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GOVERNMENT OF WESTERN AUSTRALIA

Hydrogeology of the Dumbleyung 1:250 000 Sheet

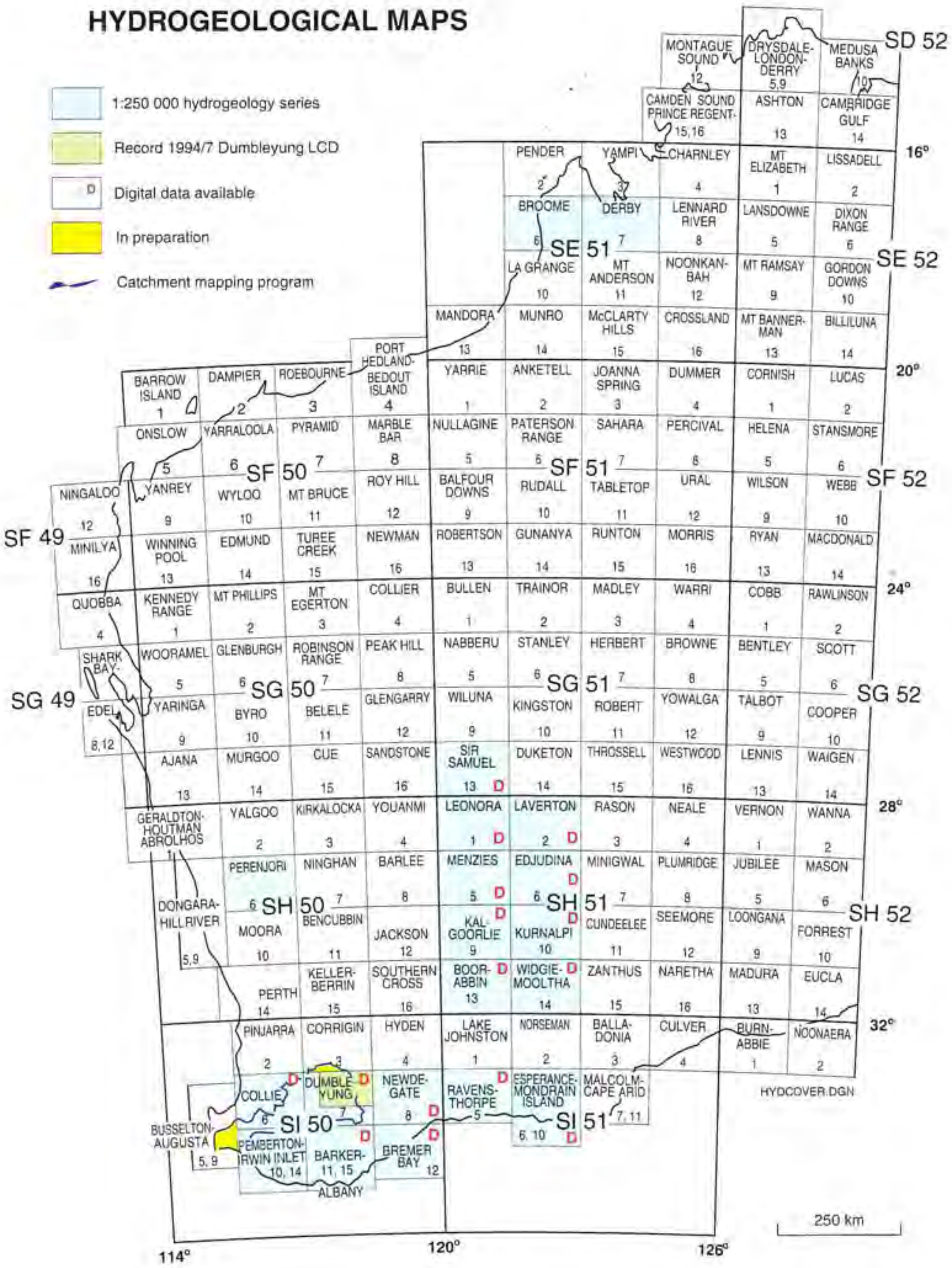
Hydrogeological Map Explanatory Notes Series

Water and Rivers Commission Report HM 6

2000

Water and Rivers Commission

WATER AND RIVERS COMMISSION
Hyatt Centre
3 Plain Street
East Perth
Western Australia 6004
Telephone (08) 9278 0300
Facsimile (08) 9278 0301



Cover photography: Aerial view of Coblinine River looking northeast from Lake Dumbleyung towards White Water Pool. Photograph courtesy of Damian Shepherd, Agriculture Western Australia, and Rob Baxter, Blackwood Basin Group.

HYDROGEOLOGY OF THE DUMBLEYUNG 1:250 000 SHEET

by

E. L. LEONHARD

Water and Rivers Commission
Science and Evaluation Division

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Science and Evaluation Division
Water and Rivers Commission
3 Plain Street
EAST PERTH
WESTERN AUSTRALIA 6004
Telephone (08) 9278 0522 Facsimile (08) 9278 0586

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Contents

Figures

Tables

Map

Appendix

Hydrogeology of the Dumbleyung 1:250 000 sheet

by

E. L. Leonhard

Abstract

The Dumbleyung 1:250 000 hydrogeological sheet covers the southwestern corner of the Yilgarn–Southwest Groundwater Province. Groundwater in the Dumbleyung sheet area occurs in weathered and fractured granitic and gneissic bedrock, dyke margins and quartz veins, palaeochannels and surficial sediments.

Groundwater within the sheet area is generally saline to hypersaline, although small supplies of brackish to saline groundwater, suitable for stock, may be located at the base of the clayey weathered profile in a gritty section above fresh bedrock. Scarce, local and small supplies of potable groundwater may occur within alluvial sediments associated with the Beaufort, Arthur and Coblinine River palaeochannel systems, bedrock faults and fractures in the southwestern portion of the map sheet, and eolian and colluvial sediments resting within topographic hollows and at the foot of slopes abutting the palaeodrainages.

Towns within the Dumbleyung sheet area rely on water provided by the Great Southern Town Water Supply Scheme, which is augmented by local bitumen and rock catchments that direct surface water to excavated earth dams. Excavated dams provide the majority of farm stockwater supplies. Minor quantities of fresh to brackish water are also developed from soaks and seasonal wet areas. In general, there is little potential for fresh groundwater development.

Keywords: Hydrogeological maps, groundwater resources, aquifers, salinity, palaeochannels, palaeodrainage, catchments, Dumbleyung.

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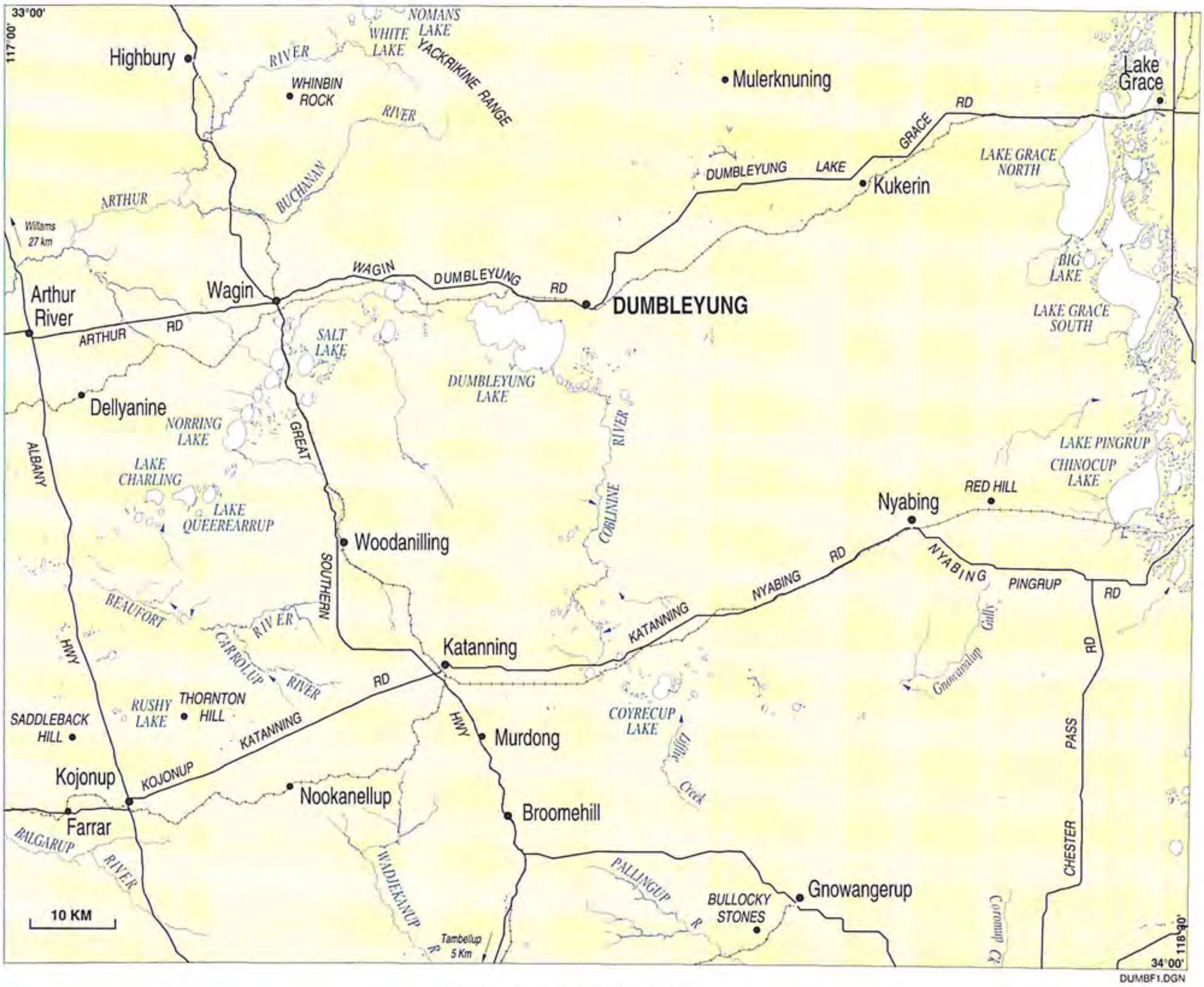

Figure 1. Location map

1 Introduction

1.1 Location and land use

The DUMBLEYUNG[1] 1:250 000 hydrogeological sheet (SI 50-7 of the International Series) comprises an area bounded by latitudes 33°00' and 34°00' S and longitudes 117°00' and 118°30' E, whose centre is approximately 250 km southeast of Perth. DUMBLEYUNG covers a portion of the southwestern Wheat Belt of Western Australia and derives its name from the small town of Dumbleyung (Fig. 1).

The biggest population centre on the sheet is Katanning with a population of 4035, followed by Wagin (1337), Kojonup (1035) and Gnowangerup (737) (Australian Bureau of Statistics, 1996). Other towns within the DUMBLEYUNG area include Arthur River, Broomehill, Gnowangerup, Highbury, Kukerin, Nyabing and Woodanilling. An extensive network of sealed and gravel roads provides excellent access to urban and rural areas across DUMBLEYUNG. The major population centres of Katanning, Wagin and Kojonup are linked to Perth and the south coast by the Albany and Great Southern Highways. The Great Southern Railway line runs south - southeasterly through Wagin and Katanning, with linkage to Albany. Railway branch lines run east - northeasterly from Wagin to Lake Grace, and from Kojonup to Nyabing.

Landuse in the area is predominantly agricultural, with sheep, wool and grain the main revenue-generating commodities produced by the region. Gold mineralisation is known at four localities with 7911 kg having been won from Griffins Find, located 14 km west-northwest of Lake Grace. Gypsum, for the manufacture of plaster, was mined from the Lake Grace palaeodrainage system prior to 1945 (Bowley, 1945).

1.2 Climate

The climate is semi-arid with hot, dry summers and cool winters. The mean daily maximum temperatures for January are 32°C at Lake Grace and 30°C at Kojonup, and in July they are 15°C at Lake Grace and 14°C at Kojonup. The mean daily minimum temperatures range from 15°C in February at Lake Grace and 13°C at Kojonup, to 5°C in August at Lake Grace and Kojonup (Bureau of Meteorology, 1999).

