Government of Western Australia
Department of Environment

PERTH GROUNDWATER ATLAS

Second Edition
2004

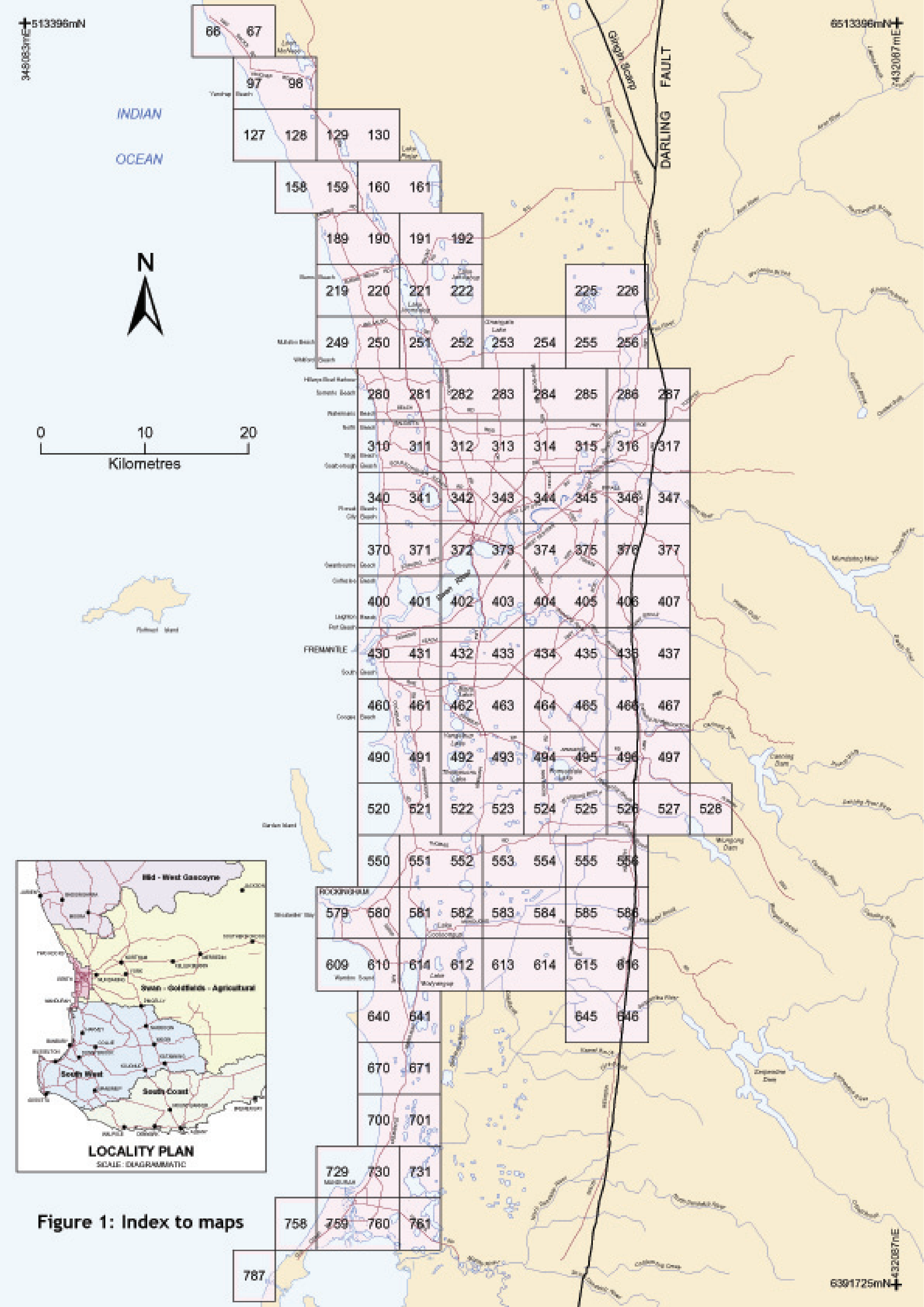

Figure 1: Index to maps

PERTH GROUNDWATER ATLAS
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Department of Environment
2004

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The Online Perth Groundwater Atlas

This text only version of the *Perth Groundwater Atlas*, Second Edition, 2004 is intended for use with the online *Perth Groundwater Atlas* (Atlas) available at <groundwater.environment.wa.gov.au/pga>. It does not contain Depth to groundwater maps, as the information in the maps is included in the online Atlas.

The online Atlas includes all of the datasets used in the printed version of the Atlas. Functionality includes being able to search for a property and easily calculate the depth to groundwater at that location.

Complete printed copies of the *Perth Groundwater Atlas*, Second Edition, 2004 are available from the Department of Environment's Information Centre.

Acknowledgments

The Department of Environment wishes to thank the Department of Land Information (DLI) for the data used in the compilation of the *Perth Groundwater Atlas*, Second Edition, 2004. Without access to the digital information, generously supplied by DLI, the preparation of the Atlas would not have been possible. The Department also acknowledges the use of Geological Survey of Western Australia Bulletin 142, cited in the explanatory notes accompanying this Atlas.

Preface

Each year in Perth about 75 million kilolitres of highly treated scheme water is used to irrigate gardens. This is about one third of all scheme water supplied annually to the Perth metropolitan area. Garden bores can reduce the demand on the scheme water supply system and therefore reduce the need to develop new public water supply sources. Not all areas of Perth are suitable for bores, but where good quality and accessible groundwater exists, garden bores are a way of tapping this resource.

Even though groundwater is readily available, it remains precious and very important to our environment and must be used responsibly. Many wetlands around Perth are formed when the groundwater surface, known as the watertable, is higher than the land surface. These wetlands support plants and trees that in turn attract birds and many other animals. Most of Perth's original wetlands have been lost to changed land use, so those remaining are vital areas for native plants and animals. Groundwater also discharges to streams in some areas, causing them to flow.

As custodian of water resources for Western Australia, the Department of Environment is encouraging responsible use of groundwater through the use of garden bores in appropriate areas. The *Perth Groundwater Atlas* is designed to help in this endeavour. The Atlas provides a guide for estimating depth to groundwater for the purpose of drilling garden bores. It also provides a guide for establishing the suitability of an area for garden bores and an indication of groundwater quality in the region. The 2004 edition of the *Perth Groundwater Atlas* has been revised to extend water table contours to cover the StreetSmart extent, where reliable watertable information was available. Additional specialist information may need to be obtained from the Department of Environment.

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Disclaimer

The information contained in this edition of the *Perth Groundwater Atlas* (Atlas) is provided voluntarily as a public service. The information is made available in good faith and is derived from sources believed to be reliable and accurate at the time of publication. However, the information is provided solely on the basis that readers will be responsible for making their own assessment of the matters discussed herein and that they should verify all relevant representations, statements and information.

Changes in circumstances after the Atlas has been published may impact on the accuracy of the information presented. No assurance is given as to the accuracy of any information or advice contained in the Atlas and readers should not rely on its accuracy.

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Introduction

The *Perth Groundwater Atlas*, Second Edition, 2004 has been designed to help water-bore drillers, irrigators, and private householders establish groundwater bores in the superficial aquifer within the Perth metropolitan area (Figure 1).

The aims of the Atlas are to provide the drilling and irrigation industries, and private householders, with information to:

- estimate the depth to groundwater of the superficial aquifer beneath a property,
- estimate the depth to the base of the superficial aquifer beneath a property – this is the maximum allowable bore depth permitted without an approved groundwater licence,
- give an indication of the salinity of the groundwater at the bore site, and
- indicate those areas where the use of information in the Atlas, or groundwater conditions, may present problems for development of a groundwater bore within the superficial aquifer.

