Group 3B (TW4)

The pH values of the samples taken in the Group 3B area range from 7.8 to 7.9 over the period August 1996 to December 1996, with an average value of 7.87 and a standard deviation of 0.05.

The Electrical Conductivity (EC) of the Group 3B samples varies between 1640μS and 1770μS with an average value of 1697μS and a standard deviation of 54μS. This level of conductance falls within the high-salinity water (C3) classification of irrigation water. (USDA Handbook No.60).

The surface and sub-surface water quality is of acceptable standard for irrigation uses, provided sufficient drainage and salinity management is undertaken (USDA Handbook No.60).

The poor water quality measured in groups 2B and 3B does not result in land salinisation on the productive floodplain due to the dominantly good quality water maintained within the surficial aquifer. Changes in the water quality are undoubtedly most affected by the frequency of natural recharge, shown in the decrease in the major chemical species of all groups after a rain event that increases the groundwater level.

8.2 XRD/XRF Analyses of Clay Samples

Clay samples (TPC1 to TPC6) were taken from 6 locations on the Tarwyn Park property (Figure 22) and submitted to the Microstructural Analysis Unit in the Department of Materials Science, University of Technology for analysis by X-ray Diffraction and X-ray Fluorescence to determine the chemical composition of both the alluvial and insitu clays on the Tarwyn Park property.

The results of the analyses are included in Appendix E. They show the main mineralogy of the clays over the Tarwyn Park region to consist of quartz, illite and kaolinite. Sample TPC2 is from the slope below the Large Southern Dam as shown on Figure 11 and shows montmorillonite in addition to the other minerals. The presence of montmorillonite supports the occurrence of ionic exchange between the groundwater and the clays on this slope as inferred from the extended Durov diagram (NCGMQR3; Page 21, Figure 4). Ion exchange, resulting in the increase of Na^+ and reduction of Mg^{2+} and Ca^{2+} in solution, contribute at least in part to the poor quality water in this area. Sample TPC4 was taken from the dark grey/brown alluvial clays on the floodplain near the northeastern edge of the Tarwyn Park floodplain. The clay in this area is characterised by the presence of hydrated minerals such as gypsum and