The average annual rainfall decreases easterly and northerly across the sheet area, ranging from 535 mm at Kojonup, 482 mm at Katanning and 440 mm at Wagin, to 354 mm at Lake Grace. The highest monthly mean rainfall coincides with the passage of winter cold fronts between May and September with peak rainfall events in June and July. Summer thunderstorms in January and February have delivered both the highest recorded daily rainfall of 142 mm and also the highest monthly rainfalls of 255, 225, 228 and 214 mm at Wagin, Katanning, Kojonup and Lake Grace, respectively (Bureau of Meteorology, 1999).

The potential evaporation from a free water-surface increases from an annual average of 1800 mm in the southwest of DUMBLEYUNG to about 2200 mm in the northeast (Bureau of Meteorology, 1999).

1.3 Physiography

The DUMBLEYUNG area lies in the southwest of the Darling Plateau, which is part of the Great Plateau of Western Australia (Chin and Brakel, 1986). The area is a gently undulating to hilly etchplain comprising denudation plains, erosional slopes, and depositional and alluvial flats of Tertiary to Quaternary age (Finkl and Churchward, 1973). Topographic elevations range between 300 m and 420 m above the Australian Height Datum (AHD) (Fig. 2). Prominent topographic highs include Saddleback Hill, at an elevation of 320 m AHD, and Thornton Hill, at an elevation of 390 m AHD (Fig. 1).

The major drainage divides separating the Williams, Blackwood, Avon, Frankland, Pallinup and Gordon River Catchments are shown on Figure 2. The Lake Grace System drains northward into the Avon River Catchment, and the Beaufort and Arthur River systems drain westward and form part of the Blackwood River Catchment. The river valleys within these catchments are broad and flat with braided and meandering stream channels. These drainage systems tend to become disorganised into chains of salt lakes, as seen around

1 Capitalised name refers to the standard map sheet

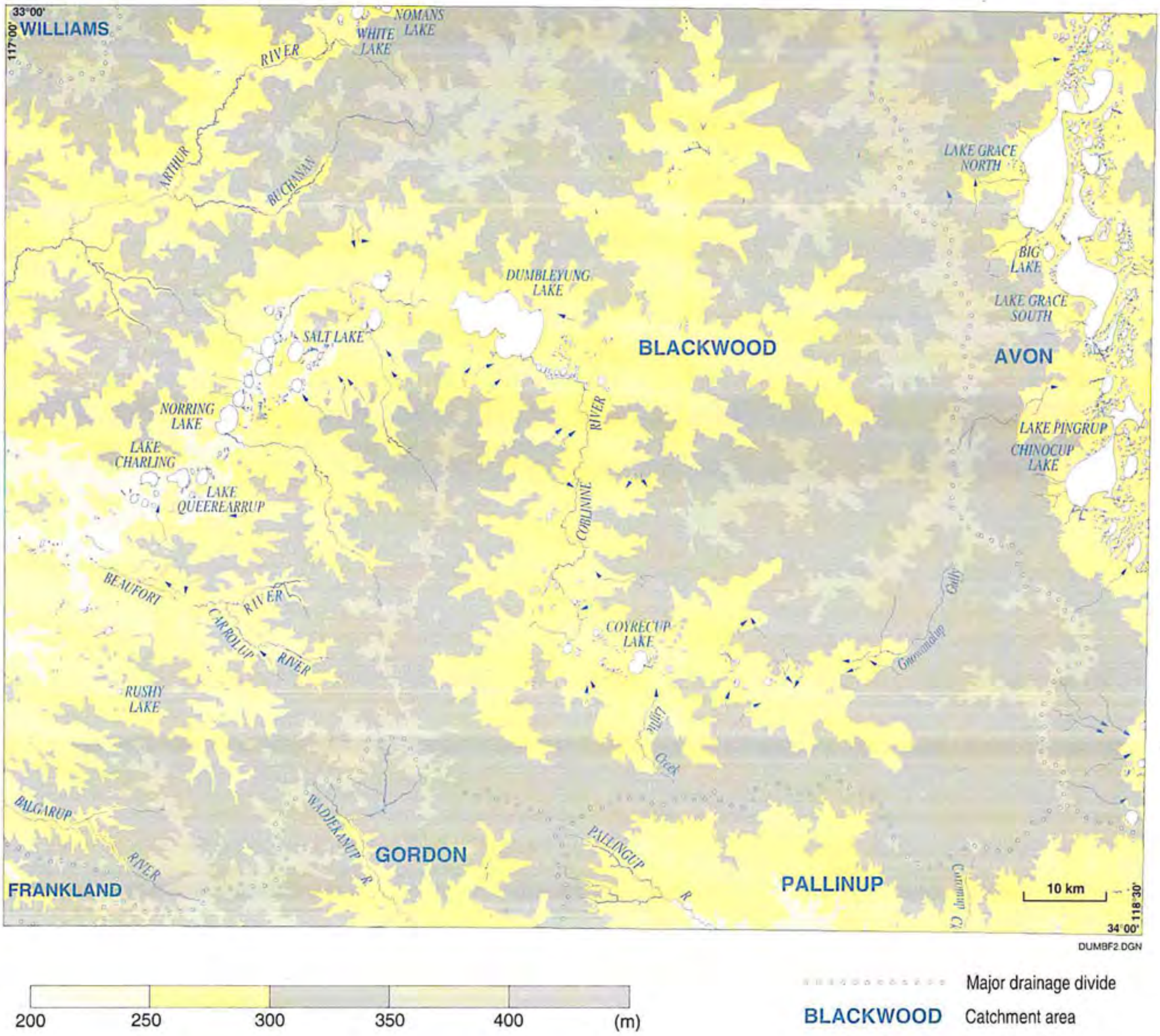

Figure 2. Topography

Coyrecup Lake within the Coblinine River valley, and Lake Queerearrup, Lake Charling, Norring Lake and Salt Lake within the Beaufort River valley.

Dumbleyung Lake is one of the permanent salt lakes in the Beaufort River valley and the largest natural permanent lake in Western Australia. The water level of the lake has risen substantially since the surrounding land was cleared (Beard, 1980).

A series of sand dunes exists in the southwestern quadrant of Dumbleyung within the Beaufort River system. They are primarily low lunette dunes that have migrated in a west-northwest direction. However, they are generally covered by vegetation and are currently stable.

1.4 Vegetation

Mallee–marri–wandoo forests, York and Salmon gum woodland, casuarina and dryandra heath, tea–tree and a succulent steppe of saltbush and samphire were the dominant pre-European vegetation associations on Dumbleyung. Since European settlement most of the indigenous vegetation has been cleared for agriculture, mainly crop cultivation and sheep grazing, with scattered remnants occurring primarily on Government Reserves and in areas of shallow bedrock (Beard, 1980). The vegetation of ephemeral wetlands occupying valley floors has been degraded by increases in groundwater salinity and rising water levels, commonly resulting in the development of salt flats. This change has been accompanied by the death and replacement of the indigenous tea–tree thickets by more salt-resistant samphire species.

Beard (1980) classified the vegetation of DUMBLEYUNG into ten major vegetation systems. These correspond to portions of the Avon, Darling and Roe Botanical Districts that cover DUMBLEYUNG and are shown in Figure 3. The Darling Botanical District occupies the western portion of the sheet, and includes Kojonup and the Beaufort River, and comprises the Beaufort, Jingalup and Williams Vegetation Systems (Fig. 3). The central portion of the DUMBLEYUNG area falls within Beard's Avon Botanical District and contains elements of the Narrogin, Wagin, Broomehill, Dumbleyung and Tambellup Vegetation Systems. The Roe Botanical District covers the eastern portion of DUMBLEYUNG, and corresponds to the Hyden and Ongerup Vegetation Systems.

The eastern boundary of the Darling Botanical District (Fig. 3) is defined by the limit of mallee–marri–wandoo forests (Beard, 1980). These woodlands are characteristic of the Williams, Beaufort and Jingalup Vegetation Systems, where they occupy sloping and undulating terrain. Vegetation differentiation within the Darling Botanical District occurs in response to:

- areas of shallow basement in the Williams Vegetation System where casuarina becomes dominant,
- an increase in alluvial and eolian deposits within the Beaufort Vegetation System where *Eucalyptus marginata* and *occidentalis* occur in association with the marri and wandoo, and
- an increase in rainfall in the Jingalup Vegetation System which promotes taller woodland trees and a greater diversity of understorey vegetation.

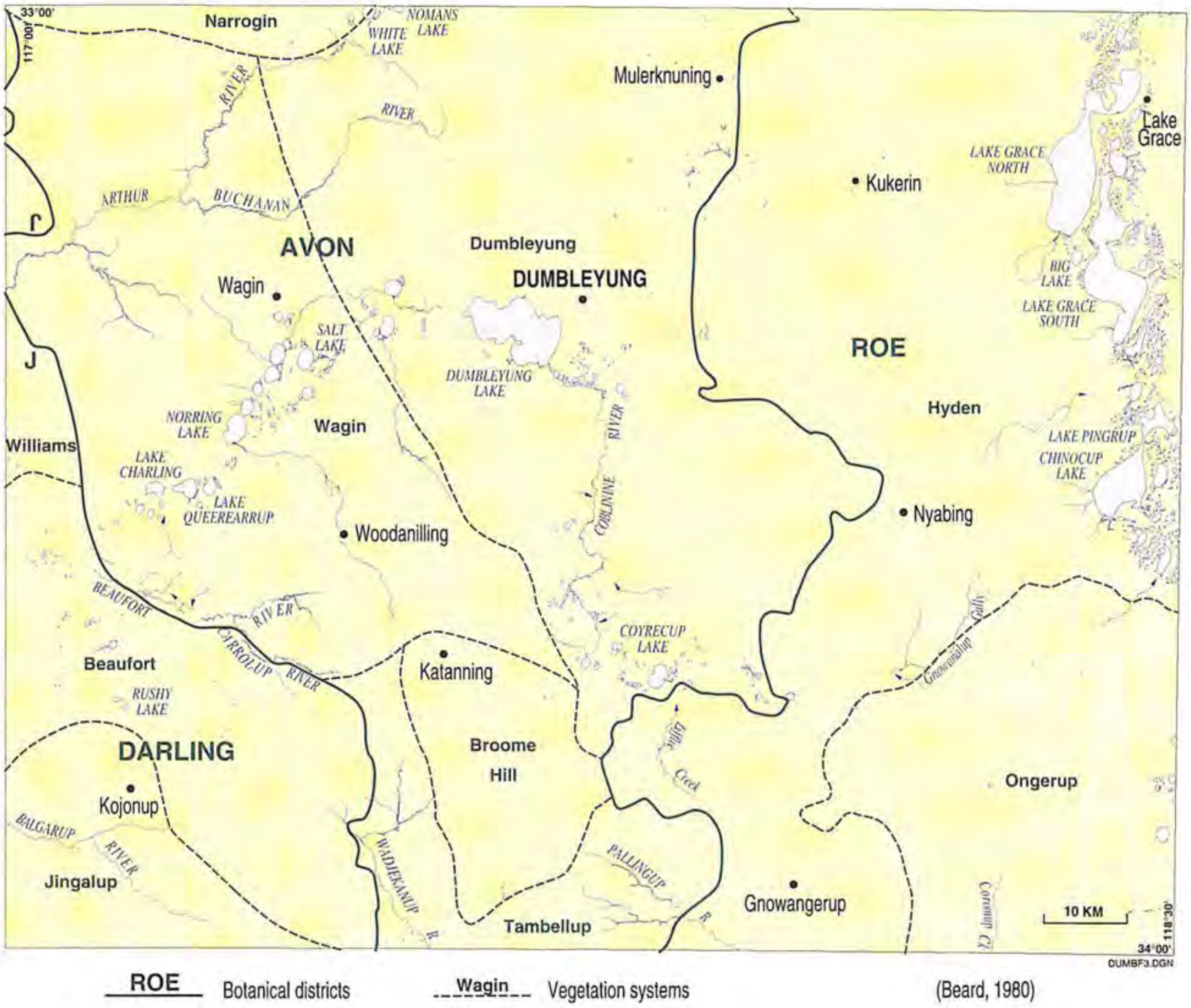

Figure 3. Vegetation systems

The Avon Botanical District (Fig. 3) is characterised by low woodlands of mallet (*Eucalyptus astringens*), York gum (*Eucalyptus loxophleba*) and wandoo (*Eucalyptus wandoo*) within the Narrogin, Wagin, Broomehill, Dumbleyung and Tambellup Vegetation Systems. The Narrogin Vegetation System occupies a small portion of the DUMBLEYUNG area along the northern boundary where small patches of dryandra heath grow in association with the woodlands. The Wagin Vegetation System appears as a mosaic of mallet and wandoo woodland on laterite mesas and breakaways, with the slopes occupied by low woodlands of York gum and wandoo. Heaths, dominated by dryandra, occur on patches of laterite throughout the system. The Broomehill Vegetation System was originally covered by a mallet and wandoo woodland with York gum appearing infrequently where it replaces the mallet in the more dissected and undulating terrain. The Dumbleyung Vegetation System is a dryandra-dominated heath on lateritic residuals with York gum, salmon gum, red morrel and wandoo woodland occupying more undulating terrain. Patches of tea–tree are found on salt flats with scrub-heath and low woodland on low-level sandplains. The Tambellup Vegetation System covers a small area between the Broomehill and Beaufort Vegetation Systems, and is dominated by wandoo and flat-topped yate woodland.