Areas for garden bores

The areas that are generally suitable for drilling garden bores include:

- the north western urban corridor (Tamala limestone and sand)
- the central sandy areas north and south of the Swan River (Tamala sand and Bassendean Sand)
- the north eastern urban corridor in areas without clay soils (Guildford Clay)
- suburbs west of Jandakot (Bassendean Sand)
- suburbs around Winthrop (Tamala sand and Bassendean Sand)

Areas generally unsuitable for drilling garden bores include:

- the Cottesloe peninsula (because of underlying salt water)
- suburbs around Secret Harbour and Port Kennedy (limited groundwater resources)
- within 200 metres of the ocean or the Swan River Estuary (because of saltwater intrusion)
- areas in and around the foothills (where groundwater is limited)
- near some Perth wetlands (lowering of watertable by bores may affect these systems)
- near contaminated sites (where the groundwater may be polluted)

Some areas are regarded as unsuitable for bores for several reasons and it is in your own interest to follow the guidelines set out by the Department of Environment. Bores near the coast, for example, may produce salty water that will harm your garden. Those in the foothills can be unproductive and only produce small amounts of water. Refer to the section on **Groundwater supply and quality** for a more detailed description of these issues.

If there is any doubt regarding the suitability of a site being considered for a bore, please contact the Department of Environment, Groundwater Information Line.

Groundwater supply and quality

Groundwater for garden bores in the Perth metropolitan area is drawn from the superficial aquifer. The superficial aquifer is recharged by local and regional rainfall infiltration across the Swan Coastal Plain. Water infiltration from soak wells and roadway sumps, water caught from rooftops, roadways and parking lots, together with effluent leach-drains and excess garden/lawn water enhance rainfall recharge to the superficial aquifer.

The top of the superficial aquifer is represented by the watertable, which underlies the land surface. The watertable of the superficial aquifer is also referred to as the groundwater level. Groundwater within the superficial aquifer moves generally in a westerly direction and radially for the various groundwater mounds, with discharge into lakes, river systems or the Indian Ocean (Figure 2).

The superficial aquifer is available for home bore access without registration or licence. It is generally separated by a clay layer from confined aquifers, which are used to provide a high quality drinking water supply. Water may not be abstracted from confined aquifers without a licence.

Groundwater level, supply and quality (salinity and acidity) is not uniform across the Perth metropolitan area. Clarity, appearance and smell will also vary. Groundwater contamination arising from abandoned landfill sites, leaking petroleum tanks and other former land uses can decrease the quality of the groundwater within the superficial aquifer.

Groundwater supply

Groundwater supply is dependent upon a number of factors including the geology (Figure 3), local geomorphology, borehole construction, total groundwater abstraction rate in an area and climate. Productive supplies (> 50 m^3/day) of groundwater will commonly be associated with the coastal ridge (limestone) and most areas underlain by Bassendean Sand. The eastern portion of the Swan Coastal Plain is associated with Guildford Clay, which has limited capacity to yield groundwater and commonly has groundwater quality issues, such as salinity, acidity and staining. However, higher yields may be obtained in those areas where the Bassendean Sand underlies or is interfingered with the Guildford Clay and the bore is properly constructed to take advantage of groundwater occurrence within these unique horizons. On the Darling Scarp, sand and gravel deposits can form local aquifer systems within otherwise barren clay environments and are capable of supplying fresh groundwater.

Local geomorphology can modify and affect groundwater supply within areas of assumed good groundwater supply. Features such as collapsed cave systems (dolines), river elbows and the presence of former lake deposits can reduce available supply through the increased content of clay and peat. Knowing that these features are present underlying a property can assist in making appropriate decisions regarding the construction or development of a groundwater bore.

Borehole construction will often affect the quantity of groundwater and the longevity of groundwater supply. Boreholes should be constructed such that screens are against transmissive sand. The pump type and specification should be appropriate for the aquifer characteristics and capacity. Borehole construction should comply with the *Minimum Construction Requirement for Water Bores in Australia*, Steering Committee of the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ).

The density of bores in an area can affect the availability of groundwater. Increased abstraction can result in declining water levels that can then affect groundwater supply from boreholes, when reduced water levels expose pumps or pump inlets. Interference between local boreholes