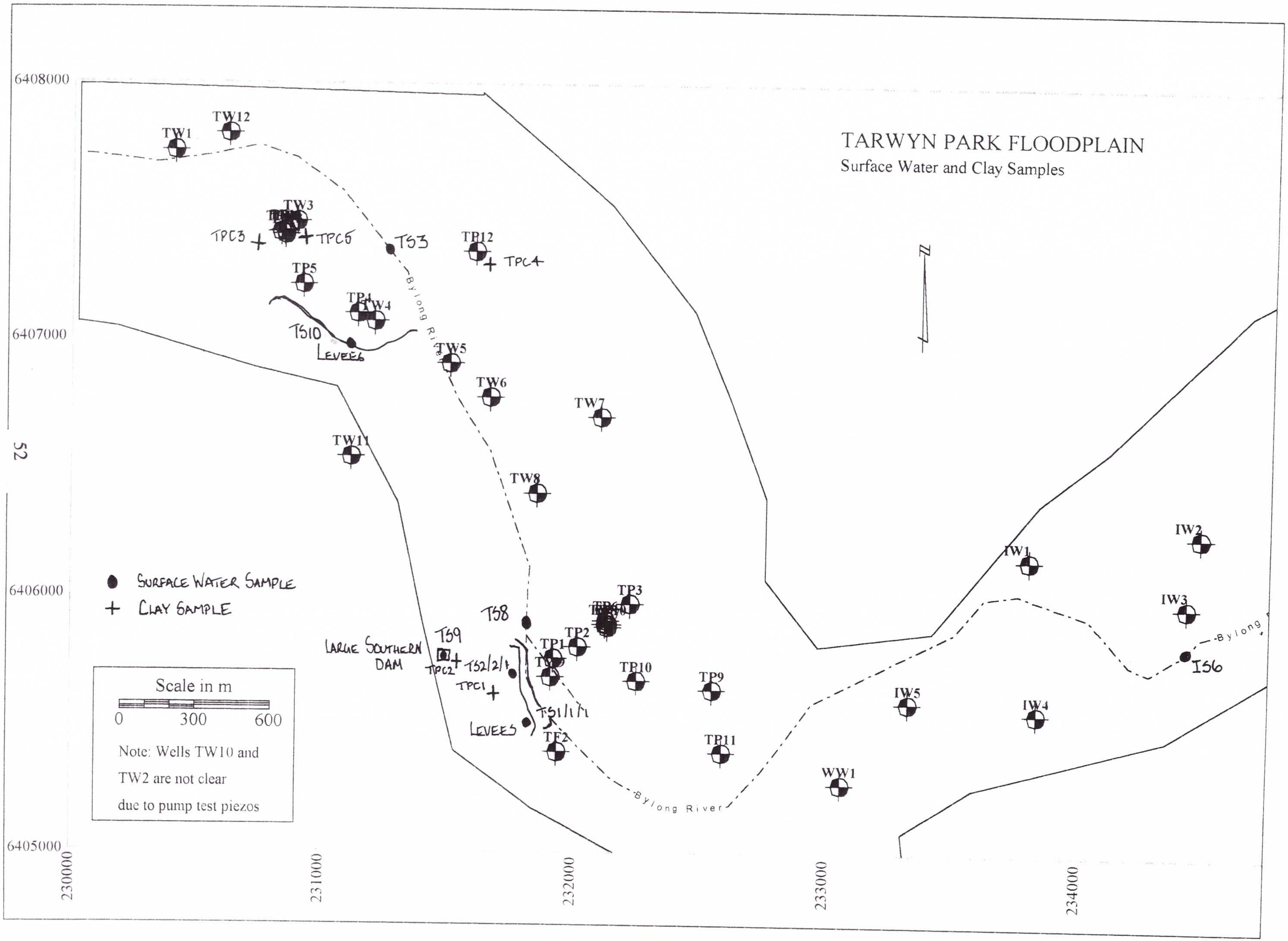


Figure 22. Surface water and clay sample locations

halite as well as quartz, illite and kaolinite. The water quality in this area is also poor, with seepage of saline water from the higher slopes common. The XRD/XRF analyses do not measure biological matter but the dark grey alluvial clay from the floodplain was observed to contain considerably more vegetal material than the clay upon the slopes. Phosphorus levels in the dark grey clays (measured as P_2O_5) are more than twice that of the hill slop clay.

The XRF shows the expected high percentage of aluminium silicates in the clay samples. There is a weak correlation between the relative Na and Cl percentages of the alluvial clay compositions (measured as oxides) and the high salinity measured in the groundwater, specifically in TPC4. At this site, saline water (measured at >2000 mg/L TDS) was observed seeping onto the floodplain, and the XRD indicated the presence of evaporites halite and gypsum in the clay.

8.3 Discussion

The hydrogeochemistry presented and discussed in NCGMQR3 and above has been summarised below.

Generally the groundwater quality entering and leaving the Tarwyn Park floodplain system is good with high throughflux and minimal chemical interaction ensuring consistent water quality. Close to the edges of the floodplain however, zones of high salinity characterised by 1000 - 3000 mg/L TDS and pH values (7.5-8.3) indicate surface and groundwater flow from the surrounding slopes is of poor quality. The slopes are dominated by a shallow insitu yellow/red silty clay profile overlying weathered shales and sand at a depth of less than 2 metres in places. XRD/XRF analysis of this clay indicates dominantly quartz with kaolinite, illite and montmorillonite, with relative higher sodium and potassium compounds. This supports the supposition that ionic exchange with the clay discussed in NCGMQR3 may at least in part, contribute to the high salinity measured in these areas. Tammetta in NCGMQR1 maintained that the quality of the water in bedrock was quite poor and spring runoff from shallow bedrock near the edge of the floodplain will also contribute to the quality of the water. The relatively young nature of the groundwater has been emphasised by Tammetta in NCGMQR1 and is also supported here by the similarity of the chemical constituents of groundwater and surface water away from the zones of high salinity.

The higher level of mineralised phosphorous measured in the clay on the floodplain by XRF (refer Section 8.2 and Appendix E) and field observations appears to indicate a greater relative organic matter than the clay on the slopes. This may highlight the importance of the clays in the operation of the NFS although the water quality does not appear to be related to the situation of the alluvial clays as first supposed (NCGMQR1), but to soil quality and shallow bedrock on the slopes surrounding the floodplain.

The distribution of total dissolved solids (TDS), sodium and bicarbonate have been plotted before and after a rain event of 71mm on the 29 September 1996 in which local flooding was seen to occur. Generally, the event results in lower values for all species plotted, with the exception of TW4 which showed a small rise in the TDS of the groundwater in that area. The plots are also included in Appendix D.

The relative dilution of the chemical constituents with rainfall emphasises the operation of the Tarwyn Park floodplains as a recharge system. Discussion in Section 7.3 in reference to Figures 16 and 17 also show the change in flow direction with the influx of good quality rainwater from recharge zones on the floodplain.

