Department of Lands, Planning and Environment

SUB-SURFACE HYDROLOGY
OF THE
KNOX CREEK PLAINS
(NT PORTION)

EXECUTIVE SUMMARY

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1. Typical Description of Sediments Underlying NT Portion of Area Proposed to be Irrigated on Knox Creek Plain.
The Governments of the Northern Territory and Western Australia are committed to the extension of the Ord River Irrigation Area to accommodate increased demand for irrigable land. Under 'Stage 2 of the Ord Irrigation Project', two consultancies have been commissioned. One is for the preliminary design of irrigation layout and infrastructure (Snowy Mountains Electricity Commission and QLD Department of Primary Industries) and the second for an environmental study (Sinclair Knight Merz).

An integral component of the environmental study is a hydrogeological assessment of the proposed Stage 2 development. To assist the completion of this component the Water Resources Division of the Northern Territory Department of Lands, Planning and Environment (WRD) and the Hydrogeology Branch of the Water and Rivers Commission, Western Australia (WRC), were commissioned to provide data on the sub-surface hydrology of the Knox Creek Plain. The study commenced with a review of (i) drilling data from existing oil and mineral exploration holes, and (ii) data acquired from an airborne geophysical survey which was flown in August 1994. A field survey followed in August-October 1996.

The survey comprised ground geophysical soundings (WRD), investigation and test production drilling (WRC), geophysical downhole logging (WRD and WRC) and test pumping (WRD). This report summarises the understanding of the sub-surface hydrology of the Northern Territory portion of the Knox Creek Plain (refer Figure 1).

The investigations in the NT identified up to 30 metres of permeable sediments underlying the grey cracking clay soil. These sediments are either palaeochannel clay, sands and gravel or weathered Permian-Carboniferous (PC) sandstone. These sediments are significant as they have the potential to provide drainage for irrigation development. Within the NT these clayey sandy sediments predominantly overlie impermeable shale of the Milligans Beds.

The water table in this area is some 18 m below ground level (RL approx. 11 m AHD). It is several metres higher than in the northern area of the plain (RL approx. 3 m AHD) due to the north-south trending synclinal shape of the Milligans shale bedrock and its elevation in relation to the water table. The bedrock high of the western rim of the basin appears to limit the flow of groundwater to the north west. For the NT, the regional groundwater gradient to the north-west is approximately 1.2 m in 1 km. The Keep River is not a mechanism for groundwater discharge under natural conditions in this area as the bed of the river is more than 10 m above the water table.

The quality of the groundwater varies across the plain from approximately 750 us/cm to 4000 us/cm conductivity.
The airborne electromagnetic survey was used to broadly classify the study area. The hydrogeological characteristics of each of the three sub-areas (refer Figure 4) were derived from data acquired during the field survey. All three sub-areas are considered to have the natural drainage capacity, if combined with dewatering and tight management of accessions to the water table, that will enable irrigation development.
SETTING

Climate

The area has a "Wet - Dry" tropical monsoon climate with an average annual rainfall of 780 mm. The Wet season extends from about early December to the end of March. Annual evaporation of 2800 mm far exceeds rainfall. Only in February at the height of the wet season does rainfall exceed evaporation. The mean maximum temperature range is 30.5°C (July) to 38.8°C (November) and the mean minimum range is 14.2°C (July) to 24.8°C (December).

Physiography

The NT portion of the Knox Creek Plain is bounded to the north and east by the Keep River, the west by sandstone outcrop of the Milligans Hills and the south by rocky hills which form the foot hills of Mounts Septimus and Zimmerman. This southern end of the alluvial plain is dominated by grey cracking clay soils which support tussock grass savanna and tussock grass shrub or tree savanna. South of Milligans Lagoon remnant levees of prior streams are abundant across the plain with the associated sandy soils supporting open woodland. This same vegetation also occurs on the sandy colluvial slopes of the sandstone outcrop on the south and western edges of the plain.

Geology

Bedrock underlying the plain is Carboniferous shale of the Milligans Beds. The shale lies in a synclinal structure, the axis of which trends approximately north-south. Figure 2 maps the elevation of the top of the bedrock.