The Roe Botanical District comprises portions of the Hyden and Ongerup Vegetation Systems, and includes the Lake Grace palaeodrainage system. The dominant vegetation types of this district are salmon gum (*Eucalyptus salmonophloia*) and mallee (*Eucalyptus spp.*). The Hyden Vegetation System appears as a mosaic of scrub-heath on sandplains, mallee on slopes, mallee-woodland in some valleys and continuous woodland occupying valley floors. The Pingarning Hills to the east of the Dumbleyung townsite carry York gum woodland and sheoak low-woodland. The Ongerup Vegetation System resembles the Broomehill Vegetation System but has a cover of mallee rather than mallet, with scrub-heath covering the lateritic hilltops.

1.5 Previous investigations

The geology of the DUMBLEYUNG area is described by Chin and Brakel (1985, 1986). Investigations for mineralisation include Low (1957), MacLeod (1964), Marchant (1981) and Kirby (1987). CRA Exploration Pty Ltd (1996) investigated the occurrence of kaolinite, while BHP Minerals Ltd (1982) undertook exploratory drilling for coal in the Lake Dumbleyung area.

The DUMBLEYUNG area was investigated for groundwater under a drought-relief drilling program by the Geological Survey of Western Australia (GSWA) between 1969 and 1970 (Lord, 1970, 1971). Davidson (1977) summarised the results of this program. Martin (1981) investigated the southeastern part of DUMBLEYUNG for possible drought relief drilling. The GSWA conducted hydrogeological inspections of numerous farms in the area (unpublished reports).

The hydrology of the Dumbleyung Land Conservation District, bounded by latitudes 33°00' and 33°30' S, and longitudes 117°30' and 118°30' E is described by Cody (1994). This area forms the northeastern third of DUMBLEYUNG.

The area between Kojonup and Broomehill (Broomehill Survey) was surveyed by World Geoscience Corporation in 1994 using an airborne geophysical method known as the SALTMAP airborne electromagnetic (AEM) system (Leeming 1994; Ladyman, 1995). Bradley and Dell (1998) compiled data on the SALTMAP AEM Broomehill Survey for the Cooperative Research Centre for Australian Mineral Exploration Technologies. The Water and Rivers Commission conducted a drilling program in 1996 to assist in the evaluation of the SALTMAP AEM Broomehill Survey data (Leonhard, 1999a, b).

Grein (1995) prepared an atlas of natural resources of the Blackwood River Catchment which was published by Agriculture Western Australia in 1995. The results of a drilling investigation of the Blackwood River Catchment (Panasiewicz *et al.*, 1997) have also been incorporated with hydrogeological mapping by de Silva (2000) as a digital dataset for the Blackwood River Catchment hydrogeological map and report.

Sutton (1998) examined the geological controls on salinity through the evaluation of downhole, ground and airborne electromagnetic data in association with drillhole mineralogy along two transects within the Carlecatup Creek (see Map) and Wadjekannup River catchments.

1.6 Map compilation

Data from more than 2400 groundwater bores and wells were used in the preparation of DUMBLEYUNG. These bores include those drilled for the Blackwood River Catchment hydrogeological map and SALTMAP AEM Broomehill Survey data evaluation program (Panasiewicz *et al.*, 1997; Leonhard, 1999a). Drill logs from the drought-relief program (Lord, 1971; Davidson, 1977), were re-interpreted and hydrogeological boundaries drawn in conjunction with the geological compilations of Chin and Brakel (1985). As the hydrogeological boundaries, watertable contours and groundwater isohalines are interpretative, they are approximate. However, greater confidence in the interpretation can be applied to areas of greater bore density. All groundwater borehole and well data are stored in the WIN database (the water information database system maintained by Water and Rivers Commission).

The layers of information used to compile DUMBLEYUNG are also available in digital format. These data were digitised at various scales and some data were simplified for presentation at 1:250 000 scale. The digital data files, together with their description, source and scale of capture are given in Appendix 1.

2 Geology

2.1 Regional setting

DUMBLEYUNG is situated within the Western Gneiss Terrain, which is part of the Yilgarn Craton. Bedrock comprises mainly Archaean granitoid rock, which has been intruded by dykes of Proterozoic age. It has an irregular surface formed by Late Palaeozoic continental glaciation and Mesozoic erosion. A major differentiation in bedrock relates to granite being predominant in the western half and granitoid gneiss in the eastern part. The structural geology is summarised in Figure 4.

The area appears to have been a peneplain in the Proterozoic and was severely eroded during the Permian glacial period (Chin and Brakel, 1985). By the late Cretaceous, an extensive southward-flowing drainage system had been developed (Cope, 1975).

A period of regional tectonism associated with the breakup and separation of Australia and Antarctica in the late Mesozoic and Early Cainozoic is considered to be responsible for development of the Jarrahwood Axis and Ravensthorpe Ramp (Smith and Hallam, 1970; Cope, 1975). The Jarrahwood Axis (Fig. 4) is a

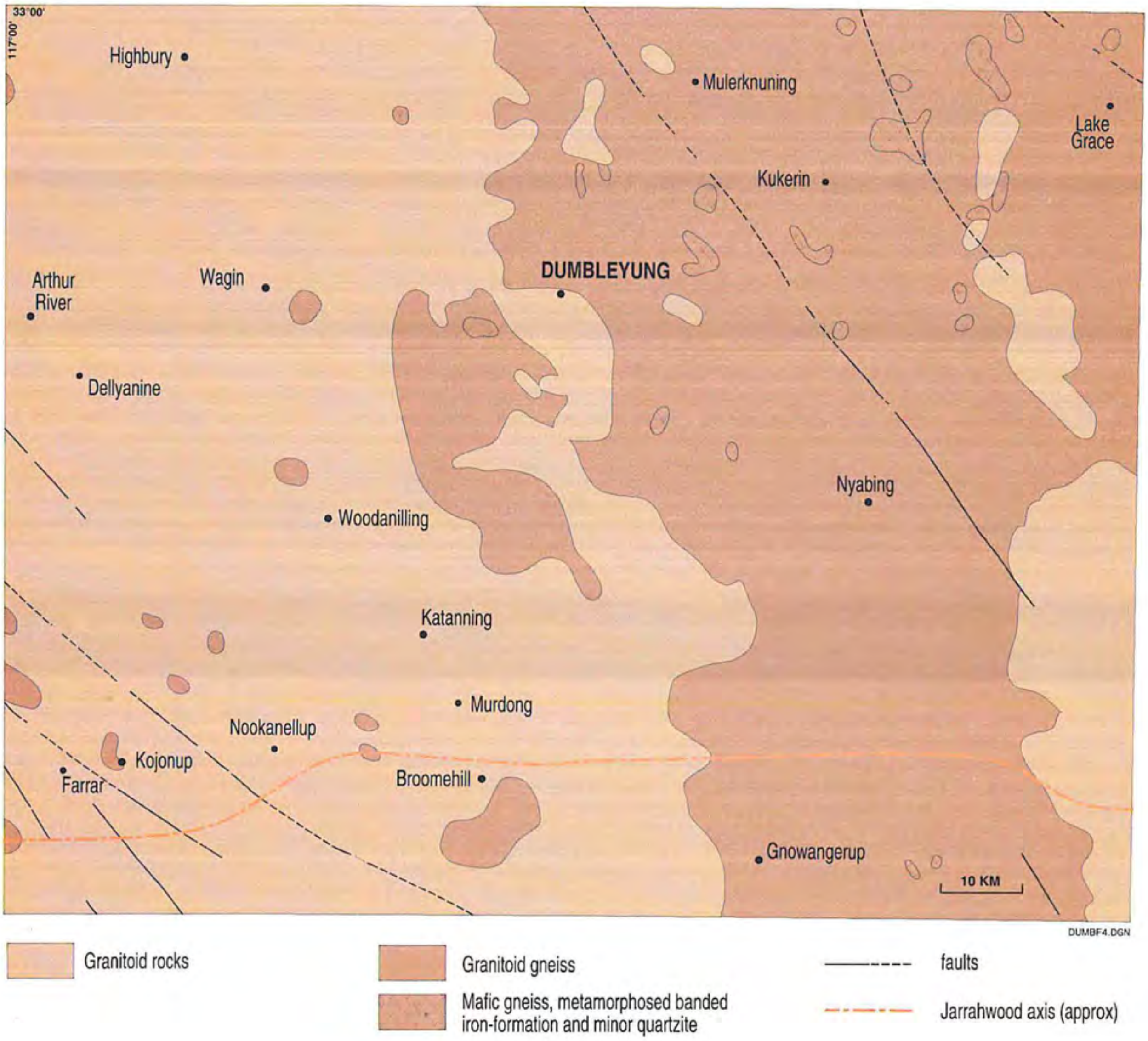

Figure 4. Geological structure

structural hingeline that marks the boundary between the Darling Plateau and the southward tilted Ravensthorpe Ramp that inclines the landscape south of the axis towards the Southern Ocean (Cope, 1975). This axis coincides with the drainage divide between the Blackwood River and the Gordon–Pallinup Rivers, near the southern margin of DUMBLEYUNG, and defines the southern extent of internal drainage (Chin and Brakel, 1986).

Uplift along the Jarrahwood Axis hingeline was responsible for a change in direction of surface drainage from southerly to east-southeasterly (Chin and Brakel, 1986). This change is represented by the preservation of a network of palaeodrainage channels associated with the Beaufort and Coblinine Rivers (Lake Dumbleyung) and Lake Grace salt lake system. The Lake Grace–Lake Dumbleyung salt lake systems were formed through the ponding of internal drainage and surface discharge behind constraining topographical and structural features.

The palaeochannels (Fig. 5) have been infilled by Tertiary sediments and reworked alluvium. Playa and salt lakes lie above older sediments within palaeodrainage valleys where the drainage is ponding. Early Cainozoic alluvial sediments are preserved across the southern portion of DUMBLEYUNG. Eolian sand dunes are preserved along the eastern and southeastern sides of these lakes.

Intense weathering during the Tertiary resulted in the development of a residual lateritic profile over most of DUMBLEYUNG. Subsequent erosion of the surface has produced a landscape of low relief with scatter outcrops of bedrock.

2.2 Archaean

A major differentiation in bedrock type exists between the western and eastern halves of DUMBLEYUNG, with the western half showing a lower grade of metamorphism. Mafic hornblende–plagioclase amphibolite is restricted to the western portion of the sheet, where the dominant bedrock comprises even-grained to seriate, biotite granite and adamellite. These rock types are amongst the younger rocks on DUMBLEYUNG and have only been locally deformed and metamorphosed to greenschist or amphibolite facies. A zone, some 30 km wide, generally coincides with the transition between granitoid rocks in the west and gneisses to the east (Chin and Brakel, 1986). This linear zone of seismic activity, called the South-West Seismic Zone, trends in a north-northwesterly direction through the approximate centre of the sheet.

The eastern part of DUMBLEYUNG is dominated by recrystallised, banded, granitoid gneiss. Mafic enclaves, up to 2 km long, are abundant and are similar to the mafic granulite present at Lake Dumbleyung. A few enclaves of metamorphosed, banded iron-formation occur in the granitoid gneiss, and together with quartzite, appear to have originated as part of a layered greenstone succession. These enclaves have a granoblastic fabric that is associated with granulite-facies metamorphism and may represent layered intrusions emplaced prior to the development of gneiss, or outliers of greenstone belts deformed with the Western Gneiss Terrain. Low-grade gold and base metal mineralisation is recorded as a patchy distribution within the mafic granulite and greenstone enclaves (Chin and Brakel, 1986).