Plots of saturation indices with respect to calcite spatially and temporally are provided in Appendix D. Group 1 samples are undersaturated with respect to calcite, with the amount of calcite in the groundwater increasing down flow from this group. Groups 2 and 3 are both dominantly oversaturated and supersaturated with respect to calcite, indicating that calcite is precipitating at these locations and times. Calcite precipitation may result from adding HCO_3^- through either sulfate reduction or recharge events that result in the dissolution of CO_2 from the upper soil zone brought about by biological activity (NCGMQR3). The saturation indices plotted against sample temperature allows the seasonal variation in calcite precipitation to be better analysed.

Log activity plots of the samples with respect to calcite over time and space are supplied in Appendix D with a table showing sample groups and dates. These show the effect that a rainfall event such as on the 29 September has on the precipitation of calcite in the different sections of the aquifer. In the case of Group 2B samples, a long dry period results in a slight increase in the activity of CO_3^{2-} and a relatively large decrease in the activity of Ca^{2+} as calcite is precipitated from the time of sample TF2/7/2 to TF2/8/2. Rainfall reverses this process to TF2/17/3 and TF2/22/4.

The impact that the contour levees have on the water quality is not clear. Certainly the better water in TW9, immediately beneath the levees on the upper floodplain relative to TF2 further to the southeast (see Figure 5), indicates some beneficial effects are imparted (Figure 23). The lowermost levee in this area forms the main flow of the Bylong River.

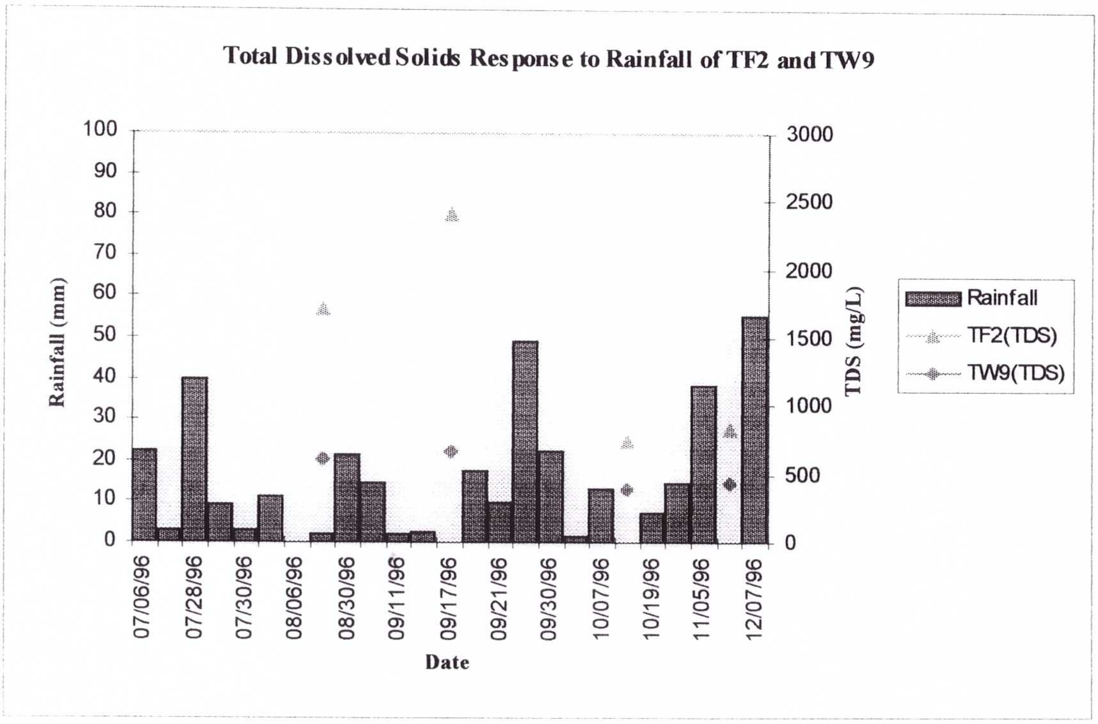


Figure 23 - TDS of wells TW9 and TF2 over time

However the lack of completion data or lithological logs on both bores prevents more analysis than the empirical observation. Piezometers TP4 and TP5 were installed near the contour levee at Renfrew Park to help determine this but their location is too far removed from the levee to provide conclusive data as to what effects exist (refer Figure 5(b). Efforts to auger piezometers closer to the levees were frustrated by shallow bedrock (1.5 - 2 m).

9.0 WATER BALANCE

A generalised water balance for the subsurface water in the Tarwyn Park region can be calculated to determine the average change in storage over the period of analysis. In a steady state system with the aquifer in equilibrium the change in storage would be zero. Petts et al (1996) state that in most cases in rural areas surface runoff is a minor component of the water balance and that most flooding occurs as a result of excess saturation of the aquifer. This appears to be the case here, with the majority of water eventually infiltrating through to the water table. In fact, assuming a resaturation factor of approximately 0.1 (taking into account air pressure, and soil retention parameters) and using the average groundwater accession from this rain event (0.45m), which was the average water level rise recorded in the wells between 19 September 1996 and 10 October 1996 due to the rain event excluding anomalous TW1 accession. The amount of rainfall taken into storage would be 62% of the 71mm precipitated in the rain event. This provides an extremely rough indication of gross infiltration of the floodplain.

