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Salinity in the Northern Gulf Region
Condition report for the Northern Gulf Regional Management Group

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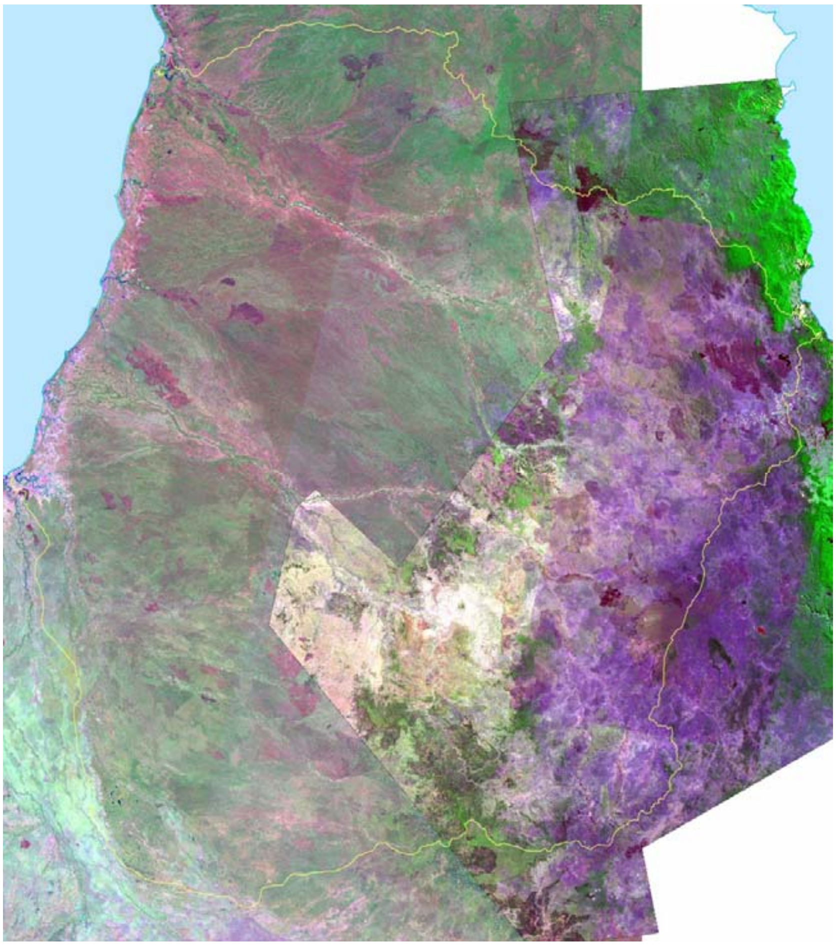

Northern Gulf Resource Area Satellite Map

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Summary

There is very little information on salinity hazards and the risk of further salinisation in the Northern Gulf region. In this report we summarise the information that is known, referencing all studies that have been done. Large naturally saline areas occur on the coastal plains, and smaller outbreaks are known to occur further inland. From the sparse data available we can infer that there may be significant salt stores in soil profiles and aquifers in considerable areas. However, due to the limited extent of tree-clearing to date, the risk of further salinisation is low in non-irrigated areas. Currently available hazard and risk maps are broad, based on very little information, and should not be used to advocate any changes in land use without further studies. In irrigated or potential irrigation areas, it is essential that thorough studies of salt stores and hydrogeology be carried out if salinisation is to be prevented. The main areas of current concern for development of salinity in the irrigated areas of the region are in the Cattle Creek and Two-Mile Creek sub-catchments (MDIA) of the Upper Mitchell River. In some parts of these areas salt loads occur in the groundwater or in the lower strata of the soils. In some of these areas the groundwater has risen to within 2-4m of the soil surface. This combination of factors presents an imminent threat of salinisation. Hence continued monitoring of groundwater levels and quality is essential in all irrigated areas. One of these risk areas (Cattle Creek) is currently the subject of a pilot salinity risk assessment. Once the risk factors and processes are better understood land and water management strategies can be further improved to minimize the risk of salinisation.

Introduction

This report is an output of a project on Salinity that forms part of the Foundation Bid of the Northern Gulf Resource Management Group. In this report we summarise the information on salinity in the Northern Gulf region that is available and indicate priority areas where further information is required if changes in land use are being considered and salinisation is to be prevented.

The Northern Gulf region consists of the catchments of the Norman, Gilbert, Staaten and Mitchell Rivers. It includes much of the Shires of Mareeba, Carpentaria, Croydon and Etheridge and small parts of Cook and McKinlay Shires.

Experience from southern states has shown emphatically that prevention of salinity is far more cost-effective than cures, and in many cases land has become unproductive in perpetuity once salinised.

Spatial data from the studies described in this report has been compiled into an ARC View GIS project at NRM&E Mareeba as part of this project. When reading the report, please note that we have attempted to define all technical terms and acronyms in the Glossary.

Salinity: what, where and why

Salinity is all about the amount of salt in the landscape, and how it is moving or accumulating. Salt can be defined as material that dissolves readily into cations and anions when in water. The cations are most commonly sodium, calcium and magnesium, and the anions are usually chloride, sulfate and bicarbonate. Any combination of these cations and anions is a salt, but the most common salt in Australian soils and waters is sodium chloride. Salts originate mostly from weathering of rocks and from the sea via rainfall. Gunn and Richardson (1979) discussed the nature and possible origins of salt in some landscapes of eastern Australia. Salts are subsequently moved around the landscape, so that they now also occur within soil profiles and the deep layers of unconsolidated material overlying rocks, often referred to as the regolith, in groundwater, surface water and irrigation water. The glossary defines various terms related to salinity, and describes how it is measured.

When the concentration of salt in soil or water is high enough to adversely affect plant growth (or palatability in the case of water), we call the soil or water saline. Salt in soil affects plant growth by increasing osmotic potential of soil water and thereby making it more difficult for plants to extract the water from the soil. Salts can also be toxic when at sufficiently high concentrations.

When discussing salinity it is also worth defining *sodicity*, which is related, but not the same. Soil or water is termed sodic when sodium constitutes a high proportion of the total amount of cations. In most soils, most of the cations are attached to the negatively charged soil particles and are termed exchangeable cations. Of course cations also exist as salts in the soil water (along with anions), especially in saline soils. The exchangeable cations are in equilibrium with the cations in the soil water, so if sodium chloride makes up a large proportion of the salts in soil water, then a high proportion of the exchangeable cations will also be sodium, and the soil will be sodic. Thus saline soils are usually also sodic. However, sodic soils are not necessarily saline i.e. sodium may constitute a high proportion of the exchangeable cations in the soil, but salt content may be low. Sodic soils tend to set hard when dry, be sloppy when wet and have low permeability to water, air and roots, leading to poor plant growth.

Salt is quite mobile in landscapes, moving with water and accumulating where water stops moving as a liquid. Therefore, landscapes with wet climates contain little salt; over time it has leached out of the soils in deep drainage, left the landscape in groundwater and streams and ended up in the sea. However, in very dry climates, where evapotranspiration (the total loss of water as vapour from plants and soil) is greater than rainfall for most of the year, water in the soil tends to move up to the soil surface, bringing salts with it. When the water is lost to the atmosphere as water vapour, the salt remains, accumulating at the surface. Much of the Northern Gulf region falls between these two extremes of climate, with evapotranspiration being greater than rainfall for some of the year, and rainfall being greater than evapotranspiration for some of the year. As a result, salts have been leached out of some parts of the landscape and have accumulated in others. We have very limited information on the amounts and locations of salt in the Northern Gulf, but what is known will be discussed below. Where salinity occurs naturally it is called *primary salinity*, whereas if salinity has developed due to changes in land use or management it is called *secondary salinity*.