Granitoid rock is exposed as sheets and monadnocks. Elsewhere, it has been deeply weathered to as much as 50 m, but commonly ranging between 20 and 30 m. The residual lateritic profile typically consists of clay, sandy clay and clayey sand. A basal saprock unit composed of decomposed granitoid rock and gritty coarse-grained quartz saprock (saprolitic grit) is often present above bedrock. The gneissic bedrock generally weathers to clay and lacks the saprolitic grit horizon.

2.3 Proterozoic

Numerous basic and intermediate dykes of Proterozoic age intrude the Archaean rocks of the Yilgarn Craton on DUMBLEYUNG. These dykes range in composition from dolerite to diorite. They are abundant on all parts of the sheet, most with an easterly and some with a northerly orientation (Chin and Brakel, 1986).

2.4 Cainozoic

Discrete alluvial deposits of Early Cainozoic age are preserved in elevated positions across the western portion of DUMBLEYUNG and comprise a suite of transported material overlying weathered bedrock. Tertiary palaeodrainage sediments are being eroded and alluvium of Quaternary age is being deposited in the eroded channels. Material interpreted as being Early Tertiary in age includes the Kojonup Sandstone, palaeochannel and palaeochannel tributary deposits, and laterite. Late Tertiary to Quaternary deposits comprise eolian dune sand, colluvium and alluvium. The stratigraphy on DUMBLEYUNG is summarised in Table 1.

2.4.1 Early Tertiary

The Kojonup Sandstone is an orthochemical, siliceous, fine-grained sandstone found in positions of elevated relief, approximately 300 to 320 m AHD, in the southern part of DUMBLEYUNG, south of the Southern Rivers Drainage Divide (Wilde and Backhouse, 1976). It is believed that the Kojonup Sandstone is a fluvial deposit of Eocene age and is coeval with sediments found in the Beaufort and Lake Grace palaeodrainage systems (Waterhouse *et al.*, 1994). Lacustrine conditions developed in response to uplift along the western part of the Darling Plateau resulted in the deposition of the Kojonup Sandstone. Subsequent southward tilting of the Ravensthorpe Ramp, together with epeirogenic uplift of the Darling Plateau in the Late Eocene ending the period of lacustrine sedimentation, culminated in the development of the present drainage divisions (Cope, 1975).

Palaeochannel deposits in the western, central and eastern parts of the map sheet were layed down as a result of regional uplift that modified the fluvial systems, choking and constricting drainage (Fig. 5). These deposits can be divided into two units; an upper unit composed mostly of clay and silt with lesser amounts of sand overlying a lower sequence of interbedded sand, clayey sand and clay that is partially carbonaceous (Waterhouse et al., 1994). The lower unit overlies the Archaean basement and is distinguished from the upper unit by its darker colouration and the presence of oxidation products forming mottled yellow and red zones. Excavations for farm dams along the flank of palaeochannels have exposed white alluvial clay (Waterhouse *et al.*, 1994), which can be distinguished from residual lateritic clay by its homogeneous, non-stratified structure. The lack of correlation between boreholes in palaeochannel deposits is indicative of a meandering river system. The lacustrine clay within palaeodrainages may have been deposited as the river gradients decreased (Waterhouse *et al.*, 1994). A trend towards angularity in sand grain roundness from early to late palaeochannel deposits reflects the change from fluviatile to lacustrine environments, and indicates a decline in flow energy and reduced sediment transportation distances (Folk, 1974).

Table 1. Stratigraphy

Age	*Code*	*Unit*	*Max. thickness Intersected (m)*	*Lithology*
Quaternary	*Czs**	Eolian sediments	~5	Sand
	Ql	Lacustrine sediments	~20	Gypsiferous clay and silt
	Cz	Alluvium and colluvium	~25	Clay, silt, sand and gravel,minor silcrete, calcrete and laterite
Tertiary	*Tk**	Kojonup Sandstone	~2	Siliceous sandstone
	Ta	Alluvium	~10	Gravel and sand
	Tw	Alluvium and lacustrine sediments	~65	Gravel, sand, silt and clay
Proterozoic	*Pd*	Dykes	-	Dolerite and diorite
	q	Veins	-	Quartz
Archaean	*Ag*	Yilgarn Craton	-	Granitoid rock, fresh and weathered to clayey sand, sandy clay, sand and laterite
	An	Yilgarn Craton	-	Granitic gneiss, fresh and weathered to clayey sand, sandy clay, sand and laterite
	Aq	Yilgarn Craton	-	Quartzite
	Ai	Yilgarn Craton	-	Banded iron-formation

* *Units have not been individually mapped and are therefore not shown on Dumbleyung.*

Alluvial sand and gravel deposits are found stranded on hills above palaeodrainages (Chin and Brakel, 1986). These sediments comprise unconsolidated assemblages of silt, sand and gravel of varying proportions forming sheetwash and channel deposits, and are often buried by younger colluvium and alluvium. Channel deposits are relics of palaeochannel tributaries. Sediments within Ngopitchup Swamp, 23 km southeast of Kojonup, are Tertiary aged alluvial sheetwash deposits.

Intense weathering through the Tertiary period (Chin and Brakel, 1986) produced a residual lateritic profile covering most of DUMBLEYUNG outside the Tertiary drainage systems. Weathering patterns reflect the bedrock geology and structure, with dolerite dykes, for example, weathering to clay with well-defined saprock transitional zones of broken dolerite or quartzite (contact alteration product) commonly within a matrix of grey, sticky-sandy clay (Leonhard, 1999b).

The residual lateritic profile is commonly between 10 and 30 m thick and comprises a varied upper sequence of clay, sandy clay, clayey sand and sand (saprolite) above a basal zone of angular partially weathered granite and gneiss representing the decomposed bedrock zone (saprock). Saprolite commonly comprises both a pallid (kaolinitic) zone and overlying mottled (ferruginous or iron oxide stained) zone. Laterite, either massive or pisolitic (lateritic gravel or 'buckshot gravel') is usually present as an upper or surficial unit of the weathered profile

2.4.2 Late Tertiary–Quaternary surficial deposits

Late Tertiary to Quaternary deposits comprise eolian dune sand, colluvium and alluvium. Sediments interpreted as being of Late Tertiary to Quaternary age include fluviatile and lacustrine deposits within playa lakes and drainage channels.

Eolian quartz sand forms stabilised dunes on the eastern and southeastern sides of playa lakes and clay pans within the Beaufort River and Lake Grace palaeodrainage systems. Radiocarbon dating indicates a short-lived dune-building episode 15 000 to 20 000 years ago (Chin and Brakel, 1986).

Colluvium consists of gravel, sand, silt, clay and a mixture of these, and is present as a veneer on totally weathered bedrock and older alluvial sediments. Thicker accumulations of colluvium may be found in topographic hollows and at the foot of slopes.

Lacustrine deposits within the playa and salt lakes, and fluviatile sediments within the present drainage systems, unconformably overlie older alluvium. These sediments are of Late Tertiary to Quaternary age and comprise sand, silt and clay, which accumulated in response to periodic flow or inundation following seasonal heavy rain. Evaporation of the water within playa lakes and flood plains results in the formation of salt crusts and the precipitation of gypsum crystals.

Minor siliceous duricrust (silcrete) that appears on DUMBLEYUNG typically forms within the lateritic profile. Calcareous duricrust (calcrete) occurs within weathered valley-fill sediments adjacent to and overlying palaeochannel deposits.

Shell deposits on the eastern and southern sides of Lime Lake, 12 km south-southwest of Wagin, are of Quaternary age (Chin and Brakel, 1986).

3 Hydrogeology

3.1 Groundwater occurrence

Groundwater occurs in three different aquifer types that can be described by ten hydrogeological units, including one with moderate to major groundwater potential (Table 2). These aquifer types comprise Quaternary surficial sediments, alluvium and colluvium (*Ql* and *Cz*); Early Tertiary palaeodrainage sediments (*Tw*) covering the major palaeodrainage systems of the Lake Grace, Beaufort and Coblinine Rivers and minor palaeochannel tributary sediments (*Ta*); and the Archaean Yilgarn Craton bedrock and Proterozoic igneous rocks (*Ag*, *An*, *Pd* and *q*).

The rock types on DUMBLEYUNG, being composed of granitic and gneissic bedrock (*Ag* and *An*), characteristically form poor aquifers. They are associated with thin saturated profiles within the weathered bedrock, and have low permeability. The most significant aquifer type is formed within the basal sand of palaeodrainage systems (*Tw*), although these aquifers contain mainly hypersaline groundwater (Fig. 5).

Groundwater yields from fractured and weathered Archaean granitoid bedrock depends on the degree of bedrock fracturing and weathering, basement structures, position of groundwater recharge areas, and presence of preferred pathways for groundwater recharge within the weathered profile. The location of higher yielding groundwater bores within the granitoid bedrock (*Ag*) of the southwesterly quarter of DUMBLEYUNG indicates an association with faulted and fractured bedrock. Cant's Bore (113 m^3/day) located off of Broomehill Road, Broomehill (WIN Site ID 2330-2-SW-0019) and Robertson's Bore (91 m^3/day) located off of Coomelberrup Road, North Badgebup (WIN Site ID 2430-1-NW-0012) are examples of bores producing groundwater from faulted and fractured granitoid bedrock.

Proterozoic dolerite dykes (*Pd*) within the Archaean granitoid bedrock are common and weather to relatively impermeable clay that can retard groundwater flow. Groundwater may discharge as seeps or into soaks at the up-gradient side of dykes owing to the damming of groundwater flow behind less permeable clayey material of the weathered dyke. Quartz veins (*q*) are commonly well fractured, which when saturated, will enhance groundwater storage and aquifer permeability. Ladyman's Bore, located off of Bibikin Road, Dumbleyung (WIN Site ID 2431-3-SE-0017), is an example of a bore producing groundwater from a saturated, quartz vein.

The Early Tertiary basal gravel and sand deposits within palaeodrainages (*Tw*) and other associated sediments in palaeochannel tributaries (*Ta*) have high permeabilities and contain significant quantities of

Table 2. Hydrogeological divisions and aquifer potential

Aquifer	*Code*	*Hydrogeological unit*	*Aquifer potential*
Surficial sediments	*Ql*	Lacustrine sediments	Minor
	Cz	Alluvium and colluvium	Minor to moderate
Palaeodrainage sediments	*Ta*	Fluviatile and palaeochannel tributary sediments	Minor to moderate
	Tw	Palaeodrainage sediments	Moderate to major
Igneous and metamorphic rocks	*Pd*	Dykes	Minor
	q	Quartz veins	Minor
	Ag	Weathered granitic rock	Minor
	Ag	Fractured granitic rock	Minor to moderate
	An	Weathered gneissic rock	Minor
	An	Fractured gneissic rock	Minor