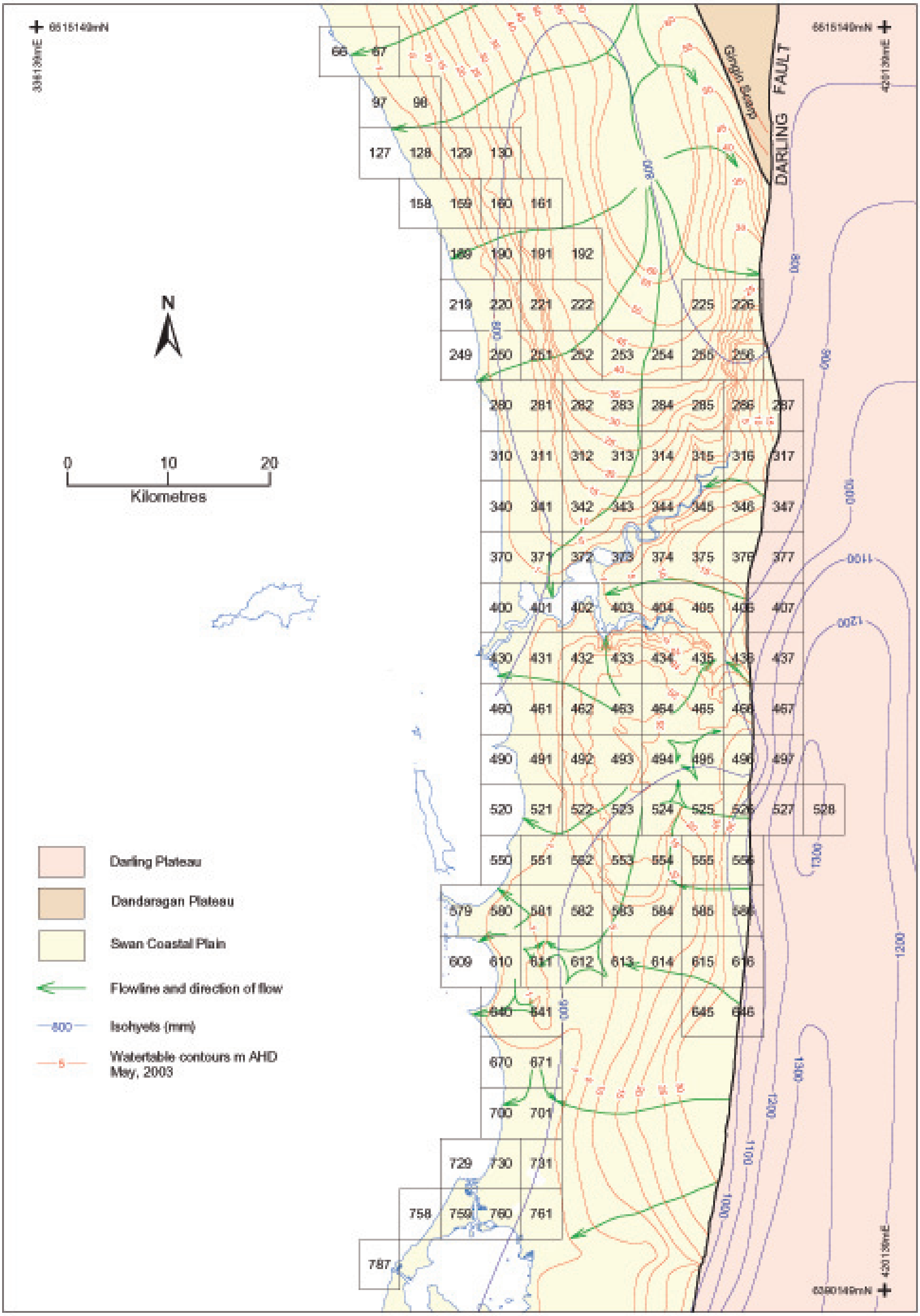

Figure 2: Watertable contours and flow directions

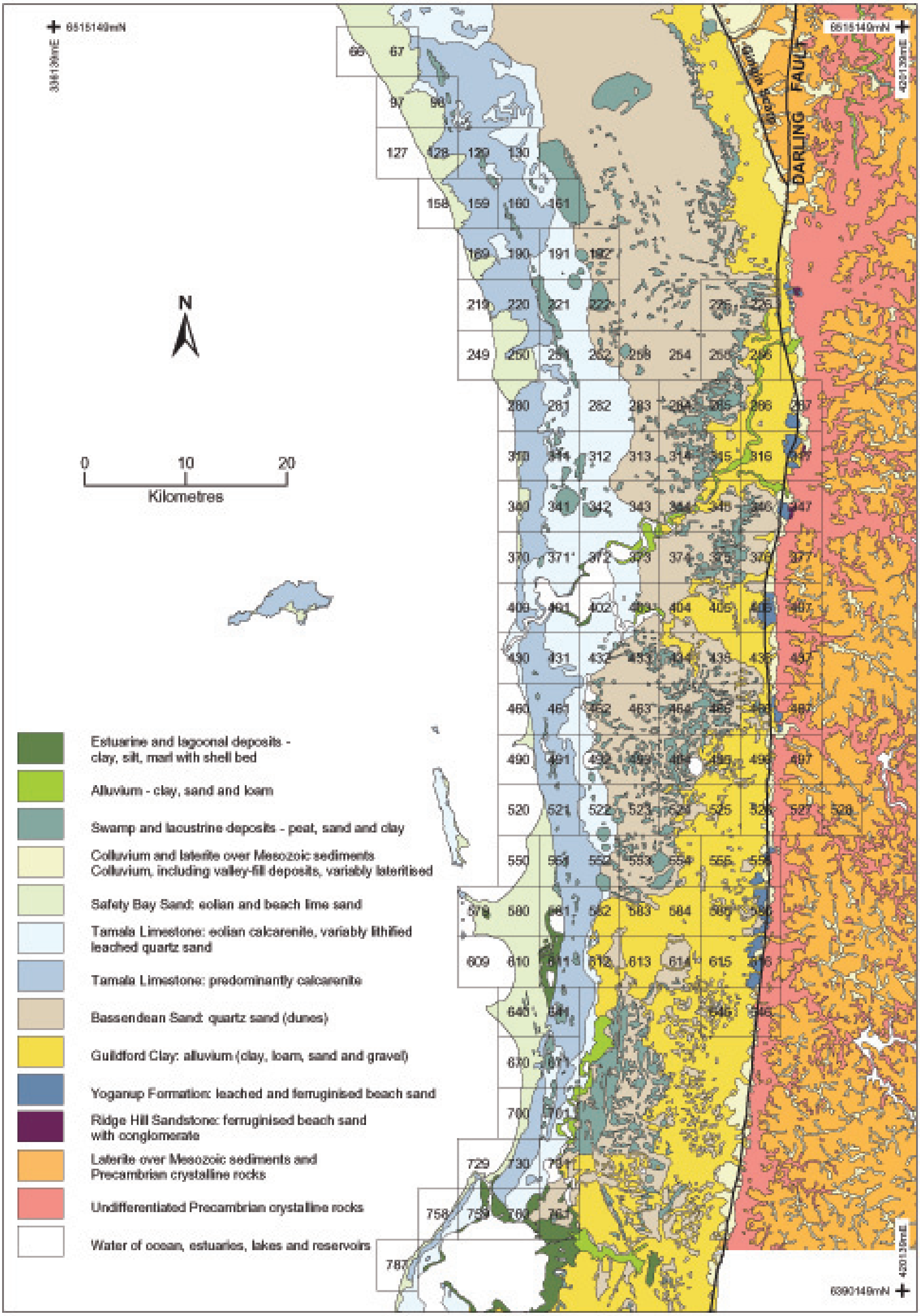

Figure 3: Surface geology

can occur when groundwater bores are positioned too close to one another, bore construction is inadequate, aquifer characteristics limit supply or local abstraction rates are too high for the aquifer to support.

Rainfall patterns are important to sustaining groundwater levels within the superficial aquifer, as it is fed directly through local rainfall infiltration. Short term changes in fluctuations in groundwater level are typically seen throughout the year. The groundwater level will be at its highest at the end of winter, following winter rainfall recharge and will continue to decline through summer due to decreased rainfall, bore extraction and evapotranspiration (plant use). Seasonal changes in the watertable can cause groundwater supply problems in shallow bores and can induce changes in groundwater acidity, clarity and colour (iron staining). Long term changes in the superficial aquifer may result from drought or reduced annual rainfalls, urban drainage or local over-extraction. Western Australia has had about a 20% decrease in winter rainfall since the early 1970s. This decrease has resulted in a drop in the watertable of the superficial aquifer across the majority of the Perth metropolitan area. Whether this pattern forms a long-term weather cycle, or is part of a changing climatic scenario has yet to be determined. Declines in groundwater levels have already resulted in the failure of many older bores, which were drilled to shallower levels commensurate with groundwater conditions at the time of bore construction.

Groundwater salinity

Salinity is the measure of total dissolved solids (TDS) or salts within groundwater and is reported as milligrams per litre (mg/L).

The salinity of the groundwater below the Perth metropolitan area varies considerably (Figure 4). In general, areas underlain by sand or limestone will have access to groundwater with a quality that is suitable for watering household gardens. The range of salinity of natural water is:

Description	Salinity range
Fresh	0 – 500 mg/L
Marginal	501 – 1000 mg/L
Brackish	1001 – 5000 mg/L
Saline	> 5000 mg/L

The following tables are guides to the salt tolerance of various garden plants and grasses, growing under average conditions of soil and drainage:

Garden Plants

Salinity (mg/L)			
< 500	**< 750**	**< 1500**	**< 2000**
Roses	Stone fruit	Celery	Fig
	Citrus	Peas	Olive
	French beans	Grapes	Silver Beet/Spinach
	Strawberries	Cabbage	Asparagus
	Flowers	Lettuce	Beet root
	Bulbs	Tomatoes	
		Potatoes	
		Pumpkin	

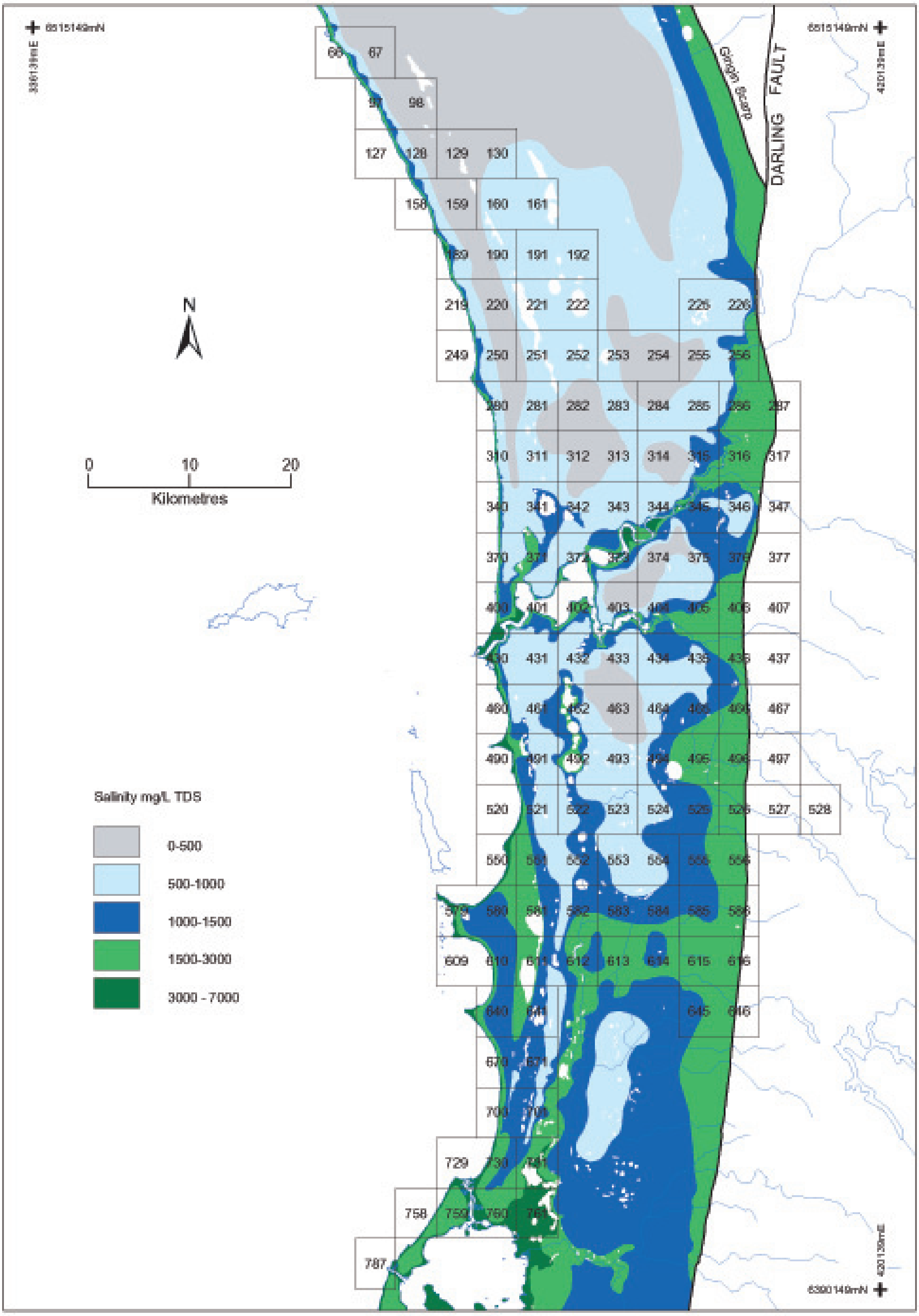

Figure 4: Generalised groundwater salinity

Grasses

Salinity (mg/L)			
< 500	500 – 1500	1500 – 2500	3500 – 13000
		perennial ryegrass	saltwater couch (saltene)
		tall fescue	
		kikuyu	
		couch	
		buffalo	