Where topography, climate and vegetation cover remain stable over long periods of time, such as in the Northern Gulf region (albeit with substantial annual fluctuations), the distribution of salt in landscapes tends to be fairly stable. However, changes to vegetation such as tree clearing tend to change the water balance and hence the movement of salt. When trees are cleared, evapotranspiration tends to decrease, which can increase the amount of water leaching through the regolith and reaching the watertable. The increased recharge then raises the watertable, which increases the discharge of water and salt to the surface in low parts of the landscape. Where, to what extent, and how quickly this happens depends on the topography and hydrology of the landscape and the amount of salt in the regolith and groundwater. For example, where the movement of groundwater is restricted by underground dykes, groundwater can rise quite rapidly. Even if the groundwater is not particularly saline, increased evaporation from discharge areas can concentrate the salt, making those areas saline. This form of salinisation, called dryland salinity, tends to develop over a few decades following tree clearing.

Irrigation can also cause salinisation of soil and water, for several reasons. First, irrigation increases the amount of recharge to groundwater, thus having similar effects to tree-clearing. Once the groundwater is within a few metres of the surface, capillary action will draw water to the surface, concentrating salt in the root zone. Irrigation also adds salt to the soil; even good quality water contains some salt. The better the quality of the irrigation water (the lower its salinity), the higher the rainfall, and the higher the *leaching fraction* (the proportion of applied water that leaches below the root zone), the less likely that soil salinisation will occur. However, in order to prevent salinisation of the root zone, rising groundwater must be drained before it reaches 1-2 metres from the surface, and must then be disposed of without causing problems downstream. Salinisation caused by ‘irrigation’ can also occur where water from artesian bores is allowed to flow freely at the surface.

Erosion can also increase the salinity of surface soil, by removal of the less saline topsoil and exposure of the more saline subsoil. The exposed subsoil may not be saline, but is frequently sodic. Areas in which saline or sodic subsoils have been exposed by erosion are termed erosional scalds.

When discussing whether salinity will increase in extent or severity, we use the terms *salinity hazard* and *salinity risk*. These terms have been used differently in the past, but are now defined as follows. *Salinity Hazard* refers to the inherent landscape or catchment characteristics that make that catchment naturally susceptible or prone to the development of salinity problems. *Risk* refers to the probability that salinisation will occur in the event of certain changes in the area’s water balance (caused by land use practices as well as other dynamic features such as climate, rate of groundwater rise, depth to watertable, recharge rate, stream discharge quantity and quality, and amount, type and condition of vegetation). So we have *hazard* as the natural susceptibility already present, and *risk* as the likelihood of salinity developing due to changed circumstances. Predictions of future salinisation are made on the basis of hazard and risk, and include the dimension of time. Predictions are usually achieved by modelling the various pathways of water in the water cycle, and require sound data on both the constant and variable characteristics of a particular landscape (Salinity and Contaminant Hydrology Group, 1997). The data required to predict salinisation is not available for most of the Northern Gulf region. We have extremely limited knowledge of two critical factors: the salt stores in the regolith and the nature of the shallow groundwater systems that mobilize salt near the surface.

NR&M has published several fact sheets regarding salinity. They are listed in the Reference section under NR&M, and can be found at www.dnr.qld.gov.au

History of salinity assessments in Queensland and the region

Although small outbreaks of salinity have always been known in northern Queensland, land degradation due to salinisation has not been considered an issue of concern until recent decades. In the Northern Gulf region there is very little information explicitly on salinity and only broad-scale information on related land resource parameters, with the exception of the upper Mitchell catchment in the MDIA.

A state-wide survey carried out in 1990 indicated that DPI (now NRM&E) staff were aware of 10,000 ha of severely affected land and approximately 74,000 ha at risk of salinisation in the future over the state (Gordon, 1991). The survey indicated areas where staff knew salinity occurred, and did not attempt to assess salinity hazard in areas unfamiliar to staff at the time. Virtually no occurrences were recorded in the Northern Gulf region, apart from in the MDIA. The awareness and/or extent of salinity had increased by 2000 (Gordon et al., 2000). Workshops leading to that report indicated that outbreaks of salinity and/or waterlogging tend to be localized in extent and that there were numerous 'ways in which salinity was expressed, resulting from various combinations of geology and landforms. Salinity tended to occur at the change of slope in valley floors, as leakage from elevated Tertiary sediments and basalts, and as salinity in marine sediments. The most significant salinity-related risks for the future that were identified by regional staff included:

- rising water tables resulting from intensive irrigation
- increasing seawater intrusion resulting from excessive groundwater use adjacent to coastal areas
- deteriorating groundwater quality associated with water extraction from sub-artesian aquifers in western Queensland
- the impact of soil sodicity on future agricultural production (Gordon et al., 2000).

Broad scale assessments of salinity hazard and risk

Over the last decade, several state-wide assessments of salinity have been made. An initial simple assessment of salinity risk was carried out for the whole of Australia in the 'Salinity Management Handbook' (Salinity and Contaminant Hydrology Group, 1997). This assessment was made using climate alone. Areas in northern Australia with average annual rainfall of 700-1,100 mm were considered high risk due to a high chance of increased groundwater recharge if land use changed. That assessment put most of the Northern Gulf region in the high-risk category. However, since then it has become clear that high rainfall intensity and therefore high surface runoff probably makes most of this area lower risk.

A more sophisticated state-wide assessment of salinity using a GIS-based approach was carried out for the National Land and Water Resources Audit, a program of the Natural Heritage Trust (NLWRA, www.nlwra.gov.au) that operated from 1997 to 2002. The map showed areas that were predicted to become saline by 2050, based on a combination of climate, soil, topographic and vegetation factors (NLWRA, 2000, concept described by Searle and Baillie, 1998). While the map was published as a 'hazard' map and is described as such hereafter, using the current terminology it would be better termed a 'risk' map, as changes in vegetation were included in its production.

The NLWRA hazard assessment was carried out using the layers and categories shown in Table 1. The information that was used in the layers is described in the following section. Ground Water Flow Systems were based on the 1:2,500,000 geology coverage, shown in Figure 1. 'Excess water' was calculated using a combination of rainfall and evaporation parameters. Soils from the 'Atlas of Australian Soils' were classified into 4 classes based on the inferred permeability/wetness of the dominant soil type. The landscape description contained in the coverage was also considered along with the sub dominant soil types when assigning the land units to a salinity hazard class. Vegetation change was derived from the SLATS report for 1999. Landscape position was defined by a relative elevation (1 km resolution) and a wetness index, both derived from the AUSLIG 9" DEM, with areas expected to be wetter given a high hazard rating. The layers were weighted as shown in Table 1 so as to reflect reliability of the data and the supposed importance of the data in the process.