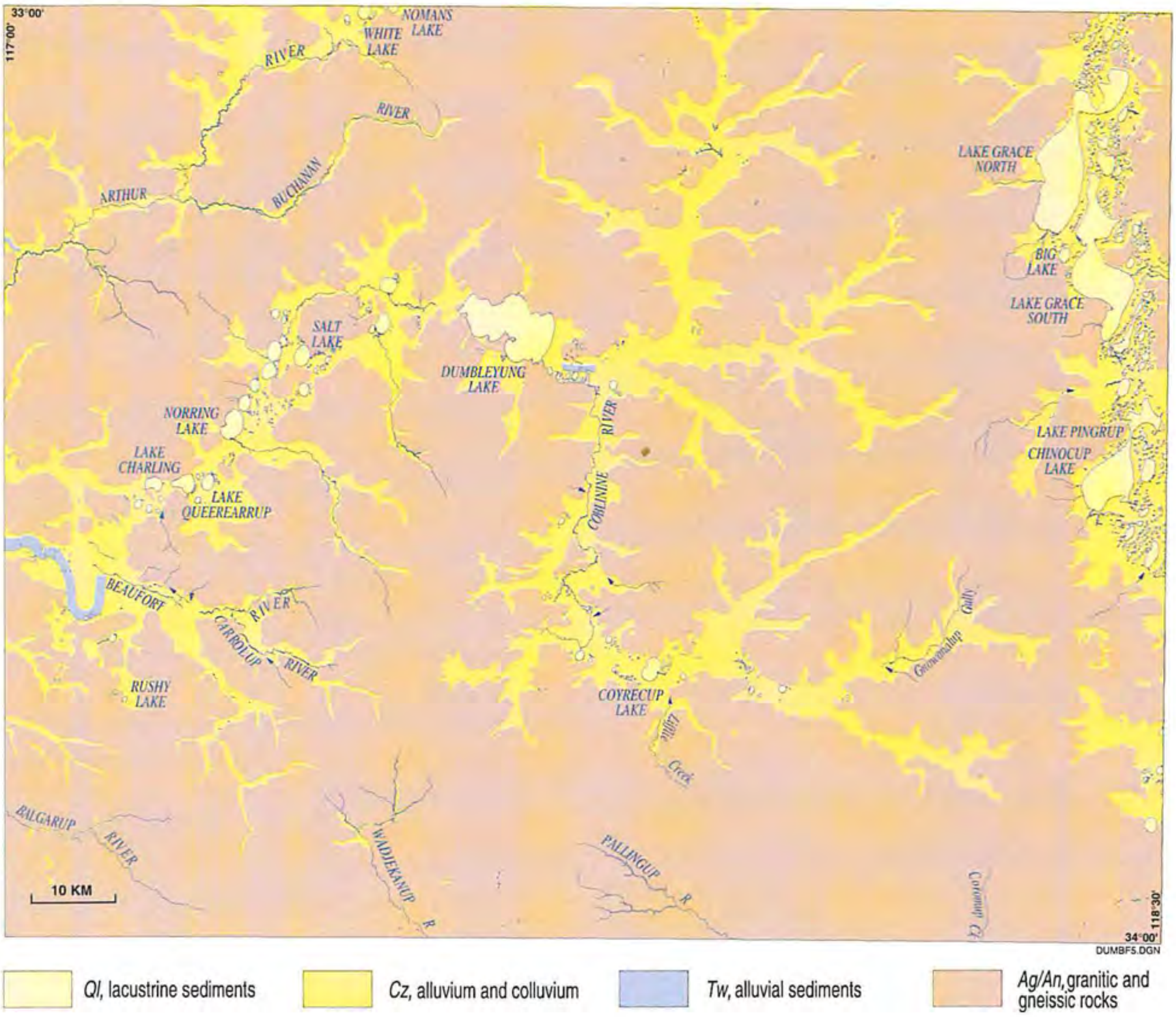

Figure 5. Palaeodrainage systems

groundwater. Sedimentary material overlying these deposits is more silty and clayey, and has lower permeability. Sand and gravel deposits within palaeodrainage systems have been located in the western portion of DUMBLEYUNG, within the upper portion of the Beaufort River catchment and east of the Coblinine River, between Dumbleyung Lake and Lake Coomelberrup (Laws, 1987). These deposits form major aquifers with extensive supplies of brackish to saline groundwater, and local, minor supplies of fresh groundwater. Pickford's Bore, located 30 km west of Woodanilling (WIN Site ID 2330-4-NE-003), the "C" Fitches Bore on the Cheviot Hills Property (WIN Site ID 2330-4-SW-0021) and the Beaufort River Tavern Bore (WIN Site ID 2330-4-NW-0012) are examples of bores producing fresh to potable groundwater from saturated, palaeochannel tributary sediments (*Ta*). Elsewhere, the palaeodrainage deposits (*Tw*), such as those underlying the Lake Grace System, contain hypersaline groundwater.

Late Tertiary and Quaternary alluvium is mostly clayey with low permeability and forms poor aquifers. Quaternary colluvium, when saturated, may form significant local aquifers.

3.2 Regional watertable

The regional watertable is interpreted as the level below which all pore space and fractures within rocks and sediments are saturated. The regional watertable is non-continuous where there are granitoid bedrock outcrops or bedrock highs. The regional watertable is relevant to aquifers formed within the residual lateritic profile (*Ag/An*) and palaeodrainage deposits (*Tw*), such as the Lake Grace palaeodrainage system. The regional watertable has been interpreted from historical and recent non-synoptic bore-water levels, and is contoured in metres AHD. In general, the watertable forms a subdued representation of the land surface, but is absent in areas of bedrock outcrop.

The depth to the watertable depends upon rock type, topography, groundwater recharge and discharge, and geological structures. For most of DUMBLEYUNG, the watertable ranges from 5 to 20 m below ground level (bgl), except in elevated areas above 350 m AHD, where the depth to the watertable commonly exceeds 20 m bgl.

The watertable within the palaeodrainages is relatively horizontal, shallow (usually less than 5 m bgl), and with very low gradient. The depth to the watertable fluctuates seasonally in response to variations in rainfall and evapotranspiration.

3.3 Groundwater flow and discharge

Regional groundwater movement across DUMBLEYUNG is controlled primarily by the bedrock highs, position of the surface water divides (Fig. 3), and palaeodrainage systems.

In central and southwestern DUMBLEYUNG, groundwater flow is west-southwesterly with some discharge into palaeodrainages associated with the Beaufort River and Blackwood River catchments. Groundwater discharge from these palaeodrainages is commonly through evaporation from the numerous salt lakes, which include Dumbleyung Lake, Gundaring Lake, Salt Lake, Dorducking Lake, Lime Lake, Murrin Lake, Parkeyerring Lake, Lake Norring Little, Norring Lake, Lake Flagstaff, Lake Queerearrup and Lake Charling.

Groundwater flow in the eastern part of DUMBLEYUNG, is towards the salt lakes of the Lake Grace palaeodrainage system, including Lake Grace North, Lake Grace South, Carinup Lakes, Lake Altham, Lake Pingrup, Lake Dorothy and Chinocup Lake (Fig. 5). This palaeodrainage system forms part of the Avon River catchment, where regional groundwater flow is in a northerly direction.

Within the Gordon and Pallinup River catchments, the regional groundwater flow is in a southerly direction. Groundwater discharges into streams within sub-catchments of the region that drain into the Gordon and Pallinup Rivers.

Regional groundwater flow is typically slow due to the low permeability of the clay within the residual lateritic profile and to the low hydraulic gradient of the palaeodrainages. Groundwater tends to discharge at breaks in slopes and at the foot of slopes adjacent to drainage systems, into saline pools, or into salt lakes such as Dumbleyung Lake.

Local groundwater flow and discharge within DUMBLEYUNG is dominated by aquifers which are structured such that groundwater recharge and discharge sites are closely associated, with separation distances commonly less than 3 km. Aquifers of this variety are defined by Pannell *et al.* (1999) as local aquifers. Groundwater flow will be towards topographically lower elevations with groundwater discharging as seeps or into drainage systems. Flow is affected by basement topography, particularly around monadnocks of granitoid bedrock and subsurface granitoid highs, and by the low-permeability of the totally weathered bedrock. Preferred pathways for groundwater movement equate to structural components, such as dykes and faults, which modify groundwater flow by constraining or directing groundwater movement down the hydraulic gradient (Fig. 6). These pathways can be locally significant for groundwater recharge to aquifers formed within fractures and fault systems, associated with quartz veins, and developed along the topographically high side of dykes.

3.4 Aquifers

3.4.1 Surficial sediments (*Ql* and *Cz*)

The surficial aquifers on DUMBLEYUNG comprise lacustrine (*Ql*), and alluvial, colluvial and eolian (*Cz*) sediments of Late Tertiary to Quaternary age. These sediments mostly occupy topographically low areas adjacent to and within palaeodrainages. Recharge to the surficial aquifers is by direct infiltration of rain and indirectly by surface runoff from adjacent landforms and minor groundwater flow from weathered bedrock and fractured rock aquifers.

Quaternary lacustrine sediments (*Ql*) are found within palaeodrainages and generally comprise gypsiferous

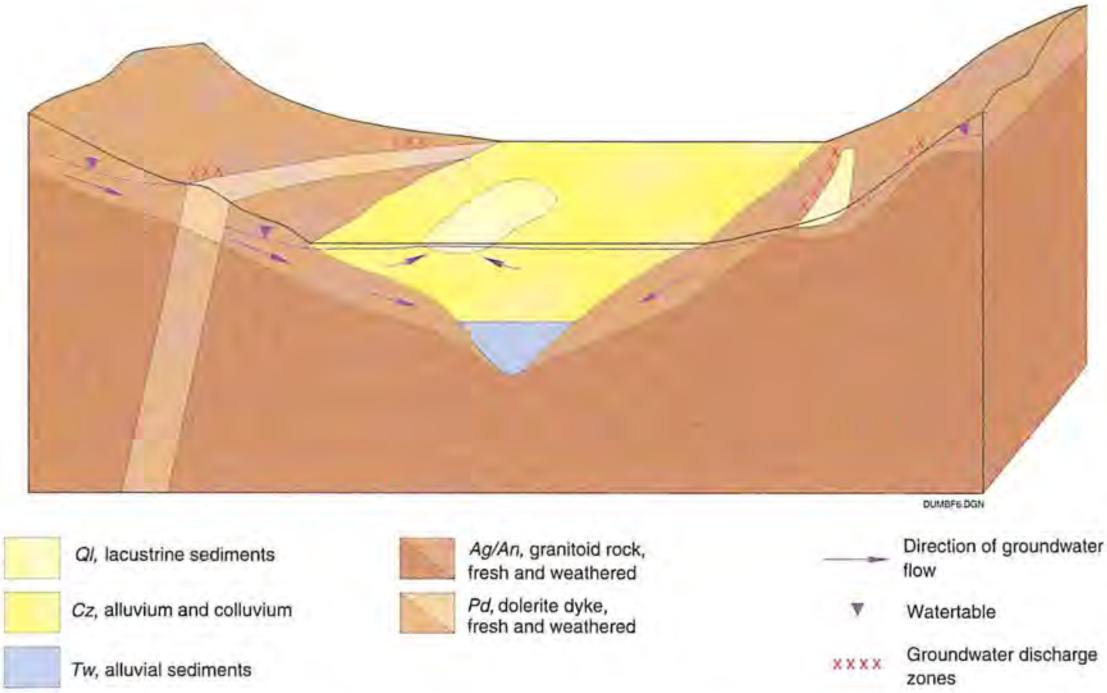

Figure 6. Block diagram portraying groundwater discharge

clay, silt and minor fine-grained sandy clay. Extremely low hydraulic gradients, between 0.04 m and 0.17 m per km, occur within the palaeodrainages. These low grades indicate that groundwater flow within the palaeodrainages is negligible with groundwater discharge occurring mainly by evaporation from the salt lakes. Groundwater within the lacustrine sediments is generally hypersaline and is not utilised for water supplies.

Alluvial, colluvial and eolian sediments (*Cz*) occur as deposits adjacent to and overlying palaeodrainages. Surficial aquifers can be locally significant at the foot of slopes bordering drainage systems where recharge is enhanced through surface runoff. Perched aquifers may exist temporarily where colluvium and eolian sediments overlie claypans and residual clay.

Groundwater salinity is generally between 1000 and 20 000 mg/L of total dissolved solids (TDS). Groundwater supplies may be seasonally variable with aquifer storage being greater through the winter months of May and September owing to increased rainfall and lower evapotranspiration. WIN database records indicate that groundwater supplies developed from this aquifer rarely exceed an abstraction rate of 10 m^3/day (Cody, 1994).

3.4.2 Palaeodrainage sediments (*Ta* and *Tw*)

Tertiary aquifers on DUMBLEYUNG comprise gravel, sand, silt and clay situated within palaeochannel tributary (*Ta*) and palaeodrainage (*Tw*) sediments. The alluvial sediments (*Ta*) comprise sand and silt within stranded, incised channels and depressions overlying the weathered bedrock. These sediments are associated with the tributaries that fed the Early Tertiary river systems which ceased flowing due to epeirogenic uplift of the region. They are commonly perched, discontinuous and are often covered by Quaternary colluvium. Groundwater quality varies from fresh to saline (Laws, 1987). Groundwater supplies may be seasonally variable, increasing during winter owing to groundwater recharge from rain.

The Tertiary sediments defined as *Tw* consist of gravel, sand, silt and clay, which occupy the basal position within meandering channels of the palaeodrainage systems. The Beaufort River palaeochannel has been recognised over a length of some 60 km (Waterhouse *et al.*, 1994). Sediments up to 65 m thick have been identified within the Beaufort River palaeochannel near Boscabel, and greater than 50 m thick in the Coblinine River east of Dumbleyung Lake (Cody, 1994). The sediments in the basal position of the palaeochannel occupy a relatively narrow channel, 200–500 m wide, where they overlie weathered bedrock.

The depth to groundwater in the palaeodrainages is typically less than 5 m. Groundwater within these sediments is generally saline to hypersaline with salinity exceeding 14 000 mg/L TDS in the main drainage channel (Cody, 1994; Leonhard, 1999b).