Saline groundwater can underlie areas that are situated west of nearby wetlands, located within elbows of the Swan River or positioned close to the Darling Scarp. Groundwater from bores located near the Indian Ocean, Peel/Harvey Estuaries or Swan/Canning Rivers can be brackish to saline due to the mixing of saline water or extension of the saltwater interface, or wedge.

The saltwater interface is a wedged-shaped boundary between the saline, denser ocean / river water below and fresher, less dense groundwater above. This wedge will generally extend inland by no more than 250 metres and is maintained by the pressure of the continual flow of groundwater. When the abstraction of groundwater exceeds groundwater flow/recharge capacity, inland movement of the saltwater wedge occurs. The displacement of fresh groundwater by saline groundwater within the wedge can cause bores in the area to become brackish or saline, limiting the use of groundwater. Groundwater underlying suburbs situated within points, spits and peninsulas, such as North Fremantle, Mandurah, Cape Peron and adjacent to Peron and Shoalwater, is particularly vulnerable to saline intrusion from the adjacent marine salt water.

The Department advises against drilling garden bores in the areas underlain by the saltwater interface. If garden bores are sunk near the saltwater wedge, these bores should be as shallow as possible to maintain an adequate supply without drawing up brackish or saline groundwater. If bores located in these areas are too deep or excessively pumped, the groundwater may become progressively more saline and unsuitable for garden irrigation.

Groundwater staining

Many areas across the Perth metropolitan area are affected by surface staining from groundwater (the pale grey background on the Atlas maps). This staining is the result of on-going evaporation and subsequent concentration of iron hydroxide, and less commonly manganese or calcium oxides. While most of the groundwater staining observed within the Perth area is caused by iron hydroxide (reddish brown stains), some in coastal areas, such as Mindarie Keys, Hillarys, Scarborough, Munster and Rockingham, is the result of excess dissolved calcium (white stains) precipitated as calcium carbonate. Surface staining by oxides of iron, manganese or calcium is an aesthetic problem only and does not affect the quality of groundwater for irrigation.

Data from boreholes and information from drillers indicates that the level of soluble ferrous iron, which is responsible for the brown staining, commonly decreases with depth towards the base of the superficial aquifer. If reddish-brown to black surface stains are observed in the local neighbourhood, then the risk of groundwater staining can be decreased by requesting the bore be drilled to and screened near the base of the superficial aquifer. In areas portraying visible staining, home reticulation systems should be designed to utilise drip irrigators and direct sprinklers such that over-spray onto light coloured surface is minimised.

Manganese (Mn) is a naturally occurring constituent of groundwater and is commonly associated with dissolved ferrous iron. Manganese concentrations greater than 0.05 mg/L can cause discolouration of groundwater and rusty-brown to black stains on pale coloured surfaces, brickwork and paving.

The development of a ‘white coating’ following the evaporation of bore-water is associated with excess calcium (hardness) within the groundwater of the superficial aquifer. The calcium is derived from the lime-sand of the Safety Bay Sand, and when oxidised during pumping and reticulation, forms calcium hydroxide, which precipitates as a white powder or coating on vegetation, sprinkler heads, paving and brickwork.

Groundwater odour

Odours associated with groundwater come from a number of natural and industrial sources. The most common odour reported from bores is produced by the release of hydrogen sulphide (H_2S) resulting in a ‘rotten egg’ smell. The odour of groundwater with as little as 0.5 mg/L of hydrogen sulphide is detectable by most people. Concentrations less than 1 mg/L give groundwater a ‘musty’ or ‘swampy’ odour, while concentrations greater than 1 mg/L has a characteristic pungent smell similar to ‘rotten eggs’. Hydrogen sulphide can result from a number of different sources. It can occur naturally in groundwater from the decomposition of underground deposits of organic material, such as peat.

Sulphate is also one of the major dissolved constituents of rain. Although sulphate and sulphide can react naturally with groundwater to produce hydrogen sulphide, the most common process for the production of hydrogen sulphide appears to be the reduction of sulphate by bacteria. A 1 to 2 mg/L concentration of hydrogen sulphide will make the groundwater very corrosive to steel and copper plumbing. Naturally formed hydrogen sulphide is most commonly removed by aeration. Other forms of treatment include activated carbon-filters. Regular treatment of the bore with chlorine (chlorination) may reduce and control bacteria responsible for the production of hydrogen sulphide.

‘Fishy’ odours are generated by a group of bacteria called Pseudomonads. These bacteria grow where there is oxygen and often form slime-like growths (bio-films). These slimes commonly grow over the scales of fish and produce the same characteristic smell. When these odours are observed, the well water is probably oxygenated and also carries a range of organic material that these bacteria can use for growth.

‘Septic’ odours relate to the presence of sewage and septic tank wastes but can also be generated during anaerobic degradation of organic material. Generally the water may also show a moderate amount of cloudiness and sometimes may have a grey colour. Normally the presence of septic odours should trigger testing of the water for the presence of coliform bacteria.

‘Kerosene-like’ odours are primarily due to the presence of hydrocarbons (diesel and petroleum products) in the water. If the bore develops ‘kerosene-like’ odours you should ring the Department of Environment.

‘Garlicky’ odour is generally associated with the presence of methane gas. Methane gas is formed by the decomposition of organic material. The biggest danger from the presence of methane is its explosiveness. Methane gas can be removed by aeration.

‘Fruity’ odours are very uncommon in bores and are usually associated with the presence of yeast, some of which can produce a range of ‘fruity’ esters during growth. Yeasts are not a common part of the groundwater flora and their presence would indicate that high carbohydrate or organic acid