Two versions of the map were produced, using slightly different combinations of the parameters described. Figure 2 shows the Northern Gulf section of the map produced for the NLWRA. Figure 3 shows the Northern Gulf section of the map designated the 'Queensland Salinity Hazard' map. In both maps, the occurrence of soils with low permeability in flat areas were the main factors leading to moderate or high salinity hazard.

Table 1. GIS layers and categories used to produce the Queensland Salinity Hazard map (NLWRA, 2000)

Conceptual layer	Weighting	No Salinity Hazard	Possible Salinity Hazard	Likely Salinity Hazard	High Salinity Hazard
Ground Water Flow Systems	5	Depends on Classification			
Climate	1	Low volume of excess water	Small volume of excess water	Moderate volume of excess water	High volume of excess water
Soils	1	Highly permeable,	Moderately permeable,	Moderately permeable,	Slowly permeable,

		well drained soils	imperfectly drained soils	imperfectly drained soils	poorly drained soils
Vegetation Change	5	No Change (Still wooded)	Wooded to Pasture	Pasture to Crop	Wooded to Crop
Landscape Position	3	Short steep catchments	Moderately sloping catchments	Long gently sloping catchments	Long flat Catchments

A process for more detailed (1:250,000) systematic mapping of salinity hazard ('SHAM') in Queensland has been agreed between lead State and Federal agencies as part of the National Action Plan for Salinity and Water Quality (NAP, www.napswq.gov.au, 2000-2007). This mapping predicts areas of higher to lower probabilities of salinity hazard occurrence, based on the best available natural resource information at this scale and an expert system operating in a GIS environment. The currently funded program is limited to 21 'priority' catchments in Australia, the most northerly of which is the Burdekin. However, with the process and expertise now well established, it should be feasible to conduct similar hazard mapping in other at-risk catchments in the coming years. The concept for the SHAM process is to identify combinations of biophysical attributes that result in greater inherent capacity for the mobilization of salt. The fundamental components of potential for salt mobilization are:

- Regolith salt store (how much salt is present in the soil and sub-strata?)
- Recharge capacity (how much water is available to drive mobilization?)
- Discharge potential (is there potential for that salt to discharge to the surface or streams?)

Efforts to model salinity hazards and to delineate hazard areas in the Northern Gulf must address these components by using appropriate bio-physical attributes of the landscape. Until this process is conducted over the region it will not be possible to systematically delineate salinity hazard areas.

Currently available information on salinity hazard and risk in the region have been compiled by Gordon et al. (2000), Webb, Holden and Herbert (2000), Webb (2003) and Webb, Herbert and Philip (2004).

For completeness we also mention the National Dryland Salinity Program (NDSP, www.ndsp.gov.au), which was a large research, development and extension program operating from 1993 to 2003. A great deal of information was generated but no work was carried out specifically in the Northern Gulf region; most was carried out in the Murray Darling Basin.

Information for the region on which salinity assessment has been or could be based

In the previous section the information used to assess salinity hazard and risk was mentioned. We need salt stores, recharge capacity and discharge potential, which are derived from data for soils and regolith, climate, vegetation, topography, groundwater flow systems and existing and potential land uses.

Surface water salinity can be useful for assessments of salinity in the landscape. However, it only starts to increase when there has been a considerable shift in land use and salt loads within the catchments. That is not the case in the Northern Gulf, so the NR&M database on surface water hydrology and quality (WATERSHED) was not interrogated for this report. Ryan et al. (2002) noted significant salinities in several watercourses in the upper Mitchell catchment.

Soils

Salinity hazard assessments in the region have used soil maps to infer two distinct parameters. Firstly, permeability and the ability to allow recharge to groundwater, and secondly, salt store. Soil maps are not ideal for either purpose, as they usually describe the top 1 or 2 m or so whereas the salt content and permeability of deeper layers may be important components of salinity hazard. However, soil maps were used because they provided the only data for estimating these factors over the region. Most of the soil information described is archived in the NRM&E Soil and Land Information database (SALI). A wide variety of soils are present in the region, and several soil classification schemes have been used in the studies mentioned, so the classification schemes used (Great Soil Groups, Factual Key, Australian Soil Classification) and the soil names mentioned in this report are defined in the Glossary.

The first significant study of the land resources in the region was the CSIRO Land System study of the Leichardt-Gilbert area carried out in the 1950's (Perry et al., 1964). That study covered approximately the southern half of the Northern Gulf region. Already then it was recognized that "some of the heavier delta soils may present salting problems". The northern half of the Northern Gulf region was covered in the Land System study of the Mitchell-Normanby area carried out during the 1960's (Galloway et al., 1970). These two Land System surveys cover the whole of the Northern Gulf region at a scale of 1:1,000,000. The land systems were classified according to agricultural potential by Wilson and Philip (1999) using a limiting factor approach. In the 1960's the soils of the whole of Australia were mapped at a scale of 1:2,000,000 in the 'Atlas of Australian Soils' (Northcote et al., 1968). The map has recently been reproduced using the new Australian Soil Classification (Isbell, 1996, NLWRA, 2001). The Queensland part of the 'Atlas' was actually produced at a larger scale and sections were published at a scale of 1:500,000 in the Shire Handbooks of the Mareeba, Etheridge and Carpentaria shires (for example, Curry and Lloyd, 1978, for Mareeba Shire). The CSIRO and System surveys and the 'Atlas' referred to salinity and sodicity of some soils and the position of those soils in the landscape.

Subsequent to those broad-scale maps several soil and soil landscape maps have been produced for smaller areas. A soil and vegetation survey of the 'Mayvale' land system southeast of Normanton ('sandy forest country') indicated that the soils were all Duplex or Gradational profiles with low fertility and low salinity (1:250,000 scale, Webb et al., 1974). Most soils however had highly sodic subsoils and associated waterlogging in wet years. The cropping potential of the eastern Etheridge Shire was assessed and mapped at a scale of 1:1,000,000 by Kent and Shepherd (1984). Erosion was considered a constraint in the area, but the development of salinity was not considered. A similar area was covered in more detail by Grundy and Bryde (1989). They produced a map of soil associations at a scale of 1:250,000 and assessed agricultural suitability using soil and climate data. They considered salinisation as a potential limitation and included recharge and discharge potential as constraints. They noted that dense stands of *Melaleuca bracteata* (black teatree) on the black earths and grey clays of the basaltic plains may indicate the presence of shallow groundwater and potential for rising saline groundwater if clearing took place, as had happened in southern Queensland. The soil survey of Cape York Peninsula covered the northern part of the Mitchell catchment (Biggs and Philip, 1995), and an assessment of salinity hazard was made as part of that work (Biggs, 1994).

Several studies have been carried out more recently of soils in current or potential irrigation areas. Soils of the Mareeba-Dimbulah Irrigation Area were mapped at a scale of 1:25,000 by Enderlin et al. (1997). Soils in a strip 5 km on either side of the Gilbert River from Chadshunt to Mt. Sircom were mapped at a scale of 1:100,000 (Enderlin, 2000a) and soils of the Einasleigh town common were mapped at 1:50,000, (Enderlin, 2000b). Those surveys included assessments of salinity, and are referred to again below. Finally, several sections of the region, downstream of potential water storage sites, were mapped at a scale of 1:500,000 or 1:1,000,000 by Wilson and Philip (1999), and assessed for suitability for irrigated agriculture. This study used airborne gamma spectrometry as a mapping tool to help re-interpret existing land systems information.