Recharge to these aquifers is low due to the occurrence of overlying clay and impeded rainfall infiltration. Groundwater flow is minimal due to the low hydraulic gradients of the palaeodrainages.

Groundwater discharge from the aquifers is primarily by vertical leakage into salt lake and claypans, from where it evaporates.

3.4.3 Igneous and metamorphic rocks (*Ag, An, Pd* and *q*)

Bore data in the WIN database indicate that granitoid rock aquifers (*Ag, An*) on DUMBLEYUNG are low yielding, with bore yields commonly less than 20 m^3/day. Groundwater is recharged directly from rainfall and flows radially away from topographic highs towards topographically lower lying areas. Groundwater discharges to overlying Tertiary sediments, along valley slopes, and is lost to the atmosphere by evapotranspiration. In some areas, groundwater within the saprolitic grit is confined beneath clay and may be subartesian to artesian (Cody, 1994). The salinity of groundwater obtained from the residual lateritic profile commonly ranges between 3000 and 7000 mg/L TDS.

Dykes (*Pd*) generally weather to impermeable clay and, although not prospective for groundwater, may form barriers that enhance groundwater availability up-gradient of the dyke. Quartz veins (*q*) can form fractured rock aquifers and transmit groundwater along the fractured zones (Smith *et al.*, 1997).

Open bedrock faults and fractures within the uppermost 5 to 10 m of bedrock are prospective for groundwater. Major faults, trending southeasterly, have been identified in the southwest of DUMBLEYUNG. Elsewhere, the occurrence of bedrock fractures and faults is local and generally obscured by the residual lateritic profile and sediments. Groundwater recharge to fractured rock aquifers is normally through preferred pathways, resulting in the occurrence of fresher groundwater than the surrounding regional groundwater. Fractured rocks may be highly permeable, with bore yields often exceeding 100 m^3/day. The salinity of groundwater from fractured-rock aquifers in the southwestern quarter of DUMBLEYUNG commonly ranges between 2000 and 6000 mg/L TDS.

4 Groundwater quality

4.1 Regional groundwater salinity

Groundwater throughout DUMBLEYUNG is mostly brackish to hypersaline, ranging from 3000 to more than 30 000 mg/L TDS (Fig. 7). In general, groundwater salinities increase eastward, coinciding with lower rainfall, higher evaporation, and the increasing occurrence of gneissic bedrock.

The groundwater within palaeodrainage aquifers (*Tw*) beneath salt lakes is largely hypersaline, ranging from 14 000 to above 30 000 mg/L TDS. However, less saline groundwater has been abstracted from aquifers within the Beaufort and Arthur River palaeodrainages in the western part of DUMBLEYUNG (Waterhouse *et al.*, 1994). Smaller occurrences of fresh to marginally saline groundwater, up to 3000 mg/L TDS, occur locally within surficial sediments (*Cz*) and palaeochannel tributary alluvium (*Ta*). Minor supplies of brackish to saline groundwater are found within residual material developed from the weathering of the granitoid bedrock (*Ag/An*). Groundwater in major faults (Fig. 4) in the southwestern quarter of DUMBLEYUNG is fresher than the surrounding regional groundwater salinity.

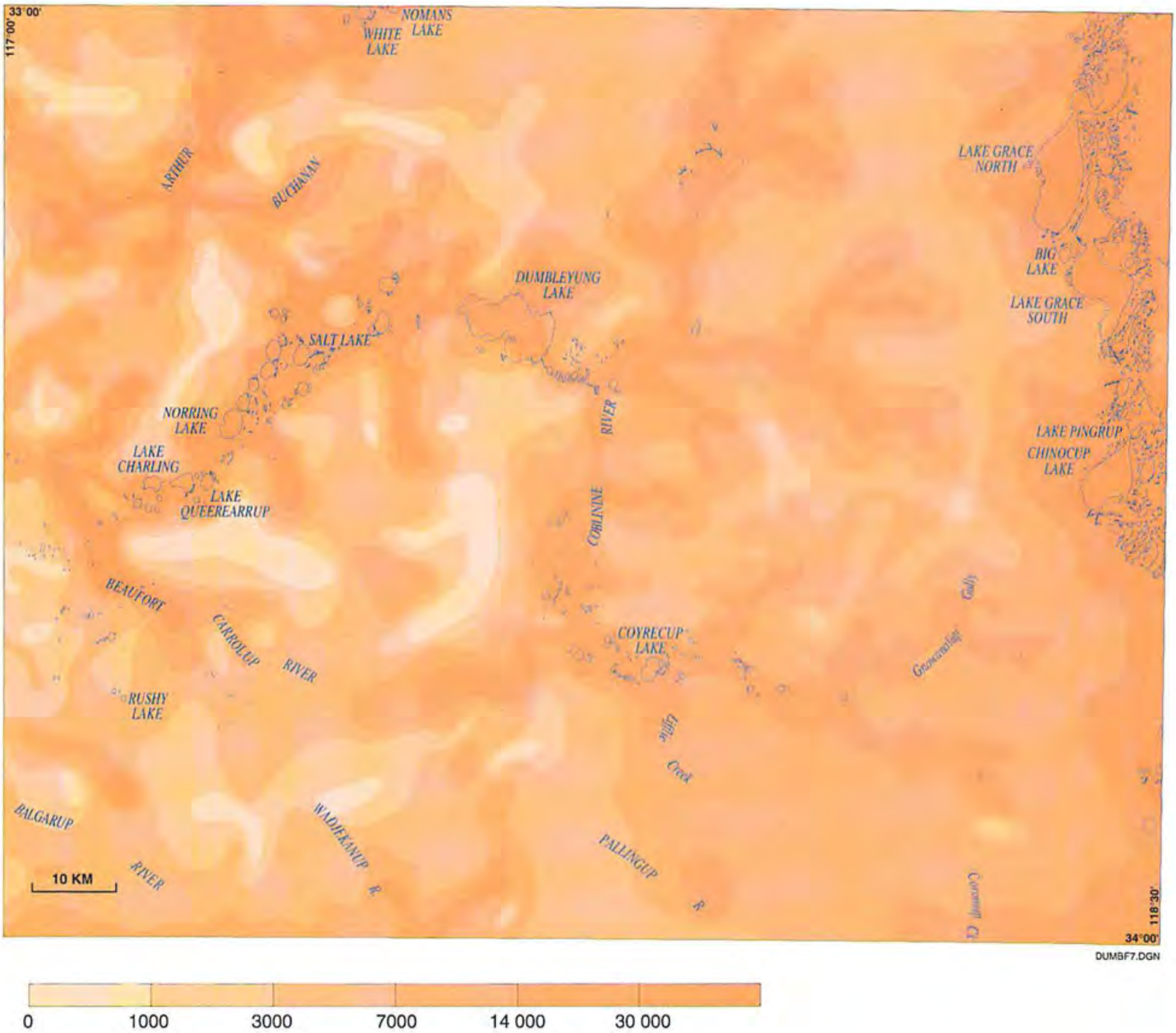

Figure 7. Groundwater salinity at the watertable

The distribution of groundwater salinity is represented on Dumbleyung by isohalines (in mg/L TDS) that have been derived from non-synoptic borewater samples. The isohalines represent the groundwater salinity, near the watertable, that would be encountered by an investigation bore; the salinity may increase with depth.

4.2 Hydrochemistry

The chemical analyses of groundwater samples from selected WRC bores, AGWEST monitoring piezometers and private bores are given in Table 3. In most aquifers, sodium and chloride are the most dominant ions.

The source of sodium and chloride ions (salt) is marine aerosols carried by rainfall (Hingston and Gailitis, 1976), and accumulated within the weathered bedrock profile. The accumulation of salt in the weathered bedrock profile is attributed to the net rainfall recharge after evapotranspiration by native vegetation before clearing, which restricted groundwater recharge. Poor surface drainage, much of which is internal, and low hydraulic gradients result in salt being concentrated and retained in groundwater within palaeochannels.

Table 3. Selected groundwater analyses

Bore record no.	*Aquifer code*	*pH*	*Electrical conductivity* mS/cm	*TDS*	*Total hardness*	*Alkalinity CaCO3*	*Ca*	*Mg*	*Na*	*K*	*HCO3*	*Cl*	*SO4*	*NO3*	*SiO2*	*P*	*F*
				mg/L													
Surficial sediments																	
2330-4-SW-0027	*Cz/Ta*	6.8	2.99	1 590	378	64	23	78	463	5	78	856	104	1	26	0.01	0.1
2430-4-SE-0010	*Cz/Ta*	6.4	3.3	1 700	400	25	20	85	490	3	31	960	86	2	40	-	0.2
Palaeochannel sediments																	
2330-1-NW-0001	*Ta/Cz*	6.9	0.557	302	36	48	3	7	92	6	59	105	54	1	5	0.05	0.1
2330-1-NW-0017	*Ta/Cz*	7.1	0.507	270	40	20	1	9	80	2	24	126	15	12	15	0.01	0.1
2330-1-NW-0006	*Ta*	9.0	1.03	550	80	100	14	11	190	1	73	179	117	42	34	-	0.6
2330-4-NE-0003	*Ta*	7.2	0.35	197	27	17	1	6	56	2	21	75	22	8	16	0.02	0.1
2330-4-SW-0027	*Ta*	6.8	2.99	1590	378	64	23	78	463	5	78	856	104	<1	26	0.01	0.1
2331-1-SW-0007	*Ta*	6.8	1.56	830	128	20	2	30	253	3	24	452	35	1	40	-	0.1
2331-2-NW-0003	*Ta*	7.3	0.755	420	46	20	2	10	128	1	24	182	26	34	24	0.03	0.4
2331-2-NW-0016	*Ta*	6.8	1.6	880	139	20	3	32	269	3	24	450	43	18	47	-	0.1
2330-1-SW-0032	*Tw*	8.0	24.9	16 400	2 660	544	140	563	5 260	50	656	9 020	1 040	1	40	-	0.3
2330-2-NW-0010	*Tw*	8.2	18	11 000	2 700	317	145	559	3 360	17	387	6 400	337	1	12	0.02	0.6
2331-3-SE-0017	*Tw*	8.6	20.3	12 000	2 850	246	145	604	3 530	44	268	6 900	552	1	91	0.01	1.3
2430-4-NE-0024	*Tw*	6.2	33.6	20 900	3 400	85	119	762	6 770	46	104	11 900	1 190	1	64	-	0.5
Igneous & metamorphic rocks																	
2330-2-SW-0019	*Ag* (fractured)	8.9	4.95	2 830	360	97	10	82	920	7	70	1 420	266	2	59	-	0.6
2330-3-SE-0006	*Ag* (fractured)	7.0	8.77	4 860	1 400	280	116	275	1 350	11	342	2 650	215	1	71	0.1	1.3
2330-3-SW-0016	*Ag* (*q*)	7.4	10.6	6 110	2 600	230	375	402	1 350	6	281	3 480	298	1	56	-	0.2
2431-3-SE-0017	*Ag* (*q*)	6.8	0.365	239	49	88	8	7	53	3	107	57	9	1	-	-	0.5
2331-3-NW-0021	*Ag* (faulted)	7.7	1.87	1 180	748	334	163	83	127	4	407	202	367	1	26	0.01	0.3
2331-4-NW-0021	*Ag* (fractured)	6.6	2.31	1 300	260	68	19	51	380	5	82	580	-	8	-	-	-
2430-1-NW-0012	*Ag* (fractured)	5.1	7.16	3 840	580	5	12	133	1 220	39	6	2 160	162	36	72	-	1.0
2430-4-SW-0005	*Ag* (fractured)	-	2.95	1 700	447	38	4	23	313	3	46	466	-	9	-	0.19	0.2
Weathered crystalline bedrock																	
2330-1-SE-0034	*Ag*	8.1	17.8	10 700	2 600	402	172	519	3 240	17	491	6 260	226	1	10	0.01	0.9
2330-1-SW-0001	*Ag*	6.3	17.7	10 700	2 000	50	162	398	3 380	17	61	5 970	657	1	45	0.01	0.1
2331-3-NE-0009	*Ag*	9.3	8.49	5 150	1 420	227	86	293	1 310	17	210	2 680	187	4	72	0.01	1.1
2530-4-SE-0040	*An*	8.5	9.46	5 580	1 780	351	170	330	1 420	36	394	3 000	350	43	15	-	0.3
2431-2-SW-0018	*An*	6.9	14.9	9 010	1 300	325	63	271	2 970	51	397	4770	607	1	76	-	0.9
2431-3-SW-0003	*An*	6.5	4.34	2 360	530	62	23	114	685	16	76	1 320	83	1	79	0.1	0.6

Electrical conductivity = (mS/cm @ 25°C); TDS = Total dissolved solids (Calculated); - = Not detected

5 Rising watertable and land salinisation

During early settlement in the area, the Wadjekanup River, in the southern part of DUMBLEYUNG, was reputedly fresh and used for stock watering (Leeming, 1994). The clearing of native vegetation and its replacement by shallow rooted annual crops has modified the natural hydrological cycle because of the inability of annual crops to intercept and utilise rainfall as completely as native vegetation. This change has resulted in an increase in net recharge to the groundwater flow systems, and an associated rise in the watertable. The rise in the watertable has been estimated at between 0.1 and 0.4 m/year (Smith *et al.*, 1997, Martin, 1992).