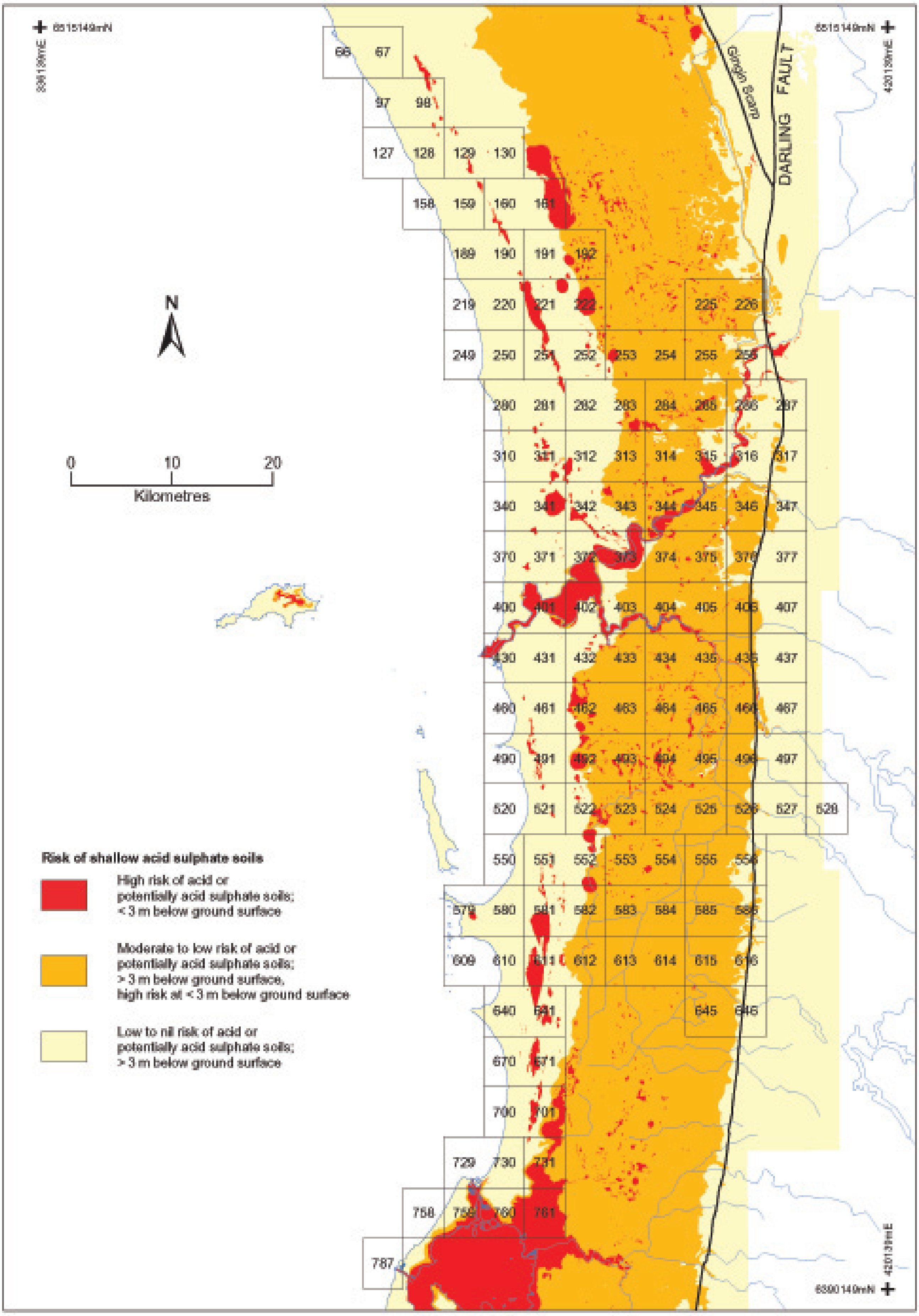

Figure 5: Potential acid sulphate soil risk

pollution is occurring. If the bore develops ‘fruity’ odours you should contact the Department of Environment.

Groundwater acidity

Groundwater acidity is commonly caused by the decay and oxidation of organic matter (peaty sediments). These processes can produce inorganic acids. Acidity is measured by pH, which utilises a scale of 0 – 14. Acid groundwater refers to groundwater with a pH generally less than 4.5. Groundwater with a pH greater than 7 is considered alkaline.

Groundwater acidity can be a problem for some bores in the Perth area. Acidity can be due to a number of causes including draining or disturbance of peaty sediments, referred to as acid sulphate soil. Peat occurs within natural sediments of present and former wetlands. These sediments can contain substantial amounts of sulphide and sulphate minerals, such as pyrite and jarosite, which are safe if not disturbed and remain under the watertable. Where these minerals are just below the surface of the watertable, lowering of groundwater levels by pumping can allow air to enter and react (oxidise) with the sulphide and sulphate minerals, which produces sulphuric acid (H_2SO_4). The sulphuric acid leaches into the groundwater and can cause further contamination by dissolving minerals, releasing potentially problematic concentrations of aluminium, iron and heavy metals, such as arsenic.

Areas have been mapped where acid sulphate soil may have the potential to generate significant amounts of acidity if the watertable is lowered by drainage, over-production or is exposed by development (Figure 5). The Perth area has been ranked into three categories based upon the occurrence of acid sulphate soil (peaty sediments) at different depths. High risk areas are those areas where acid sulphate soil may occur within 3m of the ground surface. Moderate risk areas refer to areas where there is a low chance of acid sulphate soil occurring within 3 m of the ground surface, but it may be present below this depth. Low risk areas are those areas where the geomorphology limits the occurrence of wetlands and the associated deposition of peaty sediments. Over-pumping of bores in or next to areas of high to moderate risk may result in an increase in groundwater acidification.

There are several things that can be done if you are in or adjacent to an area designated as having a high risk of acid sulphate soil occurring. Check the pH of your neighbours’ garden bores or test the pH of the newly drilled garden bore before pump installation. pH can be measured by using universal indicator test strips, available from pool supply outlets. For existing bores, it is wise to keep a monthly check on the pH of your bore over the summer and autumn months and watch for changes, such as odour or groundwater staining. Groundwater acidity (pH) needs to be measured immediately, preferably at the ‘well-head’, upon obtaining a groundwater sample as light, temperature and oxidation will affect the result.

Groundwater bacteria

Microbiological activity exists in many sub-surface aquatic regions. This is usually greatest in the nutrient-rich upper groundwater regions and generally decreases with reducing nutrient supply at greater depths, however since molecular (free) oxygen is generally absent away from the top of the watertable, anaerobic bacteria will dominate at depth.

Changes in groundwater odour, clarity or pH (acidity), surface staining or an increase in reticulation/bore clogging can be indicators of bacterial activity. This may be related to poor drilling hygiene, where contaminated water/material from an affected area is being spread to other bores. The composition and bacterial content are also influenced by changes in the environment, such as increases in groundwater nutrients derived through urbanisation, pollution of groundwater or reduction in groundwater levels.

As it is difficult to get rid of bacteria once they exist in bores and reticulation systems, prevention is the best safeguard. It is recommended that drillers disinfect everything that goes into the ground with a strong (250 mg/L) chlorine solution. When the bore is completed, it should be purged (i.e. shock chlorinated). The following steps are recommended:

1) Chlorinate to ensure that the bore water (amount of water within the casing) has a minimum concentration of 250 mg/L chlorine using Sodium Hypochlorite – 12.5% or equivalent solution.

2) Allow the chlorine solution to remain in the bore for a minimum of 24 hours, preferably longer.

3) Pump the bore to waste until purged of chlorine.

For owners of new bores in places where iron bacteria have been a problem, the best prevention is to be especially alert for signs of their occurrence. The installation of a non-return valve (to stop reticulation water from entering the bore), a diversion valve (to permit disposal and testing of groundwater prior to entry into the reticulation system), and a cap to stop foreign material from entering the bore will assist in future treatment and maintenance.

For owners of bores with previous bacteria infestation, chlorination is the best way to control re-occurrence. Owners are advised to periodically clean bores by shock chlorination, as described previously. The use of combined treatments utilising chlorine and an antiseptic dispersant has been shown to improve effectiveness. The effectiveness of chlorine treatment is limited by its ability to penetrate into the geological strata, where the bacteria will be located. Evidence also indicates that continual chlorine treatments will decrease in efficiency as the bacteria develop tolerance.

Waterwise gardening and groundwater utilisation

In the Perth area approximately 60% of all scheme water used goes on watering the lawn and garden. As the driest populated continent on Earth, Australians can not afford to waste water through inefficient use or to plant gardens that require excessive water. Inefficient use and wastage of the superficial aquifer groundwater resource can degrade natural aquatic ecosystems reliant upon this aquifer.

Groundwater should always be used in a sustainable manner that limits wastage and improves efficiency. Improved water usage is derived primarily from a reduction in evaporation gained through watering vegetation early in the morning. Watering during this period can reduce unwanted effects on vegetation, such as staining or discolouration of foliage, whilst enhancing water infiltration to root systems. Watering on windy days will cause significant waste.

Deep soaking of the garden every few days rather than a little every day will encourage plants to develop a good, strong root system. Gardens and lawns should receive enough water to wet the soil to the bottom of the root zone each time you water, or until the soil is moist to a depth of about 10 centimetres. The quantity of water can be measured using a rain gauge or tin set in the garden; a centimetre of water in the gauge or tin will be equal to the approximate amount on the garden.

The efficiency of automatic irrigation systems can be improved with the installation of a rain sensor. Sprinkler heads with a large droplet size and positioned at the edges of garden beds facing inwards will reduce over-spray and evaporation. Micro-irrigation is suitable for most areas of the garden, and allows for precise placement of water to the root zones of individual plants, using a series of droppers, micro sprays and mini sprinklers.