Climate

Climate data, especially parameters other than daily rainfall, are extremely sparse for the region. Modelling is normally required to estimate evapotranspiration from given land covers. Climate information is summarized in the land resources reported listed above.

Vegetation and land use

Vegetation in the region has been mapped at a scale of 1:2,000,000 (Fox et al., 2001), and is currently being mapped at a scale of 1:250,000. Pre-clearing vegetation maps are also being produced, but in most of the Northern Gulf the absence of clearing means that the 'current' and 'pre-clearing' maps will be the same. Vegetation cover is also being monitored on a state-wide basis using satellite data in the state-wide landcover and trees study (SLATS, www.dnr.qld.gov.au/slats/). Land use in the MDIA was mapped by Rose et al. (1996) and was mapped again using 2001 satellite data by S. Blakeney (NR&M, Mareeba).

Topography

Topographic information is also extremely broad for most of the region, consisting of the contours on the 1:100,000 topographic maps and the national 9" digital elevation model (DEM). Digital elevation models calculate a ground surface using available elevation data. They enable calculation of topographic indices such as 'wetness index'. Better elevation data is available for the MDIA.

Groundwater flow systems

In order to assess salinity hazard and risk it is essential to understand the nature of the groundwater flow systems (GFS). For example, a groundwater body that is large, and has an outlet that is physically restricted, will rise more in response to increased recharge than a groundwater body discharging over a large area.

The only groundwater flow system information covering the region is contained in a broad scale GFS map of Australia (NLWRA, 2001, Figure 1). The information for the Northern Gulf region is very broad and was derived from geology alone; no groundwater monitoring has been carried out in the region apart from some small areas in potential or actual irrigation areas. The only groundwater areas that are understood to any extent are in the MDIA (see section on salinity in irrigated areas). Bores in the Great Artesian Basin are monitored, but they are not relevant to salinity in this region as the water is far below the surface. Geology maps are available at a scale of 1:250,000 across the region. Drillers' logs are a source of information that may be of some use to examine hydrogeology of the region, but this possibility has not yet been examined.

Salinity in non-irrigated parts of the region

In the Northern Gulf, salinity has only been recorded as visible outbreaks (Table 2, Table 3) and as soil salt contents in the soil surveys mentioned earlier. A problem with some early soil surveys, such as the "Atlas" and the Land Systems surveys, is that they generally only examined the soil down to 1 or 2 m depth, whereas large amounts of salt can be stored deeper in the profile. Deeper stores of salt may occur in considerable areas, particularly on the colluvial and alluvial plains, especially under heavy textured soils that are alkaline at depth. On the tidal plains soil salinity is high and in equilibrium with the tidal influences.

Regarding visible outbreaks of salinity, in the middle Mitchell and Gilbert River catchments, fractured marine mudstones underlain by other sedimentary rocks of lower transmissivity cause discharge at the change in slope. Saline discharge also occurs from the contact zone between Tertiary – Quarternary basalts overlying older deeply weathered granites, and metamorphics, granite or granodiorite in the Einasleigh River area (Herbert, Webb and Christianos in Gordon et al, 2000). Extensive parts of the region are unknown with respect to salinity outbreaks.

Aquifers of the region vary in salt content. Shallow aquifers in river sands tend to have low salinity, such as those of the Gilbert River bed sands (Hill et al., 1999), whereas the aquifers in the coastal zone are very saline. The deep artesian aquifer is saline, but has little relevance to salinisation of the land surface in the Northern Gulf region because it does not come to the surface there. Groundwater depth and quality have not been monitored outside of the irrigation areas. However, due to the lack of tree-clearing, it is unlikely that increases in groundwater level or salinity would have occurred in non-irrigated areas. Groundwater in shallow aquifers that is pumped to feed troughs is generally of low salinity except near the coast due to the influence of sea water. Sub-artesian groundwater in the Einasleigh Common area was found to be too saline for irrigation (Hill et al., 1999). Groundwater quality varies widely within the MDIA, and those monitoring programs and studies are discussed in the section on irrigated areas

Soils that could be suspected of having high salt contents in the top 6 m or so include the Vertosols, Sodosols, sodic Dermosols and other soils with an alkaline reaction trend. The presence of sodic horizons indicates an influence of sodium during soil formation, so even if salinity is negligible in the root zone, it is possible that there is residual sodium salt deeper down. In soils of the Einasleigh Common, the well-drained non-saline soils had low EM31 values and salt stores but the poorly drained Vertosols and Sodosols had high EM31 values and high salt stores down to 4-6 m depth (Hill et al., 1999). Similar work by in the Biboohra area (MDIA) has also shown large salt stores under Sodosols and sodic groups of Vertosols, Dermosols and Chromosols (Webb, Barry and Enderlin 2000). Therefore, in the absence of further information, we should assume that wherever these soils occur elsewhere in the region, they may hold considerable salt stores at depth. The Land System maps indicate where these soils occur within the various land systems, and approximately what proportion of the land system they cover. Most Kandosols and other soils with neutral or acid reaction trend tend to have low contents of salts. However, their high permeability makes them susceptible areas for recharge of groundwater that may mobilize salts to lower parts of the landscape. Recharge modeling has highlighted the possible contribution of these areas to increased recharge if vegetation is cleared (Enderlin, 2000; Webb et al., 2000).

EM31 measurements have indicated minor areas of salinity along the Gilbert River corridor, especially on lower slopes and toe-slopes of rolling Tertiary landforms, and also in the Searly unit (Hill et al., 1999).

Table 2. Summary of recorded expressions of salinity at the surface in catchments of the Northern Gulf region (from Webb, Holden and Herbert, 2000)

	Mitchell	Staaten	Gilbert	Norman
Scalds	y		y	
Saline groundwater	y		y	
Saline discharge	y		y	
Strongly sodic* soil	y	y	y	
Marine flats	y	y	y	y
Bore drains				
Riparian	y			

* ‘Sodic’ means that a high proportion of the cations in soil are sodium

Table 3. Collation of existing salinity occurrences and risks recorded in the Northern Gulf region (From Gordon et al. 2000, collated by G. Herbert, I. Webb and N. Christianos). See Glossary for definition of terms and soil types.