Using the average groundwater accession for the Tarwyn Park floodplain (0.45m) due to the 71mm rainfall event that took place on the 29, 30 September, and assuming a surficial aquifer area bounded by the lower slopes of the surrounding hills we can determine the change in storage due to the rain event. The area of the upper and lower floodplains was estimated by overlaying a unit grid over the Bylong 1:25,000 topographic map. Values were calculated at 1,562,500 m^2 for the upper floodplain and 812,500 for the lower. The water taken into storage because of the rain event is then calculated at approximately 56ML (megalitres) for the upper Tarwyn Park floodplain (see Figure 1b). The same method used for the lower Tarwyn Park floodplain (or Renfrew Park floodplain) results in a value of approximately 17.5 ML taken into storage.

Approximations of the total floodplain storage again using the estimated area of the surficial aquifer and the storativity estimates obtained from the pump tests can be computed. Other simplifying assumptions are to average the spatial variations in aquifer properties into relatively homogenous divisions. The volume of water stored in the upper floodplain in a relatively dry period (17,18 September) is estimated at 1775 ML and in the lower aquifer a substantially less 83 ML.

Computing the average hydraulic gradient of the water discharged from the lower Tarwyn Park floodplain at 0.0066, computed from water level data between TW2 and TW1 over the period of the study, and using the transmissivity T of 344 m^2/day for the lower aquifer and defining the northern outflow boundary at about 500 metres wide, then the discharge is 1135 m^3/day or 414 ML/year. At the same time, the influx into the upper floodplain can be computed at 606 m^3/day or 221ML/year, assuming an inflow boundary at the weir on the southeastern edge of the paddock at a width of 500 metres, using the T value of 404 m^2/day and an average hydraulic gradient estimated at 0.003.

It has been observed that during a relatively dry period that baseflow in the lower part of the Bylong River is zero or at most negligible. However for a gross budget calculated over a year, baseflow and surface runoff are grouped together for simplicity and to account for the flood events.

Estimates of evapotranspiration yield average yearly values of 1095 ML (refer Appendix A.). Figure 24 shows the gross water balance for the upper and lower Tarwyn Park floodplain aquifers. The value of the components are averages given in ML/year. It should be stressed that in the calculation of this budget, it was necessary to estimate and assume parameters for which obtaining data has not been viable. The budget is therefore a broad generalisation on a yearly basis. It is adequate to demonstrate the minor component that surface runoff (computed by difference in the known components) contributes to the overall budget compared to the volume in storage.

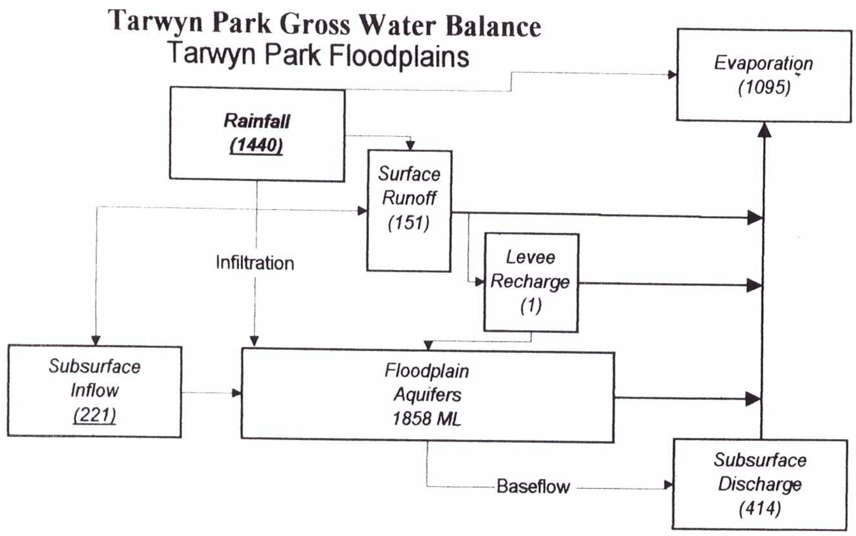


Figure 24.Gross Water Balance (values in ML/Yr)

10.0 INTEGRATION OF RESULTS WITH NATURAL FARMING SEQUENCE CONCEPT

The hydrogeology of the Tarwyn Park region is such that it mostly acts as a recharge system and is constantly flushed by good quality water from the upstream catchment and precipitation. Surface water quality is generally good even in the contour levees, which appear not only to work as catches for surface runoff from the higher slopes, but also as contoured irrigation canals from Bylong Creek. The engineering and construction of these canals is important, to prevent over siltation or erosion. The design and construction of irrigation canals has been studied by Ahmed (1992) and also Malaterre (1995) and the gradient of the canals at Tarwyn Park appear consistent with these studies.