Use mulch to conserve soil moisture. Organic mulches help retain moisture so there is less need to water. Mulches also improve soil structure as they decompose and moderate the soil temperature, two factors that assist plants to use water efficiently. Soil wetting agents are also useful for retaining moisture in sandy soils that repel water.

Waterwise garden design and management focus on working with nature to create an aesthetically pleasing, livable landscape, while using less water. Minimising the need for water in the landscape requires careful observation, planning and common sense. Principles for waterwise gardening include using the best plants for the location, preparing and mulching soil, limiting the size of lawns and watering properly for efficient water use.

- all garden bore owners should be waterwise and use groundwater efficiently.
- water only between 6 p.m. and 9 a.m.
- if possible only water on your scheduled watering days.
- only water sufficiently to meet your garden's needs – any more is a waste.
- water from garden bores should not be used for drinking.

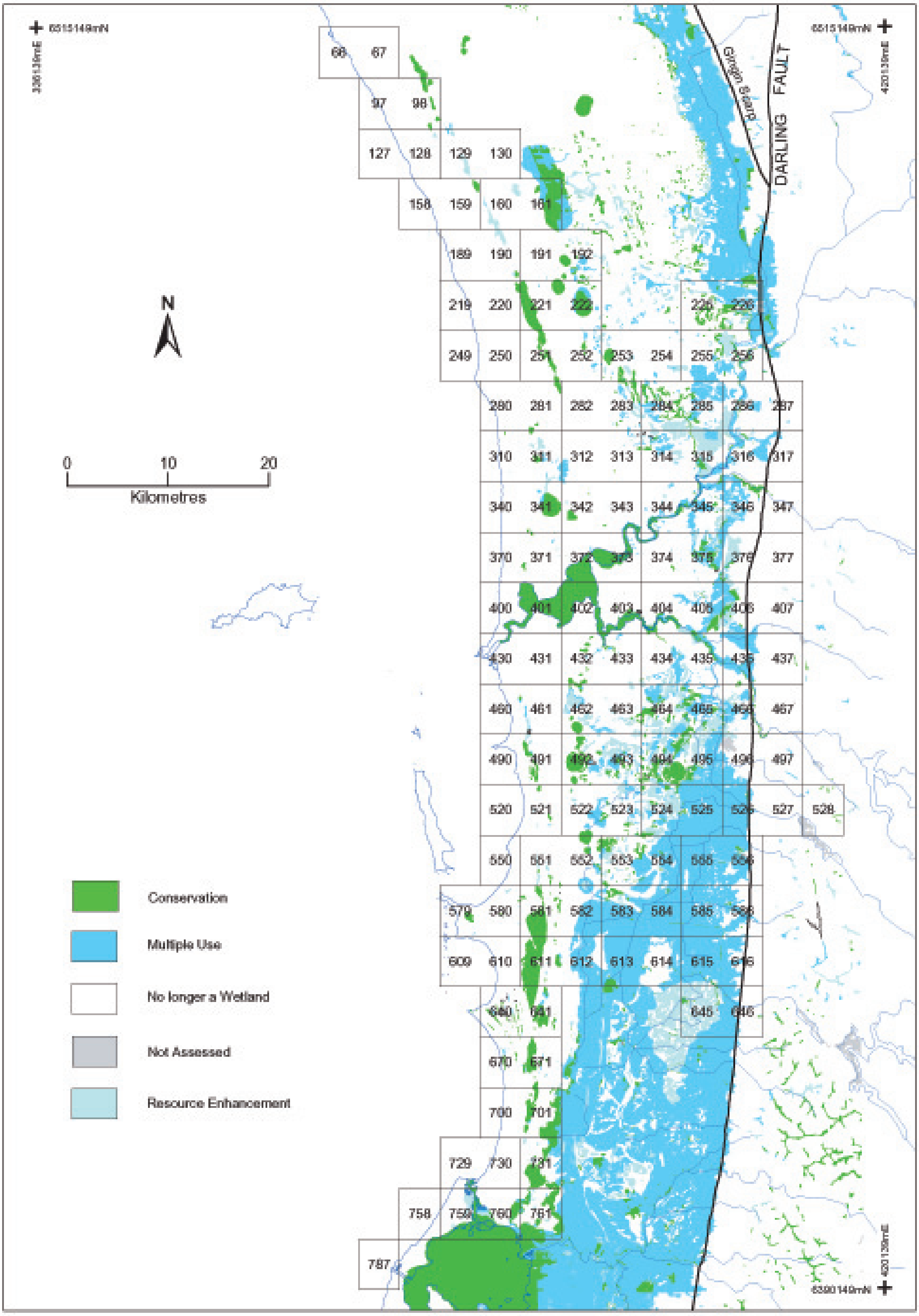

Figure 6: Geomorphic Wetlands of the Swan Coastal Plain

Groundwater bore licensing

As part of the Department of Environment groundwater management program, garden bores are exempt from licensing, while larger bores and wells may require licences. Only those owners or occupiers who use more than 1500 kilolitres of water per year, or use the water on a property in excess of 2000 m^2 (½ acre) will need a licence in the Perth metropolitan area. Also, bores are not permitted to penetrate the base of the superficial aquifer without a licence to do so from the Department of Environment.

There are currently no charges for a licence but you will need to provide the Department with some information so that the licence, when issued, ensures an appropriate volume of water is allocated for your needs. Estimates of water use are generally made using the Department of Agriculture Western Australia recommended application rate for an area of crop.

Groundwater protection areas

The Department of Environment is responsible for defining, proclaiming and protecting the catchments of Public Drinking Water Source Areas (PDWSAs). The PDWSAs are land areas where water is or will be extracted from surface water bodies or groundwater aquifers, treated to remove contaminants, then used for scheme (drinking) water supplies. These areas are proclaimed as Water Reserves, Catchment Areas or Underground Water Pollution Control Areas under the *Metropolitan Water Supply, Sewerage and Drainage Act 1909,* and Water Reserves or Catchment Areas under the *Country Areas Water Supply Act 1947*.

The Department manages land uses and activities in PDWSAs using a combination of 'Priority Classification Areas' and 'Protection Zones' for land close to abstraction points (e.g. bores and reservoirs). The priority classification areas are based on the strategic importance of the water source, zoning of the land, approved land use(s) and nature of land ownership. PDWSAs are protected to ensure the delivery of a safe, good quality drinking water to protect public health now and into the future at a reasonable cost to consumers. Some land uses may be incompatible or subject to protective conditions within PDWSAs. For more information contact the Department and ask for Water Source Protection Branch.

Wetlands

Unsustainable groundwater abstraction from a superficial aquifer can cause changes in water levels and water regimes of nearby wetlands.

The location, type and management categories of wetlands on the Swan Coastal Plain are identified in the Department's Geomorphic Wetlands of the Swan Coastal Plain dataset – an extract is shown in Figure 6. Valuable wetlands support a high level of ecological attributes and functions, therefore, activities such as unsustainable groundwater abstraction, which may lead to the loss or degradation of these wetlands, are not supported by the Department of Environment. The Geomorphic Wetlands Swan Coastal Plain dataset can be used to find out whether your proposed bore is near a valuable wetland. Valuable wetlands include wetlands shown as Conservation category and many wetlands mapped as Resource Enhancement category.

Further information

Groundwater and bores

To find out more about the water resources of Perth contact the Department of Environment by phone or e-mail:

e-mail: info@environment.wa.gov.au

For specific groundwater information contact the Department of Environment, Groundwater Information Line, by phone or e-mail:

e-mail: groundwater@environment.wa.gov.au

Additional information on the State's water resources is available from the Department's website at <www.environment.wa.gov.au> along with the online version of the *Perth Groundwater Atlas* and a series of Water Facts pamphlets on groundwater and bore water use in gardens.

For information on bore or well licensing requirements contact the Swan Goldfields Agricultural Region office on (08) 6250 8000 or Kwinana Peel Region office on (08) 9411 1777.

Information on waterwise gardening is available from the Department's website at <www.environment.wa.gov.au> or the Water Corporation on 13 10 39 or at <www.watercorporation.com.au>.