	Salinity Type	Geology	Vegetation	Salt Source	Annual Rainfall (mm)	Soil Indicators of Poor Drainage	Soils on Recharge Areas	Land-use Changes
Middle Mitchell River and Middle Gilbert River: "Strathleven" and "Wrotham Park"								
	Change of slope	Marine mudstone.	Poor native vegetation in intake areas. Sedges, pandanus in discharge areas	Mudstone and other sedimentary rocks underlain by lower transmissivity material. Concentration by evapotranspiration.	500 -700	Brown/black clays (Vertosols)		Clearing and overgrazing of elevated areas.
Gilbert River: Einasleigh River (Lyndhurst to Einasleigh)								
	Discharge from geological contact zone	Tertiary – Quaternary basalts overlying older deeply weathered granites and older metamorphics, granite or granodiorite	Bloodwood /box woodlands with speargrass in recharge areas, mostly treeless plains with some bendee and stunted red box	Salt water in Ordovician to Palaeozoic metamorphics of marine origin.	700	Mottling and gleying, bleaching of A horizon, Mn staining. Grey and dark Vertosols. Grey/brown/ yellow Sodosols	Permeable red and yellow Chromosols and Kandosols, shallow gravelly Tenosols.	Nil to minimal.
Upper Mitchell River and Upper Walsh River: Parts of MDIA, Cattle Creek, Biboohra, some areas in Leadingham Creek								
	Change of slope	Marine sediments in Hodgkinson metamorphics, weathered Mareeba granites.	Pandanus, Bloodwoods, Ironbarks, box, Grevillea spp, in recharge areas, Melaleuca spp., E platyphila, E leptophloeba and sedges in discharge areas	Marine sediments in Hodginkson metamorphics	800 - 900	Clay percentage, sodicity, hard layers, gleying, mottling, Fe/Mn nodules, columnar structure.	Deep sands, red/yellow Kandosols and Chromosols, sandy Tenosols, Lithosols	Cleared (50%), irrigation (flood and sprinkler)
	Drainage into natural discharge areas, topographic bottlenecks (Cattle Creek)	Low lying alluvial and colluvial landforms	ditto	Mobilisation and redeposition of salts, irrigation water	800 - 900	Clay percentage, sodicity, hard layers, gleying, mottling, Fe/Mn nodules, columnar structure.	ditto	Sugar replaced rice on potential discharge area, mangoes on deep sands in intake areas. All veg types cleared, including swamps on flood plains.
	Seasonally perched water tables over sodic or hardened Fe/Mn –rich layers.	Alluvium, granites and metamorphics			800 - 900	Fe/Mn nodules in discharge areas		Clearing and irrigation
	Dykes	Diorite/quartzite dykes in granites		Dissolution from weathered rocks, evaporation from dammed groundwater behind dykes.	800 - 900	Clay percentage, sodicity, hard layers, gleying, mottling, Fe/Mn nodules, columnar structure.	ditto	Clearing and irrigation

The previous discussion has indicated that salinity hazard is likely to be high in significant areas, and that permeable soils would allow high recharge rates if vegetation is cleared or irrigation water applied. However, the insignificant amount of clearing being contemplated (apart from potential irrigation areas) means that risk of salinisation in non-irrigated areas is very low. If tree clearing were to be contemplated, modeling has shown that the impact on recharge would be greatest in areas with the highest rainfall (Gordon et al., 2000). Tree clearing would be most likely contemplated on alluvial or heavy soils, but caution should be applied, as these areas are likely to have significant salinity hazard.

Salinity in irrigation areas of the region

Irrigation salinity is a form of secondary salinity resulting from the human activities of land clearing and agriculture with irrigation. This effect results from an imbalance in hydrologic conditions when the use of land changes. The risk from irrigation salinity varies with the prior natural landscape condition (salinity hazard), irrigation and catchment management and with irrigation water quality. Secondary salinisation results in salinisation of soil profiles, an increase in salinity in surface water and groundwater and a rise in groundwater levels. These symptoms lead to a range of damaging effects on plant growth, landscape health and function and on infrastructure.

This section reviews some of the salinity risk factors in the region's irrigation areas and how the risk of more extensive or serious irrigation salinity occurring can be assessed. Nearly all of the available information is from studies in the Mareeba-Dimbulah Irrigation Area (MDIA), which has a gross area of 60,000 ha (Currie and Lloyd, 1978) and lies mostly in the upper Mitchell River catchment. Minor areas of irrigation also occur along the Gilbert River and in the Mary Farms-Julatten areas of the upper Mitchell.

There have been several reports of irrigation salinity occurrences in these areas. Some reports date back to early experiences with irrigation. Irrigated farming in the Arriga flats section of the Cattle Creek sub-catchment (which has a total area of 16,700 ha) in the MDIA has experienced the effects of salt within the soil profile depressing crop growth in some low lying areas. Some rice crops were locally affected by soil salinity in the early 1980s (P. Tonello, pers. comm.) and more recently minor areas of cane have been affected. Part of an orchard of fruit trees adjacent to the Gilbert River has experienced the deleterious effects of salt being brought to the soil surface following irrigation development.

Monitoring of groundwater depth and conductivity trends are essential components of salinity and water-logging risk assessment and management in all irrigation areas. Investigation bores have been installed and monitored by NR&M throughout the MDIA since 1987, with many newer bores installed during the mid-1990s, prior to the expansion of cane and other crops in the less well drained areas of Cattle Creek, Biboohra and Leadingham Creek. These bores have been monitored regularly and the measurements are held in the NR&M Groundwater database.

Changes in groundwater levels in Cattle Creek area were first noticed in 1987 when the initial investigations commenced. Early observations identified that there was some cause for concern, with the complexity of sub-catchment geology and groundwater movement providing a challenge for scientists and decision makers (Lait, 1992). Subsequent updates on the groundwater monitoring have been provided in 1996 (DNR staff), 2001 (NR&M) and 2004 (Bell). The 1996 study (DNR staff) classified the observation bores into five trends: consistently rising, minor seasonal variation, major season variation, locally affected and dry. The consistently rising bores in Cattle Creek sub-catchment are mainly in the Arriga flats and were found to be rising at rates from 0.02m to 0.5m per year, in the period from 1987 to 1996. The depth to water table amongst this group of consistently rising bores ranged from -2.2m to -17.5m. The water in some bores was extremely saline at more than 20 dS/m (>12800 ppm). The 2001 update report concluded that groundwater levels in some monitoring bores in the Cattle Creek Catchment had continued to rise, with the Arriga Flats being the major area of concern. A general pattern has emerged that the rising trend accelerated in periods of wetter than average rainy seasons and that the groundwater did not retreat with drier years.

A basin of saline groundwater was identified in the Two Mile Creek area near Biboohra, MDIA (Jensen et al., 1996). With pressure to expand irrigated cane cropping in this area, further groundwater observation bores were constructed and monitored (Jensen, 1998). Groundwater levels were found to be reasonably high (-4m) in the central to southern part of this study area, resulting from continuous water logging from nearby Two Mile Creek and the discharge from the Mareeba sewerage treatment plant. The groundwater depth was found to be deeper (-8 to -14m) further to the north in the Biboohra section of the MDIA. Recent groundwater and soil observations in the southern part of this section have recorded water table depths of only -0.5 to -1.0m from the surface. This requires urgent remediation to avoid water logging and risk of salinisation.

Investigations into the causative factors for irrigation salinity risk in the MDIA continued in the mid-1990s with studies of the soils, salt distribution, hydrogeology and water balance. Soils of the MDIA were mapped and type profiles analysed (Enderlin et al., 1997; Webb, 1995; Webb et al., 2000). Few soils were found to have significant salt loads in the top 1.5m, which is within the maximum rooting depth for many plants. However, in some heavier textured soils of the relic floodplains of Cattle Creek and the Two Mile Creek near Biboohra, chloride levels were found to start rising at about 1.5 to 2.0 m depth. This work was used to plan Electromagnetic Induction (EMI) surveys to map the areas of higher apparent conductivity (Jensen, et al., 1996). These reconnaissance maps provided a first indication of the extent of significant salt stores in the soil and upper regolith. Subsequent deep borings to 6-20m depth were planned using these EMI-derived maps. Analyses of the bore samples showed that the higher apparent conductivity areas identified by the EMI mapping were associated with moderate salt loads in the lower soil horizons and upper regolith, typically at depths of 2-6m or deeper (Webb et al., 2000).