The water level in the canals above the water table in the floodplain and the orientation of equipotential lines in Figures 16 and 17 suggests some groundwater flow occurs laterally into the floodplain as a result of their installation. However initial and approximate water balances indicate artificial recharge from the canals does not affect the floodplain significantly. A detailed study of the canals is required to determine their impact more accurately.

The position of the canals constructed to intercept surface, subsurface runoff from the slopes surrounding the floodplain and the floodplain itself generates a hydraulic load which forces the poorer quality water away from the surface at those points that may otherwise be prone to salinity problems from groundwater discharge from the slope. An example of this is the difference in water quality between wells TF2 and TW9, where TF2 is located in the poorly defined bed of the Bylong River, has no canal between it and the slope (Figure 6.) and has much higher TDS and salinity than TW9 (refer Figure 23.). The water quality changes in TF2 due to a rain event are over one order of magnitude when fresh water is flowing in Bylong River. The quality of the water in the canals is moderate as shown in the diagrams in Appendix D.

Maps of Na+ distribution in this area before and after rainfall (Appendix D) appear to indicate little movement of saline water downstream of the canal and as far as we cam determine, the instalment of the canals has reduced the movement of saline water.

Nutrient movement is limited and overall does not reach levels to promote long - term eutrophication problems in the Bylong Creek or in the canals.

The geometry of the aquifer and the distribution of water quality in the Tarwyn Park region is consistent with the conceptual model of Natural Farming Sequence as described by the researcher.

11.0 REFERENCES

Ahmed, S.H. 1992.,Alluvial Canals Adequacy, *Journal of Irrigation and Drainage Engineering* (ASCE) JIDEDH, Vol. 118, No. 4, p 543-554, July/August 1992. 4 fig, 2 tab, 6 ref.

Anderson, P.W., and Milne-Home, W.A., **1996** *Quarterly Report 'Hydrological Evaluation of the Natural Farming Sequence applied in the Bylong Valley associated with Tarwyn Park and Homeleigh Properties Stages 2 and 3'*. National Centre for Groundwater Management, University of Technology, Sydney.(NCGMQR2)

Anderson, P.W., and Milne-Home, W.A., **1997** *Quarterly Report 'Hydrological Evaluation of the Natural Farming Sequence applied in the Bylong Valley associated with Tarwyn Park and Homeleigh Properties Stages 4 and 5.'*. National Centre for Groundwater Management, University of Technology, Sydney (NCGMQR3)

Andrews, P., 1996. Personal Communication

Australian Agricultural Research Pty Limited *'Natural Farming Sequence Commercialisation Plan, November 1994'*.(AAR)

BT Corporate Finance Report '*Advance Eligibility Ruling Application Proposed R&D Project - "Natural Farming Sequence*"(Reference 17885/18/01), 4 May 1994'.

Clark, 1977. Cooper, H.H. Jr & Jacob, C.E., 1946. *A generalised graphical method for evaluating formation constants and summarising well-field history*. Trans Amer. Geophys. Union Vol.27(4).

Dunne, T., and L.B. Leopold. 1978. *Water in Environmental Planning*. W.H. Freeman and Company, NY.

Hounslow, A., 1996. *Water Quality Data: Analysis and Interpretation*. Prentice Hall Publ.

Longworth and McKenzie Pty. Ltd.,1980. Sandy-Hollow-Ulan Railway Proposal, Environmental Impact Statement.

Malaterre P.O. 1995. "Regulation of irrigation canals: characterisation and classification". *International Journal of Irrigation and Drainage Systems*, Vol. 9, n°4, November 1995, p. 297-327.

Mishra, S., Parker, J.C., and Singal, N., 1989. *Estimation of soil hydraulic properties and their uncertainties from particle size distribution data.* Journal of Hydrology No.108, p. 1-18.

Natural Farming Sequence Joint Venture., 1995. *Quarterly Report 1 (Period 1 July 1995 to 30 September 1995)* October 1995.(NFSJVQR1)

Papadopolous, I.S., & Cooper, H.H. Jr, 1967. *Drawdown in a well of large diameter.* Water Resources research, Vol. 3.

Petts, G.E., and Amoros, C. (Eds.) 1996, *Fluvial Hydrosystems.* Chapman and Hall publishers, London.