Overlying the shale are Permian-Carboniferous sandstone and conglomerate sandstone of the Border Creek Formation and Keep Inlet Formation and Cainozoic clay, sand and gravels which have infilled palaeochannels and valleys eroded into the older Permian-Carboniferous sandstones. These predominantly clayey sandy sediments underlie the full width of the alluvial plain with a thickness up to approximately 30 m. A typical description of the sequence of sediments that overlies the Milligans Beds is summarised in Table 1. Prior to this investigation it was thought that these sediments where restricted to a narrow channel on the eastern side of the plain, with the remainder of the plain underlain directly by relatively impermeable Milligans shale. This led to the earlier conclusion that this southern part of the plain had hydrogeological conditions not favourable for irrigation.

The extent of the Permian-Carboniferous sandstone in the NT can be delineated on the airborne electromagnetic image. These resistive sediments show up as dark blue where they outcrop, and grade from light blue to yellow where they occur below the water table (refer Figure 3).
INVESTIGATIONS

Based on the application of airborne electromagnetic data in the investigation of the Keep River Plain, this same approach was also used to investigate the hydrogeological environments of the Knox Creek Plain. With the requirement to provide base hydrogeological data and a map showing an interpretation of the different hydrogeological environments, the airborne electromagnetic data was combined with traditional geological and soil maps, satellite imagery and ground based geophysical, drilling, test pumping and water quality data.

Prior to this investigation, studies of the plain included a soils survey by Agriculture WA, limited oil and mineral exploration drilling, a couple of water investigation and stock production bores on the edge of the plain, the airborne electromagnetic survey and some ground geophysical soundings. The initial interpretation of this data was that the plain was mostly underlain by shallow shale subcrop, with less than 30% likely to be underlain by the Keep River palaeochannel. The conclusion was that the plain was not suitable for irrigation due to poor natural drainage. This conclusion was made broadly for the entire plain and this investigation was conducted to further define the hydrogeology and the areas most suitable for irrigation.

The field program was based around a cross-section from Milligans Lagoon north-east to the Keep River and the ground truthing of different environments as indicated by the airborne electromagnetic image which was flown in August 1994. Fifteen joint DC/EM soundings were conducted in the region of the study area within the NT. Four investigation/test production bores (J35, 30836, 30827 and 30828) were drilled at three new sites and a fifth monitoring bore (30825) was drilled for existing test production site 29667. Two of the four sites, 29667 and 30826, were test pumped to determine aquifer hydraulic characteristics of the aquifer zones within the sandstone/clayey sandy sediments.

The water table in this area, some 18 m below ground level, is approximately 8 metres higher than in the northern area of the plain. The data indicates that this is likely due to the north-south trending synclinal shape of the Milligans shale bedrock and its elevation in relation to the water table. The bedrock high of the western rim of the basin is postulated to act as a sub-surface barrier limiting the flow of groundwater to the north west.

The regional movement of groundwater is from the south to the north. The southern groundwater system has a north-west gradient of approximately 1.2 m in 1 km. Considering a width of aquifer of 3 km across the plain and a transmissivity of 100 m²/d (approximate hydraulic conductivity, K, of 10 m/d) as indicated from short term test pumping, minimal throughflow (360 m³/d) is indicated. The implication of this is that there is minimal natural recharge. Specific yield of these clayey sandy sediments is estimated to be between 5 and 15% based on previous experience. Along this stretch of the Keep River the water table is more than 10 m below the bed of the river.
Therefore it is not likely to be a significant natural discharge mechanism for the groundwater system. The river is more likely to effect recharge in this upper reach.

Based on the data from the field program, channel 2 conductance of the airborne electromagnetic survey (Figure 3) was classified and ground truthed and different hydrogeological environments defined. These different environments were distinguished by basement geology (Figure 2), water-quality distributions and water levels.

Summarising the hydrogeological environments in the NT defined by the image, the blue to the north-east and the oval shape area on the WA/NT border is interpreted to be outcropping and shallow sub-cropping PC sandstone with good quality groundwater. The light blue to the south-east is postulated to be Devonian sandstone underlying less than 20 m of clayey sandy sediments. The yellow and reddy yellow areas delineate more than 20 m of clayey sandy sediments overlying Milligans Beds shale, with the SWL in the clayey sandy sediments and water quality varying from 750 to 4000 us/cm. The red higher conductive area to the east represents less than 20 m of clayey sandy sediments overlying shallower sub-cropping weathered Milligans Beds shale with the SWL in the Milligans Beds shale.
CONCLUSIONS

This project has investigated the sub-surface hydrology of the Knox Creek Plain and delineated different hydrogeological sub-areas underlying the proposed irrigation area.