A groundwater model was developed from the available bore data to predict groundwater levels resulting from a range of land and water management options for the Cattle Creek Catchment (Bengtson and Doherty, 1997). This comprised 14 individual models each calibrated for different assumptions regarding unknown conditions. In addition to aquifer specific yield, other unknowns in the development of this model were: amount of aquifer recharge by leakage from the Arriga balancing storage and the hydrologic properties of the southeast portion of Cattle Creek. No groundwater observation bore data was available for the latter area. So a series of models were developed to cover a range of possible values of specific yield, transmissivity and area of influence. The calibration of the model was consistent with leakage rates from the Arriga Balancing storage (a low lying area of 100ha, on the eastern margin of the catchment) of 0 to 2.5mm/day. A series of model runs was made to predict the likely effects of further expansion of irrigated cane. Model runs were also made to predict the effects of compounding this expansion with a series of abnormally wet years. Changes to the catchment water balance under this least favorable scenario were predicted to result in a rise in the water table to within 2m of the surface under up to 350ha of the Arriga Flats and to within 4m of the surface under an area totaling up to 1500 ha. The models predicted likely benefits of some engineering-based management options. For example, it indicated that dewatering of the Arriga flats through a series of extraction bores could be effective in lowering water tables.

Lait (1998) provides a detailed description and analysis of the hydrogeology and groundwater chemistry of the Cattle Creek Catchment, based on the work of DNR staff. During this study 91 bores were constructed to define subsurface geology, investigate the groundwater and establish a monitoring network. Groundwater in the Cattle Creek Catchment occurs mainly in fractured bedrock aquifers of the Hodgkinson Formation on the valley floor. Groundwater also occurs within fractures of the Mareeba Granite, in the upper part of the catchment, within colluvial and relic soils and in the alluvium of the drainage system. The transmissivity of the fractured bedrock aquifers is low and groundwater flow is slow. It is further impeded by sub-surface dykes, which traverse the southern third of the catchment. These structures effectively dam saline groundwater from the north and have caused water levels to rise. Local discharge of groundwater occurs on the valley floor where it has been ponded by dykes.

The potential for salinity in the lower parts of the Cattle Creek Catchment was confirmed in the late 1980s (Lait, 1992). Concerns were raised over the sustainability of irrigated agriculture in sections of the sub-catchment and off-site environmental impacts from increasing salt discharge into water bodies (Lait, 1998). Expansion of irrigated cropping, especially of furrow irrigated cane on the relic floodplains of the Arriga area, was linked to the development of suitable management strategies. The Cattle Creek Landcare group was formed and a series of investigations conducted into catchment, irrigation and groundwater management strategies to minimize salinity and other risks. The research projects related to improved land and water management included:

1. Groundwater management options and decision support for identifying solutions
2. Groundwater and salinity studies in the MDIA
3. Soils and Land suitability for irrigated agriculture
4. Water Balance in Cattle Creek sub-catchment
5. Irrigation efficiency (BSES extension program)
6. Mitchell River water and environmental quality management

Outputs from these projects included: Cogle and Lait (1999)[project 1]; Cogle, Rose et al.(1999)[1]; Robinson and Rose (1997) [1]; Robinson et al. (1999)[1]; Jensen et al., 1996)[2]; Enderlin et al., (1997)[3]; Webb, Rose and Okerby (1998)[4]; Ryan et al. (2002)[6]. Readers are referred to the project outputs for details of the findings.

As result of these studies some of the management actions that have been put into place to help reduce the risk of salinisation in Cattle Creek include: education and public awareness; installation of a dewatering bore; construction of interception drains and re-cycling dams, and re-use of the water collected (Warnick, 2002); lining of some channels; tree planting; improved irrigation scheduling; implementation of Land and Water Management Plans at the property scale and conversion from furrow irrigation to more efficient overhead methods. It is recommended that reviews of the effectiveness of these measures and of future management options be conducted following the release of the 2004 Groundwater update and the technical report on the salinity risk assessment.

Discharge of saline water into some streams in the region has been recorded, for example at Font Hills, Dingo Creek and the lower Walsh River, in the upper Mitchell system (Ryan, Aland and Cogle, 2002). Otherwise these authors found that stream water electrical conductivity in the upper Mitchell was generally low, indicating low levels of salts in the water.

Reconnaissance hydro-geological, land resource and salinity hazard assessments have also been conducted in some other areas in the Northern Gulf region that have been considered for possible development of irrigated agriculture (Hill et al. 1999, Enderlin, 2000a; 2000b).

Possible development of irrigated agriculture has been rejected in several areas in the region due to adverse factors, including salinity risk. Examples are Four Mile - Douglas Creek (MDIA) and in parts of the Einasleigh “Town Common” area.

This section provides a simplified review of salinity risk in irrigation areas of the region. For further detail and analysis the reader is referred to the references cited, to land and water scientists in NR&M and other agencies and to the natural resource databases that have been created as information tools.

The Cattle Creek Catchment is currently the subject of a pilot salinity risk assessment, funded by NGRMG Foundation Bid Funding, as an example of an area of irrigated agriculture in the region with known salinity risk factors. This study is updating groundwater information and some other data gaps. It aims to provide a spatial model of the current salinity status and trends from a risk assessment framework developed for the purpose. This process also tests some of the predictions made by the Groundwater model of 1997 (Bengtson and Doherty).

Gaps in information

The assessments of salinity hazard described above have been made on the basis of extremely limited data, and should only be used as very general indications. If tree-clearing, irrigation, or other changes in land use are being considered, avoidance of salinisation will require:

- Better understanding of soil/geology landscape relationships; sources, nature and location of salts in key areas
- Better understanding of hydrogeology- currently extremely limited and broad-scale. Virtually no monitoring of groundwater depth and quality trends is occurring outside of the irrigation areas.

Priority areas

In the light of the salinity hazards and risks in the region, we consider that the following activities should be considered as priorities (in decreasing order of importance).

1. Monitoring of salinity and proposed land use changes, and evaluation of strategies for preventing salinisation.
2. Salinity hazard and risk assessment for Cattle Creek catchment in the MDIA. These tasks will be carried out as part of the present project.
3. Salinity hazard and risk assessments for other areas within the MDIA, such as the Biboohra section, and other areas within the region that have been earmarked for possible irrigation development.
4. An assessment of salinity hazard map for the whole region, based on studies of salt stores and hydrogeology, starting with the areas most likely to undergo land use change.

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Glossary and Abbreviations

A horizon See horizon.

Acid See pH

Alkaline See pH

Alluvial Material deposited by rivers, especially on their flood plains.

Anion A negatively charged molecule or element. The most important and abundant anions occurring in soil and water are chloride (Cl^-), sulfate (SO_4^{2-}), carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-). Anions present in small amounts, but which are important for plant nutrition, include hydroxyl (OH^-), nitrate (NO_3^-) and phosphate (PO_4^{2-}).

Aquifer An underground body of rock or other material that is saturated with water (groundwater) and is sufficiently permeable to yield significant quantities of water to wells and springs. An aquifer is 'confined' if the upper and lower boundaries of the permeable material are essentially impervious. In an unconfined aquifer the upper surface of the groundwater (the watertable) is free to rise and fall so that it is always at atmospheric pressure.

ARCView A computer-based geographic information system.