Piper A.M. 1953. *A graphic procedure in the geochemical interpretation of water analyses.* U.S. Geological Survey, Water Res. Div. Groundwater Notes, Geochemistry, No.12, 14pp.

Rice, R.L., 1996 *Report on Hydrogeological Investigation of Tarwyn Farm - Natural Farming Sequence: 24-30 December 1995.* Geo-Ocean Horizons Pty Ltd.

Tammetta, P., 1996. *Quarterly Report 'Hydrological Evaluation of the Natural Farming Sequence applied in the Bylong Valley associated with Tarwyn Park and Homeleigh Properties Phase 1: Data Acquisition and Preliminary Evaluation'* National Centre for Groundwater Management, University of Technology, Sydney, June 1996. (NCGMQR1)

United States Department of Agriculture *Handbook No. 60*

Appendix A - Climate Data

META-DATA FILE FOR EVE2173.TXT

Daily values of Evaporation to 9am

The units are mm

The data is for the following station:

Station name : SCONE (SCONE SCS)

Station number : 61089

Latitude : 32°03'48"S

Longitude : 150°55'36"E

Elevation : 216 metres

Opened on : 1/1/50

Still open

Fields within each record are delimited by commas.

Months run down the page and days run across.

Prepared by Climate and Consultancy Section in the New South Wales Regional Office of the Bureau of Meteorology on 4 June 1997

Contact us b by fax on (02) 9296 1567 or by email on reqnsw@bom.gov.au

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Year	Month	Ave	Total	Et	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1996	Jul-96	1.8	30.4	13.7	2.6	1.6	1.2	1.0	1.4		1.8	2.8	0.4	1.6	1.0	1.8	1.0	2.4	3.0	2.8	2.4	1.6	1.2	3.4	5.0	3.2	2.8	1.8	2.0	2.2	1.6	0.0	0.8	2.2	0.8
1996	Aug-96	3.6	61.4	27.6	2.0	3.0	4.0		10.0	2.8	2.0	4.4	3.8	2.6	2.0	2.4	2.8	3.8	5.2	4.4	3.0	3.2	1.0	1.0	2.6	2.6	1.6	3.8	3.0	2.6	3.4	2.0	3.2	2.8	2.0
1996	Sep-96	4.8	86.6	39.0	0.0	3.0	3.6	4.0	4.0	5.2	5.2	6.2	5.0	3.4	5.2	4.8	5.2	7.0	5.6	3.8	8.0	7.4	4.4	6.8	2.6	3.0	3.0	4.6	7.0	2.2	4.0	4.4	0.6	5.0	
1996	Oct-96	4.4	78.6	41.3	4.4	5.2	4.0	2.8	3.0	4.4	4.2	3.0	3.8	4.6	4.8	7.0	5.0	4.4	4.0	5.0	5.4	3.6	3.0	5.2	2.6	4.6	6.2	5.0	4.6	5.6		7.2	6.6	6.8	7.8
1996	Nov-96	7.8	117.0	70.2	5.0	5.2	7.0	5.4	3.4	0.8	4.6	1.6		10.8	9.8	8.6	9.0	13.4	13.0			19.4	5.6	6.2	6.4	6.8	4.4	4.2	1.0	5.8	10.0	9.6	9.4		
1996	Dec-96	8.7	138.6	83.2	25.2	8.8	5.0	8.6	7.6	6.8	8.8	4.4	2.8	7.6	7.2	5.4	9.2			21.6	8.4	1.2	1.0	9.8	7.0		15.6	4.8						47.4	2.2
1997	Jan-97	8.2	131.4	78.8	8.6	8.0	7.0	7.4	7.0	6.0	8.4	8.4	7.6	7.0			19.4	8.0	7.2	7.6	6.6	7.2	6.8	7.6	8.6	7.8	9.2	9.0			14.4	4.4	1.8	1.0	0.6
1997	Feb-97	4.5	80.6	48.4	5.2	3.4	4.8	5.4	6.6	5.4	6.4	4.0	5.6	9.2	6.0	1.0	0.4	0.4	4.0	4.0	4.8	4.0	5.2	7.6	5.0			19.0	6.2	3.0	5.2	5.2			
1997	Mar-97	5.4	80.6	48.4			14.8	5.8	5.6	1.4	1.6	2.2		7.4	5.8	4.8	4.8	6.0	7.4	5.0	4.0	4.0	4.4	6.6	7.8	4.0	6.4	6.4	4.6	4.0	4.0	4.0	5.0		9.4
1997	Apr-97	4.5	80.4	48.2	4.0	3.4	6.2	5.2	7.0	5.6	5.4	5.4	3.6	4.0	3.6	3.8	3.0	3.4	4.0	4.0	4.2	4.6	5.6	4.0	3.0	3.8	4.0	4.0		5.8	2.6	2.8	3.0	4.4	