The watertable has risen more behind bedrock highs and dolerite dykes owing to these features impeding groundwater flow. This has led to increased groundwater discharge at the land surface and, in some localities, an increase in the extent of salt seeps and scalds, and the development of new outbreaks of secondary salinity.

Areas of high regolith salt storage (>50 mS/m) have been identified within parts of DUMBLEYUNG (Cody, 1994, Sutton, 1998, Leonhard, 1999b). This salt is now being remobilised by the rising watertable with saline seeps appearing where the watertable intersects the land surface (George *et al.*, 1997). Salt dissolution into the rising watertable has increased groundwater salinity which, when expressed through discharge sites, has resulted in the development of dryland secondary salinity and the salinisation of water-gaining streams and river systems.

The rising saline watertable is causing salinisation of farm dams, reduced crop yields and loss of vegetation. Severe salinisation exists along drainages and palaeodrainage systems that are areas of saline groundwater discharge (Cody, 1994). Other areas that are prone to secondary salinity, include breaks in slope and the foot of slopes, and valleys with shallow bedrock and large catchment areas. Farm dams can increase the hydraulic head to groundwater flow systems, thus inducing groundwater recharge which can result in waterlogging and the development of secondary salinity downslope of the dam.

Watertable rises can be managed through strategies to reduce recharge to groundwater systems or increase the discharge of groundwater within catchments. Groundwater levels can be lowered locally by abstraction or drainage of groundwater. However, these strategies may not be very effective within DUMBLEYUNG owing to the low permeabilities of the weathered bedrock aquifers that form the majority of aquifers across the area. Land management techniques, designed to maximise water use, offer the best mechanism to reduce groundwater recharge. These techniques involve greater interception of rainfall, such as harvesting surface runoff and reducing rainfall infiltration by increasing evapotranspiration. Areas that respond more readily to these techniques are generally high in the catchment, where most of the groundwater recharge takes place.

The remedial measures currently being applied may not lower the regional watertable for many years. The low permeability of the saturated weathered rock (weathered rock aquifers) and the inability of vegetation to utilise saline groundwater are the main reasons for the slow response. Intervention to local aquifers that extend over short distances (a few kilometres) may present the best opportunity to produce rapid responses with increased farm productivity (Pannell *et al.*, 1999). The identification of local aquifers and application of farm remedial measures may yield perceivable results within shorter periods, which will increase the incentive for farmers to implement salinity treatments (Pannell *et al.*, 1999).

The "Depth to watertable" side panel on the DUMBLEYUNG map sheet indicates the maximum depth of the watertable. It does not indicate the minimum depth of the watertable for predicting areas of potential waterlogging.

6 Groundwater development

6.1 Existing water supply

Groundwater development within the DUMBLEYUNG area is minimal due to the predominance of saline groundwater and the rarity of high yielding, fresh-water aquifers. The towns of Katanning, Wagin, Kojonup and Gnowangerup are supplied by the Great Southern Town Water Supply Scheme–North Katanning Extension (GSTWS–NK), which is augmented by local sources. The GSTWS–NK obtains water from the Harris Dam near Collie, which is stored in the Bottle Creek Reservoir at Narrogin and then pumped to town dams and tanks throughout DUMBLEYUNG.

Katanning utilises a 40 year-old bituminised catchment concentrated on Crown Land and adjacent to roads, farmland and an abattoir. The bituminised catchment feeds into Pinwernying Dam, a 38 year-old excavated earth dam with a clay liner. The Pinwernying Dam has a capacity of 251 400 kL and receives about 15% of its water from the local bitumen and bushland catchment and the remainder from the GSTWS–NK.

Wagin is normally supplied directly fram the GSTWS–NK via the Wickepin Tank and Cuballing Tank, and from Bottle Creek Reservoir. The town has a small local catchment that produces only small volumes of water, owing to its poor condition and small size. The Wickepin and Cuballing Tanks are filled by the Bottle Creek pump station during low-demand periods, usually overnight.

During periods of high demand, the Wagin supply can also be supplemented by water drawn from the Puntapin Rock Catchment. This catchment, located southeast of Wagin, was developed 70 years ago. The catchment feeds into Puntapin Dam, which has a capacity of 99 590 kL. The Puntapin Rock Catchment has not been used in recent years due to water quality problems occurring through the spring and summer, and the ability of the GSTWS–NK to meet winter and autumn demands.

Kojonup is supplied primarily from the GSTWS–NK, with a local dam used as a peaking supply during the summer months. Water from the GSTWS–NK is pumped to a service tank before supplying the town reticulation. The local dam has a nominal capacity of 33 400 kL and stores water derived from a bitumen catchment. There are no contamination issues arising through landuse activities on the catchment, but there is the potential for bacteriological contamination from livestock on adjacent farmland.

Gnowangerup is supplied from the GSTWS–NK and from two local sources, Gnowangerup Number 1 and Number 2 Dams. Water from GSTWS–NK is supplied from Pinwernying Dam at Katanning. The Gnowangerup Number 1 Dam has a nominal capacity of 45 250 kL and obtains water from an adjacent bituminised catchment. The dam and catchment, constructed 52 years ago on Crown Land, are in poor condition. The Gnowangerup Number 2 Dam has a nominal capacity of 29 100 kL and collects water from an adjacent bitumen catchment. The dam and catchment were constructed 38 years ago and are in satisfactory condition.

During early summer, November to early January, supply from the GSTWS–NK cannot meet town demands and is supplemented from Gnowangerup Number 1 Dam. After this period, Gnowangerup Number 2 Dam is used until it empties, about the end of summer. Any late summer demands that can not be met by the GSTWS–NK are supplied from Gnowangerup Number 1 Dam.

Roof-fed rainwater tanks provide potable on-farm water supplies. Excavated dams provide most of the stock-water supplies. Limited supplies of stockwater are obtained from groundwater aquifers, with these located predominantly in the southwestern quarter of DUMBLEYUNG.

6.2 Potential groundwater supply

The potential for groundwater supplies on DUMBLEYUNG is small. Aquifers commonly occur within the weathered profile of the granitic and gneissic bedrock and are generally of low permeability, with groundwater salinity ranging between 3000 and 7000 mg/L TDS. Groundwater within the Lake Grace, Beaufort River, Arthur River and Dumbleyung Lake–Coblinine River drainage systems is saline to hypersaline and unsuitable for stock consumption.

The saprolitic grit of the weathered granitoid bedrock is prospective for small supplies of local groundwater, although within much of DUMBLEYUNG, it is unsaturated and many bores within granitoid rocks are dry. Prospective areas may be located in mid- to lower-slope positions, where conditions are favourable for groundwater recharge.

The potential for developing potable groundwater supplies is greater in the western part of DUMBLEYUNG. Here, moderate to major supplies of groundwater have been obtained from Tertiary palaeodrainage deposits of the Beaufort River, and fractured granitic bedrock.

Moderate supplies of potable water are obtainable from perched aquifers associated with high-level palaeochannel tributary sediments (*Ta*). These sediments are commonly obscured by alluvium and colluvium (*Cz*). Groundwater yields exceeding 500 m^3/day with salinities less than 1000 mg/L TDS have been obtained from these aquifers, although the yields may not be sustainable. Potable groundwater may exist within palaeochannel deposits of the upper tributaries of the Beaufort, Arthur, Williams and Coblinine Rivers. Groundwater prospectivity increases in areas adjacent to topographically high regions, such as locations south of the Beaufort River and between the Arthur and Coblinine Rivers. Palaeochannel tributary deposits appear to extend north of Norring Lake, Lake Norring Little and Parkeyerring Lake.

Palaeochannel deposits associated with the Beaufort River may provide moderate quantities of potable water. Groundwater is obtainable from palaeodrainages (*Tw*), surficial (*Cz*) and Quaternary lacustrine (*Ql*) sediments. The area within the palaeodrainage south of the Beaufort River palaeochannel is prospective, with groundwater salinity ranging between 1000 and 3000 mg/L TDS. Quaternary lacustrine deposits, south of Lake Queerearbup and Lake Flagstaff, have potential for the development of supplies of groundwater with yields up to 550 m^3/day and salinity ranging between 300 and 1300 mg/L TDS. Other prospective Tertiary palaeochannel aquifers include the Boyerine and Beckaring Creeks, the Carrolup and Carlecatup River systems, and the upper reaches of the Coblinine River, northeast of Coyrecup Lake.

Fractured rock aquifers (*Ag*) have the potential to yield supplies of groundwater up to 1000 m^3/day with groundwater salinities typically in the range between 2000 and 7000 mg/L TDS. These aquifers are associated with major southeasterly trending faults in the southwestern portion of DUMBLEYUNG. Successful groundwater bores are situated north and south of these structures, above the palaeodrainages of the Beaufort, Kojonup and Balgarup River systems.

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Appendix 1

Digital data reference files and documentation

Design file	Level	Status	Description	Data source	Scale of capture (where applicable)
Dumbtopo.dgn	1	ON	Highways and roads	DOLA	1:250 000
	2	ON	Tracks	DOLA	1:250 000
	3	OFF	Roads	DOLA	1:250 000
	4	ON	Railways, current and abandoned, and railway siding symbol	DOLA	1:250 000
	6	ON	Pipeline and pipeline text	DOLA	1:250 000
	7	OFF	Dams, tanks and waterholes	DOLA	1:250 000
	10	OFF	Pool names	DOLA	1:250 000
	11	ON	Pool symbols	DOLA	1:250 000
	12	OFF	Farm dams and water storage reservoirs	DOLA	1:250 000
	15	ON	Indian Ocean	WRC	1:250 000
	19	ON	Lake names	DOLA	1:250 000
	20	ON	Lakes – intermittent with names	DOLA	1:250 000
	21	ON	Rivers and creeks with names	DOLA	1:250 000
	22	ON	Lakes – permanent with names	DOLA	1:250 000
	23	OFF	Rivers – omitting minor drainage lines	DOLA	1:250 000
	24	OFF	Rivers and creek names	DOLA	1:250 000
	26	OFF	Swamp names	DOLA	1:250 000
	27	ON	Swamp symbols	DOLA	1:250 000
	35	ON	Topographic contours and values	DOLA	1:250 000
	36	ON	National parks and nature reserves	DOLA	1:250 000
	41	ON	Arrow heads and text	DOLA	1:250 000
	42	ON	Highway, road and siding names	DOLA	1:250 000
	43	ON	Peaks, mountains, hills, monadnocks and ranges	DOLA	1:250 000
	44	ON	Control points: major, minor and names	DOLA	1:250 000
	45	ON	Localities	DOLA	1:250 000
	46	ON	Towns: Population > 1000; and Population < 1000	DOLA	1:250 000
	47	OFF	Control points	DOLA	1:250 000
	48	OFF	Hills and monadnocks	DOLA	1:250 000
	49	OFF	Localities	DOLA	1:250 000
	50	OFF	Homesteads	DOLA	1:250 000
					1:250 000
Dumbgeo.dgn	1	ON	Geological boundaries	DME	1:100 000
	2	OFF	Outcrop boundaries	DME	
	3	OFF	Quaternary lacustrine sediments (Ql) boundaries	DME	
	4	OFF	Hidden poly boundaries		
	5	ON	Faults concealed and inferred	DME	
	17	ON	Dolerite dykes	DME	
	18	ON	Dykes and quartz veins	DME	
	40	ON	Geological labels and lead lines	DME	
	41	ON	Cross-section lines and labels	WRC	
	45	ON	AMG Grid	DOLA	
	53	OFF	GIS, Poly labels	WRC	
	60	ON	Ticks, text for latitude and longitude grid	WRC	
	62	OFF	Latitude and longitude grid		
	63	ON	Map border		