AUSLIG Australian Survey and Land Information Group

Australian Soil Classification The current soil classification scheme used in Australia (Isbell, 1996; Isbell et al., 1997). It supersedes the 'Factual Key' scheme and the 'Great Soil Group' scheme. It is a hierarchical scheme, consisting of 14 Orders, which are further subdivided using prefixes based on their properties. The Orders occurring most commonly in the Northern Gulf region (Chromosol, Dermosol, Ferrosol, Hydrosol, Kandosol, Kurosol, Rudosol, Sodosol, Tenosol and Vertosol) are briefly defined in this Glossary. See Table 4 for approximate correlation between these Soil Orders and the older 'Great Soil Group' and 'Factual Key' names.

B horizon See horizon.

Basalt The commonest type of solidified lava; a dense, dark grey, fine-grained igneous rock composed mostly of calcium-rich silicate minerals.

Black earth One of the 'Great Soil Groups'. Black earths are very dark, heavy clays with neutral to alkaline pH at the surface. See Table 4.

Calcareous red earth One of the 'Great Soil Groups'. Calcareous red earths are massive sandy to loamy soils with free carbonate s in the lower part of the profile. See Table 4.

Capillary fringe Portion of the zone above the watertable into which water is drawn by capillary action.

Catchment Area of the landscape from which water at a given point (surface or groundwater) may be derived.

Cation A positively charged molecule or atom. The most important and abundant cations occurring in soil and water are calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+), sodium (Na^+) and in acid soils, aluminium (Al^{3+}). The hydrogen (H^+) is present in small amounts in acid soils, but is important because of its reactivity.

Cation exchange capacity (CEC) The amount of cations that the soil can hold bound to surfaces of particles. Cations are bound by negative charges on the soil particles, so the CEC is also a measure of the amount of negative charge in the soil. Most of the CEC in soil occurs on clay or organic matter.

Chromosol A 'Soil Order' of the 'Australian Soil Classification'. Chromosols have a strong texture contrast between A horizon and B horizon, which is not sodic (exchangeable sodium percentage <6) and not strongly acid (pH >5.5). See Table 4.

Colluvial Material transported down slopes by gravity.

Cretaceous See 'Geological era'

DEM Digital elevation model. A grid of elevations modelled from available elevation data.

Dermosol A 'Soil Order' of the 'Australian Soil Classification'. Dermosols lack a clear or abrupt textural B horizon, do not have a free iron oxide content greater than 5% Fe, are not calcareous throughout and have moderately to strongly structured B2 horizons. See Table 4.

Diorite A granular crystalline intrusive rock.

Discharge area Area in the landscape where the net movement of groundwater is out of the ground. Waterlogging and salinisation are most likely to occur in this area. See 'recharge area'.

Dykes Formations that hold back water. In the geological sense they are impermeable underground formations that prevent groundwater from moving laterally.

DNR Queensland Department of Natural Resources, recently Department of Natural Resources, Mines and Energy 'NRM&E' and currently Department of Natural Resources and Mines.

DNRM Queensland Department of Natural Resources and Mines, recently Department of Natural Resources, Mines and Energy.

DPI Queensland Department of Primary Industries, currently Department of Primary Industries and Fisheries, DPI&F.

Dryland Not under irrigation. See 'salinity type'.

Duplex See 'Factual Key'.

EC See 'electrical conductivity'.

Electrical conductivity (EC) The ability of a material to conduct electricity. The EC of water or a soil extract can be used to estimate its salt concentration. Measuring the EC of soil solution is difficult because of the very small volumes of water that can be extracted from the soil. Therefore, water is normally added to the soil for measurement. Salt tolerance of most plants has been calibrated against the saturation extract EC (EC_e or EC_{se}). For soils in Australia, EC is normally measured in a 1:5 soil:water extract (ie. 10g soil plus 50 mL water), giving $EC_{1:5}$. The relationship between $EC_{1:5}$ and EC_e depends mainly on texture, so it is possible to make approximate conversions between the two units. The preferred unit for EC is dS/m, but µS/cm, or mS/cm are also commonly used. The electrical conductivity of a soil profile can also be inferred from readings made by electromagnetic induction meters, such as the Geonics EM31. It measures electrical conductivity down to about 4-6 m depth, which depends largely on salt content, but also on water and clay content. The readings are expressed in mS/m, but they cannot be directly converted into EC_e or $EC_{1:5}$ values. Calibrations between the two types of readings are made occasionally as a means of calibrating EM31 readings.

EM31 Geonics electromagnetic induction meter. See 'Electrical conductivity'.

Euchrozem One of the 'Great Soil Groups'. Euchrozems are similar to Kraznozems, but less acidic. See Table 4.

Evapotranspiration Water lost as vapour from a vegetated area by direct evaporation from the soil as well as transpiration from vegetation. The two loss pathways are combined because in practice it is difficult to separate them. See 'transpiration'.

Exchangeable sodium percentage (ESP) A property of soil. The amount of exchangeable sodium (Na^+) divided by the cation exchange capacity, multiplied by 100. It is used to define sodicity of soil. See 'sodic' and 'cation exchange capacity'.

Factual Key The Factual Key soil classification (Northcote, 1979) was used for several decades and is found in many reports and maps. It was devised because the previous 'Great Soil Group' scheme was not amenable for classifying soils in the field. It is a hierarchical scheme with four 'Principal Profile Forms' forming the highest level. They are Uniform (U), Duplex (D), Gradational (G) and Organic (O). Duplex or texture-contrast profiles are those in which the texture suddenly becomes finer (more clayey) on passing from the A to the B horizon.

Gradational texture profiles are those in which texture gradually becomes finer (more clayey) with depth. Uniform texture profiles are those in which there is little, if any, change in texture throughout the profile. Uniform profiles may be coarse (sandy), medium (loamy) or fine (clayey) texture. Organic profiles are not found in the Northern Gulf region. The Principal Profile Forms are further divided on basis of texture, pH and colour, and are referred to by codes (eg Dy2.41). See Table 4 for approximate correlations between this and other classification schemes. This scheme has been superseded by the 'Australian Soil Classification'.

Ferrosol A 'Soil Order' of the 'Australian Soil Classification'. Ferrosols have B2 horizons with high contents of free iron oxide, and lack strong texture contrast between the A and B horizons. See Table 4.

Geological era Time from the beginning of the earth to the present is generally divided into 4 eras: the Proterozoic era (4,500 million to 540 million years ago), the Palaeozoic era (540 million to 245 million years ago), which is subdivided, in order of decreasing age, into the Cambrian, Ordovician, Silurian, Devonian, Carboniferous and Permian periods; the Mesozoic era (245 million to 64 million years ago), which is subdivided, in order of decreasing age, into the Triassic, Jurassic and Cretaceous periods; and the Cenozoic era (64 million years ago to the present), which is subdivided, in order of decreasing age, into the Paleocene, Eocene, Oligocene, Miocene, Pliocene, Pleistocene and Holocene epochs. Of these seven epochs in the Cenozoic era, the earliest five are commonly referred to as the Tertiary, and the most recent two as the Quaternary.

GFS Groundwater flow systems

GIS Geographic information system

Gley Gleyed soils have greyish, blueish or greenish mottles, which develop under poorly drained conditions and thus indicate periodic or frequent waterlogging.

Gradational See 'Factual Key'.

Granite An igneous rock having visibly crystalline texture, generally composed of feldspar, mica and quartz.