Sinking a bore

To ensure consumer protection, the Australian Drilling Industry Association (ADIA) recommends the use of drillers certified by the ADIA (or those with suitably equivalent qualifications). The ADIA can provide information on qualified drillers in your area.

phone: (08) 9382 5783
fax: (08) 9382 5781
e-mail: adia@vianet.net.au

Irrigation and reticulation installation companies that are members of the Irrigation Association of Australia (IAA) can advise on practical aspects of sinking bores and efficient irrigation systems. The IAA can be contacted on:

phone: (08) 9474 9089
fax: (08) 9367 6248

Commercial systems to treat groundwater are listed in the Yellow Pages under 'Water Treatment and Equipment'. Chemical analytical laboratories are listed under 'Analysts'.

Groundwater contamination

The Department of Environment can provide advice on water quality issues, and on the location of known areas where past activities have had the potential to cause groundwater contamination in the Perth metropolitan area. For this advice contact the Department of Environment and ask for the Land and Water Quality Branch.

The Environmental Health Directorate of the Health Department can give advice on the possible health effects of groundwater contamination. The Environmental Health Directorate can be contacted on (08) 9388 4999 or refer to their website at <www.public.health.wa.gov.au>.

If groundwater contamination is detected in garden bores, the issue should be referred to the Department of Environment. Contact the Department and ask for the Land and Water Quality Branch.

Drinking water protection

Perth relies heavily upon groundwater resources to provide drinking water to consumers. Accordingly specific areas are identified for protection in legislation to ensure that Perth can continue to receive safe, good quality drinking water to protect public health for now and into the future at a reasonable cost to consumers.

More information on the protection of Public Drinking Water Source Areas (PDWSAs) can be obtained from the Department. Contact the Department and ask for the Water Source Protection Branch or refer to the Water Quality Protection Notes series of documents on the Department's website at drinkingwater.environment.wa.gov.au.

Wetlands

More information on the Department's position in regard to wetlands is available on the wetland information pages of the Department's internet site at <wetlands.environment.wa.gov.au>. The Geomorphic Wetlands of the Swan Coastal Plain dataset can be accessed through the WA Atlas on the West Australian Land Information Service's (WALIS) internet site at <www.walis.wa.gov.au>. For instructions on accessing the dataset through the WALIS internet site refer to the Department's wetland pages at <wetlands.environment.wa.gov.au>.

Limitations of this Atlas

These limitations should be considered when using the Atlas:

- Information contained in the *Perth Groundwater Atlas*, Second Edition, 2004 has been collated from many sources and, although the best information currently available, is subject to modification as further information is gathered. The Department of Environment, therefore, cannot guarantee the veracity of the information in this Atlas.
- Groundwater level contours are estimated based on recorded groundwater levels measured in May of 2003 (end of summer). The Department of Environment is not in a position to guarantee the accuracy of the data due to seasonal variations in groundwater level (up to 3 metres), changes in climatic conditions, modification of land-surface elevation contours and accuracy limitations within the land-surface elevation contours data set provided by the Department of Land Information.
- The land-surface elevation contours, obtained from the Department of Land Information, are assumed to be representative and accurate for the Perth metropolitan area.
- The groundwater level contour and land-surface elevation contour maps are subject to modification by natural processes and new information. Depth to groundwater, calculated by using the contour maps, may therefore be inexact.
- Geological boundaries and the base of superficial formation contours are subject to amendment, as new drilling information becomes available. Depth to base of superficial formation is a generalised representation based upon available drillhole data and should be used as a guide to determine total depth of drilling (without an approved groundwater licence) within the superficial formation aquifer.
- The yield of individual bores cannot be guaranteed as this will depend on many factors, including hydrogeology, depth of bore, drilling technique, bore construction and pump specifications.
- Groundwater abstraction may evoke changes in the land-surface.
- The quality of the groundwater is variable and controlled by hydrogeology, seasonal and long-term climatic influences, bore construction, proximity to saltwater interface, local groundwater abstraction rates, land use modification and former land use activities. The Department of Environment, Groundwater Information Line, can be contacted for more information regarding groundwater quality.
- Although most groundwater in the Perth metropolitan area is free from harmful contamination, no guarantee can be given to exclude a bore from intersecting an unknown contamination source.
- The Western Australian Department of Health considers it an unsafe practice to drink or swim in untreated groundwater as experience has shown that groundwater may contain microbiological and chemical contamination. Groundwater should always be tested and then treated appropriately to ensure that it is safe for the intended use. The Department of Environment does not accept responsibility for any ill health caused to any living thing, or structural damage as a result of bore construction, bore operation and groundwater usage.

Depth to groundwater maps

Groundwater levels

Groundwater level contours are estimated based on recorded groundwater levels measured in May of 2003 (end of summer). Because of changes in groundwater and natural surface levels that can occur over time it should be clearly understood that the Department of Environment is not in a position to guarantee the accuracy of the data.

Depth to groundwater and additional information is available in the online *Perth Groundwater Atlas* at <groundwater.environment.wa.gov.au/pga>

References

Allen, A. D. (1981). 'Groundwater resources of the Swan Coastal Plain, near Perth, Western Australia', in *Groundwater Resources of the Swan Coastal Plain,* B. R. Whelan (ed.), Commonwealth Scientific and Industrial Research Organisation (CSIRO), Proceedings of CSIRO and Water Research Foundation of Australia Symposium, pp. 29–74.

Davidson, W.A. (1995). *Hydrogeology and Groundwater Resources of the Perth Region, Western Australia,* Western Australia Geological Survey, Bulletin 142.

Agriculture Western Australia, 1999. 'Tolerance of plants to salty water', Farmnote No. 71/99.

Steering Committee of the Agriculture and Resource Management Council of Australia and New Zealand (1997). *Minimum Construction Requirement for Water Bores in Australia*.

Davidson, W.A. and Yu, X. (2004), *Perth Region Aquifer Modelling System – PRAMS, Hydrogeology and Conceptual Model*, Department of Environment, Hydrogeology Report No. 202.

Appendix 1:
Sources of information for the Atlas

The datasets detailed in this table were used in development of the Atlas and are used in the maps and figures in the Atlas:

Figures	Dataset	Custodian	Date
Front cover	Landsat Imagery	Department of Land Information	2003
Figure 2 – Watertable contours and flow directions	Flowline and direction of flow – from Bulletin 142, Figure 27	Geological Survey of Western Australia	1995
Figure 2 – Watertable contours and flow directions	Watertable Contours	Department of Environment	May, 2003
Figure 2 – Watertable contours and flow directions	Isohyets	Bureau of Meteorology	1998
Figure 3 – Surface geology	Surface Geology	Department of Environment	2004
Figure 4 – Generalised groundwater salinity	Superficial aquifer – groundwater salinity	Department of Environment	2004
Figure 5 – Potential acid sulphate soil risk	Acid Sulphate Soil Risk Map for Swan Coastal Plain	Department of Environment	2004
Figure 6 – Geomorphic Wetlands of the Swan Coastal Plain	Geomorphic Wetlands of the Swan Coastal Plain	Department of Environment	2005
Figure 7 – Groundwater monitoring bore locations and 5 metre topographic contours	Topographic Contours (1 m and 5 m)	Department of Land Information	2000
Figure 7 – Groundwater monitoring bore locations and 5 metre topographic contours	WIN Groundwater Sites, Monitoring	Department of Environment	2003
All figures and maps	StreetSmart 2002 Index	Department of Land Information	2002
All figures and maps	Western Australian Generic Road Centreline dataset	Department of Land Information	2004
All figures and maps	WA Coastline	Geoscience Australia Department of Environment	2001
All figures and maps	Rivers	Department of Environment	2004
Depth to groundwater maps	WIN Groundwater Sites, Monitoring	Department of Environment	2003
Depth to groundwater maps	Topographic Contours (1 m and 5 m)	Department of Land Information	2000

Figures	Dataset	Custodian	Date
Depth to groundwater maps	Contour on base of superficial formations – from Bulletin 142, Figure 22	Geological Survey of Western Australia	1995
Depth to groundwater maps	Superficial Aquifer – groundwater development risk	Department of Environment	2004
Depth to groundwater maps	Superficial aquifer – groundwater staining risk	Department of Environment	2004
Depth to groundwater maps	Watertable Contours	Department of Environment	May, 2003

These new datasets were developed for this Atlas:

Watertable contours

The Atlas watertable contours are based upon May 2003 (end of summer) measurement of superficial aquifer groundwater levels from 816 Department of Environment monitoring bores within the superficial aquifer (Figure 7). These values have been used in association with estimated water levels for end of summer 2003 based on hydrographs for 71 additional selected bores.