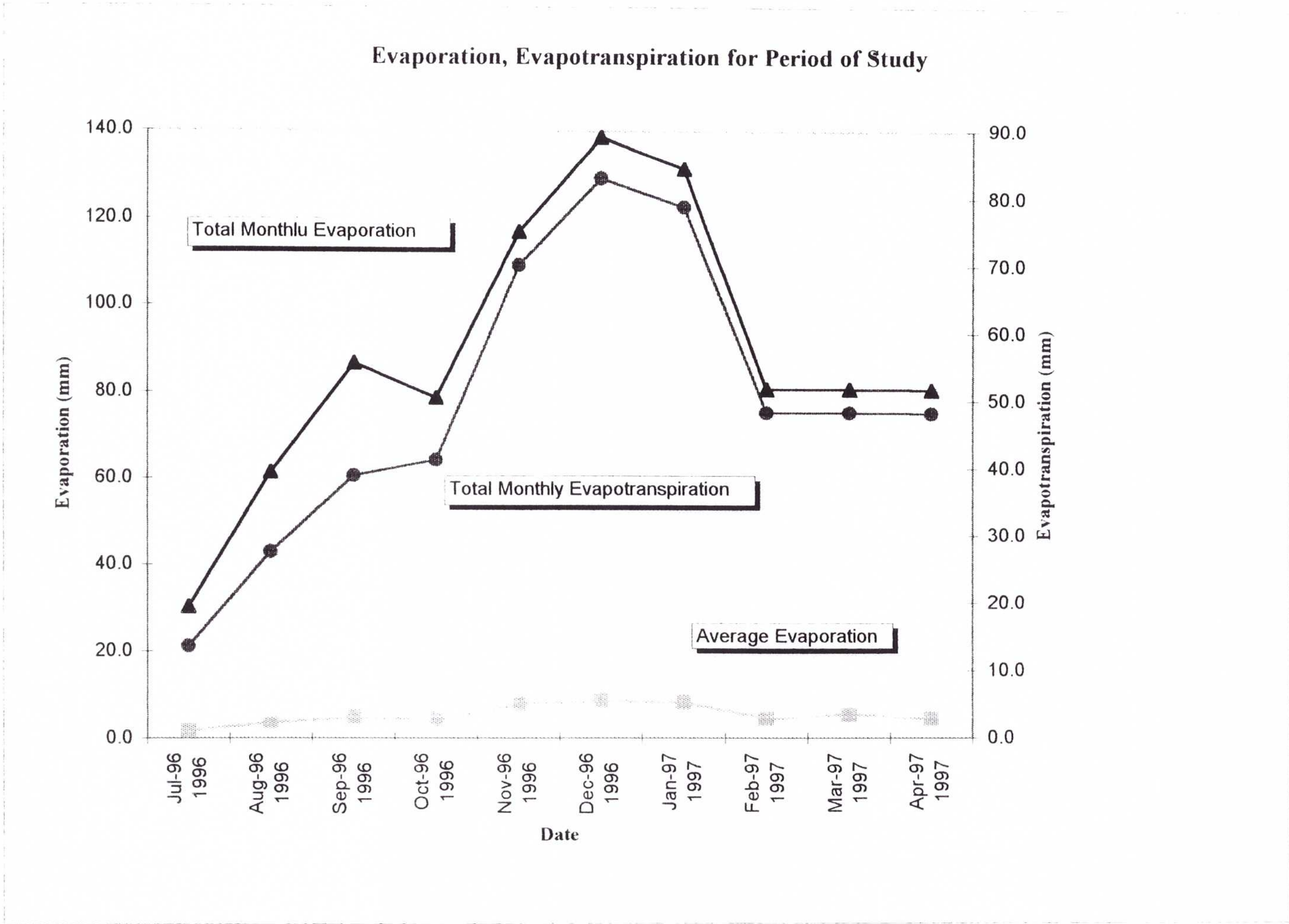

Figure A1 - Average Evaporation/ Evapotranspiration Plots

Estimates of Evapotranspiration

Evapotranspiration can be roughly estimated from the pan evaporation using the following relationships

$$Et = K_c \cdot C_p \cdot E_{pan}$$ derived from methods developed by Penman and Thornwaite (from Wilson,1969)

where
- Et = Evapotranspiration in mm
- Kc = Coefficient depending on type of crop, soil coverage and availability of water
- Cp = empirical pan coefficient
- Epan = pan evaporation

Kc was given values ranging between 0.8 to 0.5, based on well-watered grass over months from summer and winter.
Cp = 0.75