An aquifer exists beneath the NT portion of the plain, in clayey sandy sediments of Permian-Carboniferous and Cainozoic age. Regional groundwater flow is to the north-west at an approximate gradient of 1.2 m in 1 km. Aquifer recharge is postulated to be by direct infiltration through the cracking grey clay soils at a rate less than 1% of rainfall and from river bed infiltration. Hydraulic characteristics, K and S, of the clayey sandy sediments are estimated to be 10 m/d and 5-15% respectively.

Airborne geophysical mapping has shown good correlation with water quality, drilling data and outcropping geology. The use of airborne electromagnetic mapping has enabled extrapolation of geology and water quality, so that areal interpretation is possible with only a small number of drillholes in each environment. The geophysical mapping was subsequently used to define a number of hydrogeological environments.

Using the hydrogeological environments defined by geophysics and drilling, the investigation area was divided into two sub-areas. The following interpretations are made for the sub-areas delineated in Figure 4.

Sub-Area 1
Underlain by more than 20 m, up to 35 m, of clayey sandy sediments overlying Milligans Beds shale. Groundwater in the clayey sandy sediments has varying water quality from 500 to 4000 us/cm and SWL is in the clayey sandy sediments. Natural drainage is considered adequate for irrigation development if combined with dewatering and tight management of accessions to the water table.

Sub-Area 2
Underlain by less than 20 m of clayey sandy sediments overlying shallow sub-cropping weathered Milligans Beds shale. SWL is in the Milligans Beds shale. Sediment lithology is similar to sub-area 1. Natural drainage is considered adequate for irrigation development if combined with dewatering and tight management of accessions to the water table.

Sub-Area 3
Expected to be underlain by less than 20 m of clayey sandy sediments overlying Devonian sandstone which would be expected to have a similar permeability to the clayey sandy sediments. Natural drainage is considered adequate for irrigation development if combined with dewatering and tight management of accessions to the water table.
Recommended Monitoring

A baseline groundwater monitoring programme is recommended to start immediately. Bores 30826, 30828 and 29667 should be monitored for water levels at least twice yearly. Ideally, this would be in early June, after the wet season, and in late October before rainfall begins. A continuous water level monitoring device should be installed on 30826 for at least one full year to capture the water level fluctuation in the aquifer beneath the plain to confirm the recharge and discharge nature of the aquifer system.

The monitoring programme is required to provide baseline data from the system under natural conditions to enable the performance of the system under future irrigation to be evaluated. It is recommended that the monitoring programme should be undertaken by the Kimberley Development Authority or the Co-operative. The data would be provided to the Water Resources Division annually so that progressive modelling and evaluation may occur.
Table 1. Typical Description of Sediments Underlying NT Portion of Area Proposed to be Irrigated on Knox Creek Plain.

<table>
<thead>
<tr>
<th>Depth Interval (m)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 1</td>
<td>Dark grey/brown swelling clay, with minor sand (to 1 mm) organic matter rich.</td>
</tr>
<tr>
<td>1 to 6</td>
<td>Dark brown slightly swelling clay with some CaCO₃, and minor sand.</td>
</tr>
<tr>
<td>6 to 8</td>
<td>Light brown sandy clay with some CaCO₃ gypsum crystals and FeO.</td>
</tr>
<tr>
<td>8 to 11</td>
<td>Mottled red brown and pallid sandy clay.</td>
</tr>
<tr>
<td>11 to 15</td>
<td>Cream, pink and brown poorly indurated fine sandstone. Grains 0.1 to 1 mm, no structure within chips.</td>
</tr>
<tr>
<td>15 to 31</td>
<td>Cream to pink poorly indurated clayey sand with up to 60% well indurated, well rounded, poorly sorted gravels to 20 mm composed of sandstone, siltstone and micaceous schist.</td>
</tr>
<tr>
<td>31 to 32</td>
<td>Dark grey poorly indurated mudstone/shale.</td>
</tr>
</tbody>
</table>
SUBSURFACE HYDROLOGY OF THE KNOX CREEK PLAINS
LOCATION MAP OF STUDY AREA

Figure 1
CONTOURS OF SANDSTONE/MILLIGANS BEDS SHALE CONTACT m (AHD)

CONTOURS OF PC SANDSTONE/SHALE CONTACT m (AHD)

INVESTIGATION BORE AND ELEVATION m (AHD) OF CONTACT

GEOPHYSICAL SOUNDING
RIVER/CREEK

DRAINAGE LINE
EDGE OF PLAIN
TRACK

Figure 2
HYDROLOGICAL SUB-AREAS AND IRRIGATION LAYOUT

Figure 4