When drawing the superficial aquifer watertable contours the following conditions and assumptions were applied:

1) The superficial aquifer (Swan Coastal Plain) is bounded by the Indian Ocean and the Darling Scarp / Gingin Scarp.
2) The watertable contours were drawn to conform to end of summer (May) 2003 measurements.
3) The watertable contours have been generally constructed by proportional triangulation between data points.
4) The contours were manually manipulated to best fit the most likely hydrogeology of the area, particularly around lakes and rivers.
5) Surface water, such as rivers and lakes, was interpreted as a surface expression of the superficial groundwater system.
6) The surface of the superficial aquifer (watertable) appears as a uniform continuous surface across the landscape.

Watertable contour confidence

Figure 7 can be used as a general indicator of the confidence of watertable contours displayed on the depth to groundwater maps.

The hatching on Figure 7 represents areas where the land-surface elevation contour set from the Department of Land Information has been determined on a 5 metre land-surface elevation contour interval. The increased contour interval reduces the ability to determine both depth to groundwater and depth to the base of the superficial aquifer.

The bore density on Figure 7 is indicative of the watertable contour confidence. Areas of relatively high density of monitoring bores generally have higher confidence watertable contours than those areas with a lower density of monitoring bores.

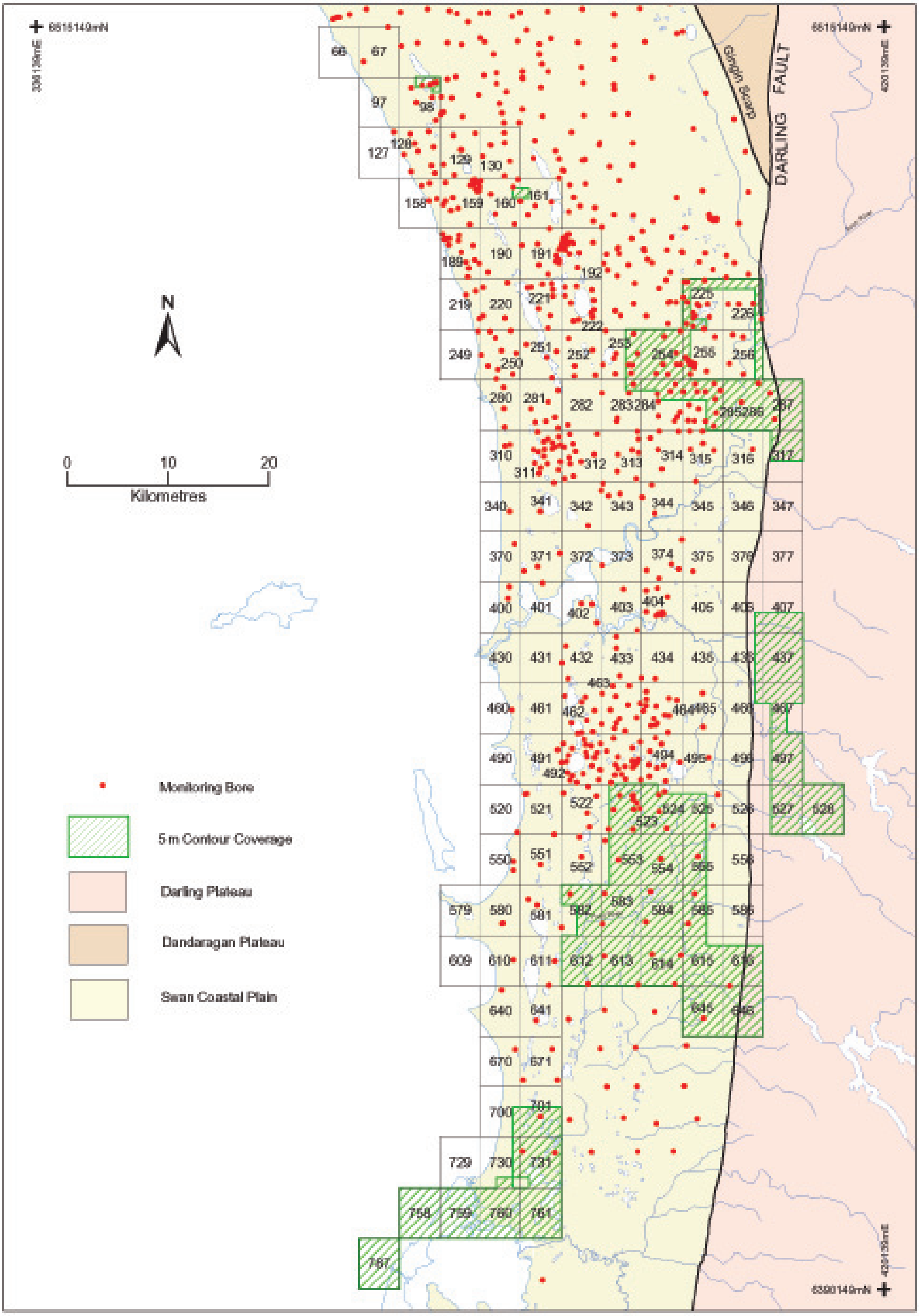

Figure 7: Groundwater monitoring bore locations and 5 metre topographic contours

Groundwater development risk

The groundwater development risk theme (the pale yellow background on the Atlas maps) was drawn to indicate those areas where the use of the Atlas for the development of a bore within the superficial aquifer may not provide satisfactory results due to poor groundwater quality or quantity. This coverage was created to portray the area where care should be observed and additional information on local groundwater conditions should be sought via neighbourhood bores, local knowledge or by contacting the Department of Environment, Groundwater Information Line.

The following conditions and assumptions were applied when creating this coverage:

1) The accuracy of the Atlas is limited by the number of monitoring bores. A high density of monitoring bores is generally associated with well-developed suburbs. A reduction in the density occurs in the outlying areas of the Atlas, such as those locations close to the Darling Scarp in the eastern edge of the coverage, or in the southern portions of the map sheet. Inconsistency between observed groundwater levels and modelled (Atlas) groundwater contours has been observed in local government areas including Ellen Brook, Oakford, Anketell, Wandi, Baldivis, Banjup and Wellard.

2) The quality of groundwater available from the superficial aquifer may not be appropriate for garden reticulation when its salinity is greater than 1500 mg/L of total dissolved solids (TDS). The salinity of groundwater varies with depth, such that a better quality groundwater may be available near surface or at depth. This parameter was determined by using information from drilling contractors and data presented in Davidson (1995).

3) The quantity of groundwater available from the superficial formation may not be appropriate for normal garden reticulation purposes. A groundwater supply less than 50 m^3 per day or 35 litres per minute has been deemed to be insufficient to develop by submersible pump (1 standard pop-up sprinkler will use approximately 10 litres per minute). Areas that are positioned near the eastern border of the Atlas area (near the Darling Scarp) or within the flood plain of the Serpentine, Swan, Canning or Southern Rivers may not have the characteristics to provide sufficient groundwater supply for economic development.

4) It is not advisable to locate a bore an area affected by the saltwater interface, where groundwater quality is expected to be poor or the quantity of fresh groundwater available is limited.

Groundwater salinity

The generalised groundwater salinity map (Figure 4) was generated from the following sources:

1) Groundwater salinity (TDS) in ‘superficial formations’ (Allen, 1981, Figure 10).

2) Superficial aquifer groundwater salinity (Davidson, 1995, Figure 32).

3) A set of 6 1:40 000 scale salinity maps for the Perth metropolitan area and adjacent 1:100 000 scale maps for the Pinjarra 2032 and Fremantle 2033 sheets (Geological Survey of Western Australia, unpublished).

Groundwater staining risk

The iron staining risk theme (the pale grey background on the Atlas maps) represents areas delineated as having an elevated iron/manganese staining risk according to data available at the time of publication. The map does not include all locations that may have iron staining potential. Groundwater staining is commonly caused by the presence of ferric iron in the groundwater (refer to section on groundwater staining), however staining is also caused by manganese and calcium.

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