Rainfall

Date	Rainfall
	mm
7/06/96	22.5
07/27/96	3
07/28/96	40
07/29/96	9
07/30/96	3
8/02/96	11
08/22/96	2
08/30/96	21.5
08/31/96	14.5
9/11/96	2
9/12/96	2.5
09/20/96	17.5
09/21/96	9.5
09/29/96	49
09/30/96	22.5
10/01/96	1.5
10/07/96	13
10/19/96	7.5
10/27/96	14.5
11/05/96	38.5
12/07/96	55.5
12/08/96	12
12/18/96	29
12/28/96	40
1/12/97	6
01/25/97	7.5
01/28/97	21.5
01/29/97	24.5
01/30/97	32
01/31/97	6
2/12/97	40
02/13/97	12
02/23/97	11
02/24/97	13

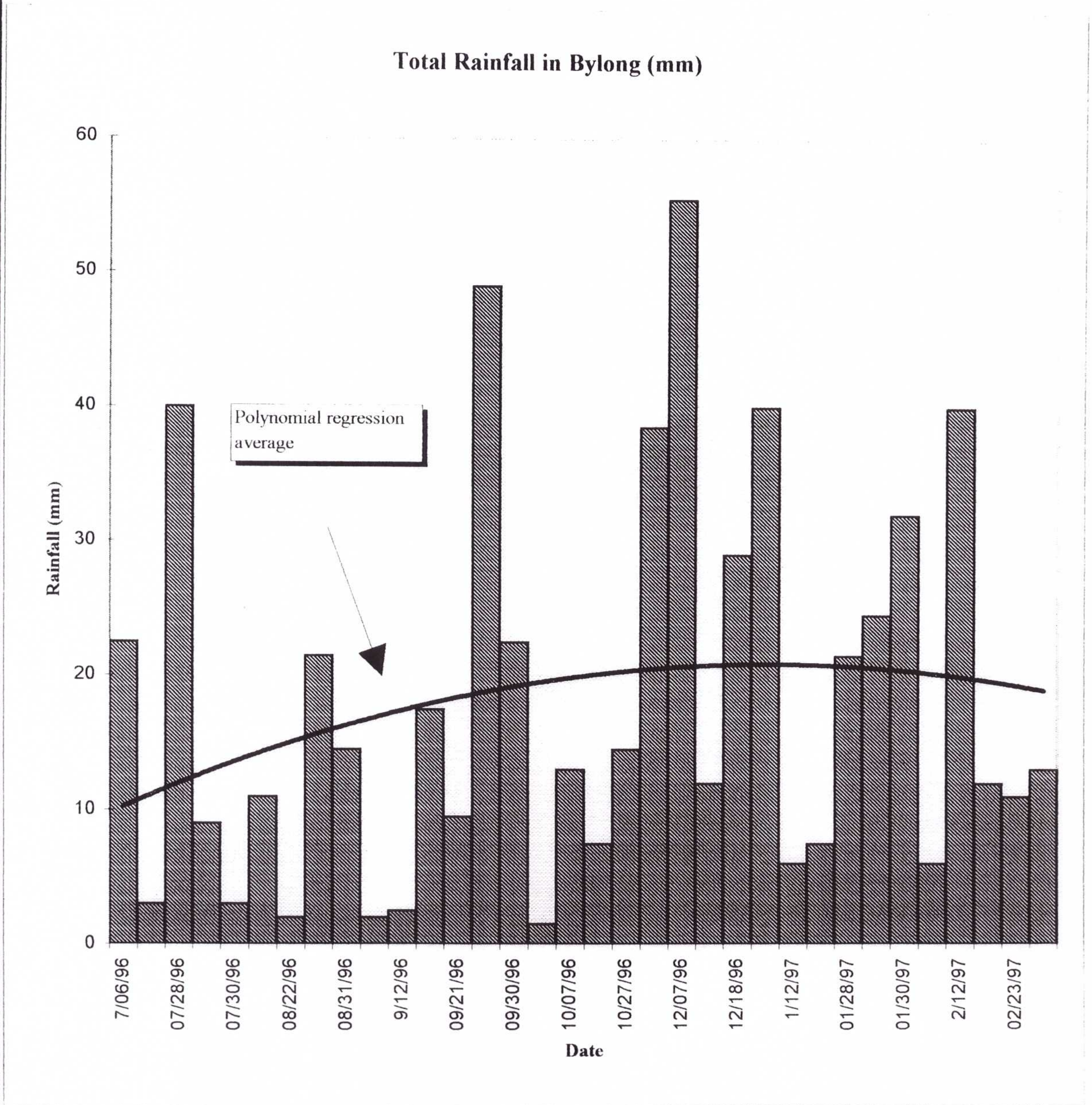

Figure A2- Total Rainfall at Tarwyn Park Homestead