Design file	Level	Status	Description	Data source	Scale of capture (where applicable)
Dumbsal.dgn	1	ON	Isohalines	WRC	1:100 000
	45	ON	AMG Grid		
	53	OFF	GIS Text labels		
	60	OFF	Latitude and longitude grid		
Dumbgwc.dgn	1	ON	Watertable - 240 m contours and values	WRC	1:100 000
	2	OFF	Watertable - 260 m contours and values	WRC	1:100 000
	3	ON	Watertable - 280 m contours and values	WRC	1:100 000
	4	OFF	Watertable - 300 m contours and values	WRC	1:100 000
	5	ON	Watertable - 320 m contours and values	WRC	1:100 000
	6	OFF	Watertable - 340 m contours and values	WRC	1:100 000
	7	ON	Watertable - 360 m contours and values	WRC	1:100 000
	8	OFF	Watertable - 380 m contours and values	WRC	1:100 000
	9	ON	Watertable - 400 m contours and values	WRC	1:100 000
	10	ON	Major surface water divides	WRC	1:100 000
	11	ON	Minor surface water divides	WRC	1:100 000
	12	OFF	Major surface water divides	WRC	1:100 000
	13	OFF	Digitized linework for major surface water divides		
	14	OFF	Minor surface water divide	WRC	1:100 000
	15	OFF	Digitized linework for minor surface water divide		
	45	OFF	AMG grid		
	60	OFF	Latitude and longitude grid		
Dumbbore.dgn	1	ON	Water bore – abandoned, < 50 m^3/day; Water bore – abandoned, > 50 m/day; and Water bore – dry.	WRC	1:100 000
	2	ON	Water bore – yield > 50 m^3/day	WRC	1:100 000
	3	ON	Monitoring bores	WRC	1:100 000
	4	ON	Water bore – yield < 50 m^3/day	WRC	1:100 000
	5	ON	Soaks and groundwater seepage areas	WRC	1:100 000
	6	ON	Well abandoned	WRC	1:100 000
	7	ON	Wells	WRC	1:100 000
	8	ON	Mineral exploration drillholes	DME	1:100 000
	9	ON	Springs	WRC	1:100 000
	62	ON	Latitude and longitude grid	DOLA	
				DME	1:100 000
Dumbply.dgn	1	ON	Ql	DME	1:100 000
	2	ON	Cz	DME	1:100 000
	3	ON	Tw	DME	1:100 000
	4	ON	Tks	DME	1:100 000
	5	ON	Ta	DME	1:100 000
	6	ON	Pd	DME	1:100 000
	7	ON	Aq	DME	1:100 000
	8	ON	q	DME	1:100 000
	9	ON	Ag	DME	1:100 000
	10	ON	Ago	DME	1:100 000
	11	ON	An	DME	1:100 000
	12	ON	Ano	DME	1:100 000
	13	ON	Ai	DME	1:100 000
	62	OFF	Text ID's and GIS labels		
	63	OFF	Clean linework		

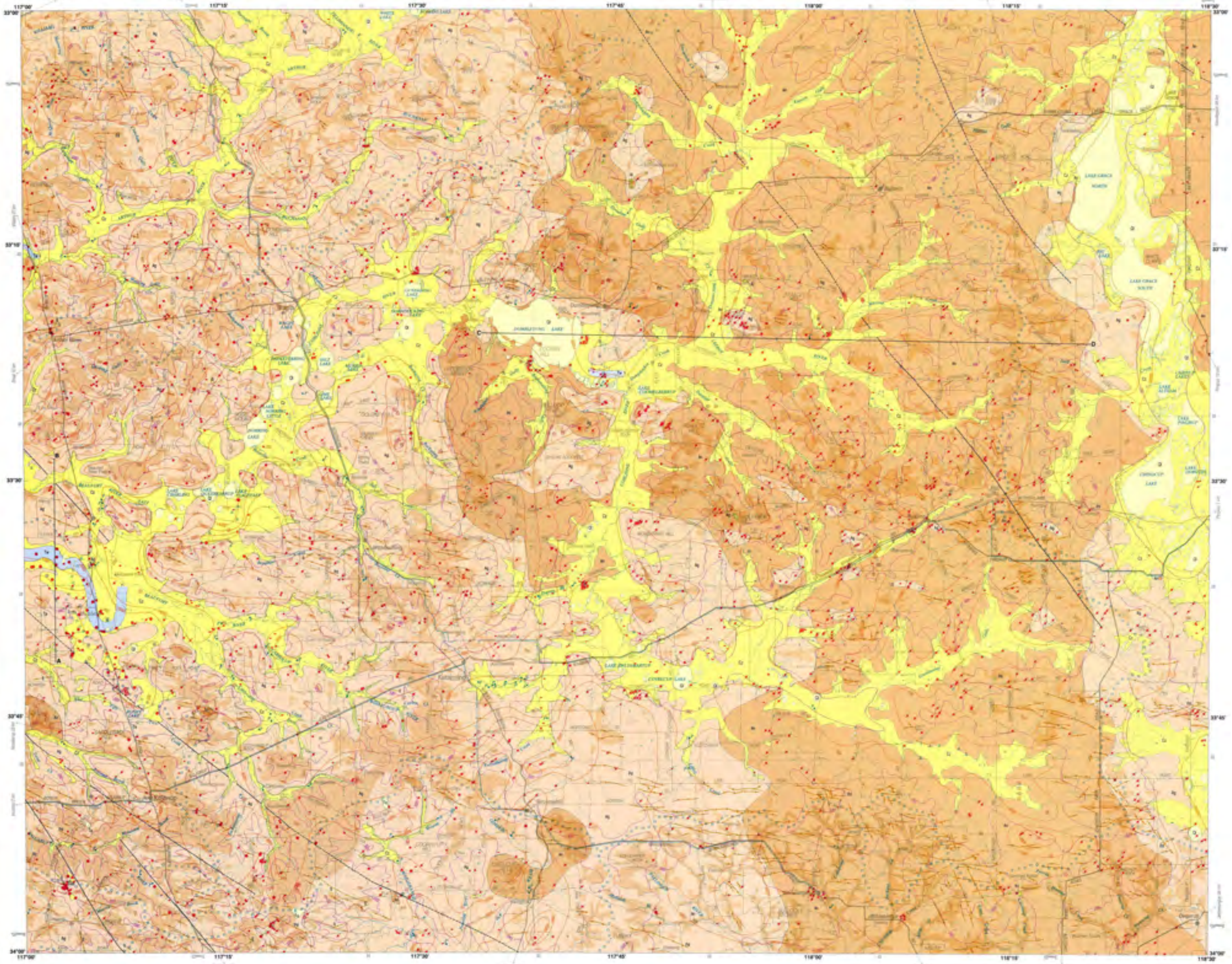
Design file	Level	Status	Description	Data source	Scale of capture (where applicable)
Dumbpan.dgn	1	ON	Linework for polygonisation and printing boundaries		
	2	OFF	Linework for polygonisation (hidden)		
	3	ON	Extent of weathering, cross-section only	WRC	
	4	ON	Groundwater features – legend and section	WRC	
	5	ON	Faults and inferred faults	DME	1:100 000
	6	ON	Bore distribution (reference scale dumbbore, replace cell moc); bores legend; bores section	WRC	
	7	ON	Isohalines – legend	WRC	
	8	ON	Topographic contour – legend	DOLA	
	9	ON	Gray linear features, legend and section		
	10	OFF	Trim marks		
	11	OFF	Printing targets for colour separations		
	21	ON	Coastline, surface water features and drainage lines	WRC	
	40	ON	Geological labels and lead lines	DME	
	41	ON	Dykes and quartz veins – legend	DME	
	42	ON	Dolerite dykes – legend and section		
	45	ON	AMG grids		
	46	ON	Map border, WRC logo – water (blue)	WRC	
	47	ON	WRC logo – leaves (green)	WRC	
	50	ON	Government logo – black outline		
	53	ON	Government logo – white		
	54	ON	Government logo – BLK 30%		
	58	ON	Government logo – BLK		
	59	ON	Government logo – BLK 80%		
	60	ON	Black text and labels		
	61	OFF	Maximum printing area		
	62	OFF	GIS labels and text Id's for polygons		
Panply.dgn	1	ON	Ql	DME	
	2	ON	Cz	DME	
	3	ON	Tw	DME	
	4	ON	Tks	DME	
	5	ON	Pd	DME	
	6	ON	Aq	DME	
	7	ON	q	DME	
	8	ON	Ag	DME	
	9	ON	Ago	DME	
	10	ON	An	DME	
	11	ON	Ano	DME	
	12	ON	Ai	DME	
	13	ON	Landmass – yellow		
	14	ON	Evaporation – graph	CBM	
	15	ON	Rain – graph	CBM	
	16	ON	Regional groundwater salinity 0 –1000 mg/L of total dissolved solids	WRC	1:100 000
	17	ON	Regional groundwater salinity 1000 – 3000 mg/L of total dissolved solids	WRC	1:100 000
	18	ON	Regional groundwater salinity 3000 – 7000 mg/L of total dissolved solids	WRC	1:100 000
	19	ON	Regional groundwater salinity 7000 – 14 000 mg/L of total dissolved solids	WRC	1:100 000

Design file	Level	Status	Description	Data source	Scale of capture (where applicable)
	20	ON	Regional groundwater salinity 14 000 – 30 000 mg/L of total dissolved solids	WRC	1:100 000
	21	ON	Regional groundwater salinity > 30 000 mg/L of total dissolved solids	WRC	1:100 000
	22	ON	Depth to watertable < 5 m	WRC	1:100 000
	23	ON	Depth to watertable 5 – 20 m	WRC	1:100 000
	24	ON	Depth to watertable > 20 m	WRC	1:100 000
	25	ON	Map area		
	26	ON	Map border		

- DOLA - Department of Land Administration
- DME - Department of Minerals and Energy
- WRC - Water and Rivers Commission
- CALM - Department of Conservation and Land Management
- CBM - Commonwealth Bureau of Meteorology

DUMBLEYUNG

WATER AND RIVERS COMMISSION



REFERENCE

AQUIFER CHARACTERISTICS

HYDROGEOLOGY

PHANEROZOIC

CAINOZOIC

QUATERNARY

TERTIARY

PROTEROZOIC

ARCHAEAN

YILGARN CRATON

SYMBOLS

GEOLOGY

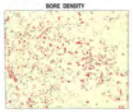
SURFACE WATER FEATURES

GROUNDWATER FEATURES

ARTIFICIAL FEATURES

TOPOCADASTRAL INFORMATION

BORE DENSITY



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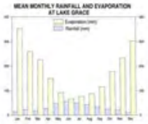
MEAN MONTHLY RAINFALL AND EVAPORATION AT LAKE GRACE



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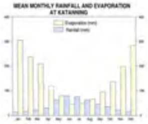

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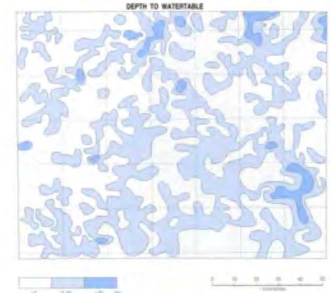

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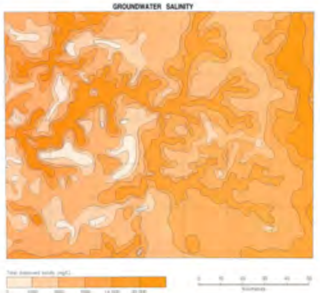

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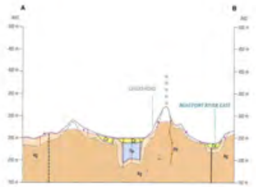

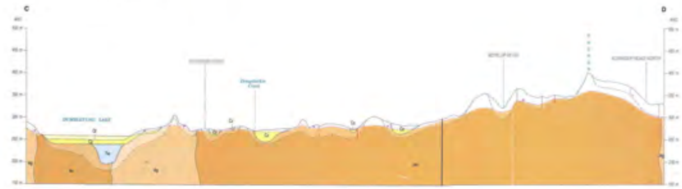

SHEET INDEX

GOVERNMENT OF WESTERN AUSTRALIA

MINISTER FOR WATER RESOURCES

WATER AND RIVERS COMMISSION

CHIEF EXECUTIVE OFFICER

SCALE 1: 250 000

TRANSVERSE MERCATOR PROJECTION

1:250 000 HYDROGEOLOGICAL SERIES

DUMBLEYUNG

SHEET SI 50-7