Granodiorite See 'granite' and 'diorite'.

Great Soil Group The Great Soil Group soil classification scheme (Stace et al, 1968) developed in Australia through the 1930's to 1960's and is still widely referred to as many of the names are in common use. It includes 43 Great Soil Groups. The ones occurring most commonly in the Northern Gulf region are briefly defined in this Glossary. This scheme was superseded by the 'Australian Soil Classification' scheme. See Table 4 for approximate correlation between the Great Soil Groups and the 'Soil Orders' of the 'Australian Soil Classification'.

Grey, Brown and Red Clays One of the 'Great Soil Groups'. Grey, Brown and Red Clays are a broad group defined by high clay content throughout the profile. See Table 4.

Groundwater Water in saturated zones in the ground, at pressures greater than atmospheric. Groundwater will flow into a bore hole. See 'aquifer' and 'watertable'.

Hazard (as in 'salinity hazard') The inherent landscape characteristics that predispose a particular area to the development of either land or water salinity. See 'risk'.

Horizon Soil layer. The A horizon is the surface layer of mineral soil, usually darkened by organic matter at the top or throughout. The term topsoil often more-or-less corresponds with the A horizon. The B horizon is a subsoil layer having concentrations of clay, oxides or organic matter and/or structure and consistence unlike the A horizon above or other layers below and/or stronger colours than the A horizon above or other layers below.

Hydraulic conductivity The ability of a material to conduct water. It is influenced by pore size and continuity, pressure and temperature. Also called permeability.

Hydrosol A 'Soil Order' of the 'Australian Soil Classification'. Hydrosols are seasonally or permanently wet soils. See Table 4.

Igneous rock Rock formed by solidification from a molten state.

Intake area See 'recharge area'.

Kandosol A 'Soil Order' of the 'Australian Soil Classification'. Kandosols lack a clear or abrupt textural B horizon, are not calcareous throughout, and the clay content of the massive or only weakly structured B2 horizon exceeds 15%. See Table 4.

Kraznozem One of the 'Great Soil Groups'. Kraznozems are deep, well-structured acidic red soils with moderate to high clay content and high iron oxide content. See Table 4.

Kurosol A 'Soil Order' of the 'Australian Soil Classification'. Kurosols have a clear or abrupt textural B horizon, the upper part of which is strongly acid (pH < 5.5). See Table 4.

Leaching For soils, removal of soluble material (including salts) by water moving through the soil.

Lithosol One of the 'Great Soil Groups'. Lithosols are shallow and rocky soils. See Table 4.

MDIA Mareeba-Dimbulah Irrigation Area

Metamorphic rock Rock formed under intense pressure or heat.

Mottling In soils, spots, blotches or streaks of colours that differ from the main soil colour.

NAP National Action Plan for Salinity and Water Quality

NDSP National Dryland Salinity Program

NLWRA National Land and Water Resources Audit

Non-calcic brown soil One of the 'Great Soil Groups'. Non-calcic brown soils are similar to Red-Brown Earths, but with no A2 horizon and no carbonate in the B horizon. See Table 4.

NR&M Queensland Department of Natural Resources and Mines. The state government responsibility for soil and salinity-related matters resides in this department. It previously resided in the Department of Primary Industries (until 1997), Department of Natural Resources (1997-2001) and Department of Natural Resources and Mines (2001-2004).

Order (as in 'Soil Order') See 'Australian Soil Classification'.

Ordovician See 'Geological era'

Osmotic potential See 'water potential'

Perched watertable Upper surface of an unconfined aquifer that is separated from the underlying groundwater by an unsaturated zone. The lower boundary of perched aquifers is usually a layer with low permeability.

pH The scale of measurement of acidity and alkalinity. A pH of 0-6 is acid, around 7 is neutral, and 8-14 is alkaline. Soil pH values are usually between 4 and 10. pH is determined by and influences a range of soil properties.

Primary salinity See 'salinity' and 'salinity type'.

Principal Profile Form See 'Factual Key'.

Proterozoic See 'Geological era'

Quartz A hard glossy mineral consisting of silicon dioxide in crystalline form, present in most rocks (especially sandstone and granite).

Quartzite Hard metamorphic rock consisting essentially of interlocking quartz crystals.

Quaternary See 'Geological era'

Recharge Water moving downwards through the soil that reaches the watertable.

Recharge area Area in the landscape where the net movement of water is downwards and into the groundwater.

Red-Brown Earth One of the 'Great Soil Groups'. Red-Brown Earths have a massive to weakly structured grey-brown to red-brown loamy A horizon, with an abrupt change to a brown to red clay B horizon with well-developed structure. The A horizon is usually slightly acid to neutral, and the B horizons are alkaline, with carbonate segregations in the lower parts. See Table 4.

Red earth One of the 'Great Soil Groups'. Red earths are massive, predominantly sandy-textured soils, often with an increase in clay content with depth, red-brown to red coloured, weak profile differentiation, except for a darker A1 horizon, and an acid to mildly alkaline reaction. See Table 4.

Regolith The unconsolidated mantle of weathered rock and soil material on the earth's surface; loose materials above solid rock. Approximately equivalent to the term 'soil' as used by many engineers, but often thicker than the term 'soil' or 'solum' as used by soil scientists

Risk (as in 'salinity risk') The probability that certain actions, including land-use management, will lead to salinity being expressed. Risk can only be high where a hazard exists.

Root zone Soil zone in which most root activity occurs. Differs depending on soil and vegetation.

Rudosol A 'Soil Order' of the 'Australian Soil Classification'. Rudosols have little pedological organisation. They are often stratified. See Table 4.

Saline (With regard to soil or water) Having a concentration of salt that is high enough to adversely affect plant growth. The most common salt in Australian landscapes is sodium chloride, so saline soils and waters are usually also sodic. See 'salinity' and 'sodic'.

Salinisation The process of salt accumulating in soil or water. Also called 'salting'.

Salinity The salt content of soil or water. The salinity of soil can be estimated by measuring the electrical conductivity of soil extracts, or by measuring the electrical conductivity of the whole soil using conductivity probes or an EM meter. See 'electrical conductivity'. The salinity of water is usually estimated by measuring electrical conductivity, but may also be measured by evaporating the water and weighing what remains, or by analysing for cations and anions and adding them together. Salt concentration in water can be expressed as mg /L (milligrams per litre) or in the past, as grains per gallon. Salt concentration in soil is often expressed as % (g salt per 100g soil). See 'saline'.

Salinity type Salinity can be expressed in the landscape in different ways depending on climate, topography, hydrology and other landscape factors, and various authors have categorised various 'types' of salinity. Here we attempt to list various definitions of 'types' that have been described in Queensland. 'Dryland salinity' is salinity that has occurred without irrigation, whereas 'irrigation salinity' is salinity that has been induced by irrigation. 'Primary salinity' is salinity that has developed without human influence, whereas 'secondary salinity' is salinity that has developed following changes in land use or management. 'Secondary salinity' may also be called 'induced salinity'. 'Change of slope' or 'catena' salinity is where salinity develops at the break of slope. 'Seepage' salinity is where groundwater discharges and salt accumulates near the bottom of slopes or in valley floors. 'Stratigraphic', or 'contact zone' salinity is where discharge occurs and salt accumulates at the zone where one type of geology overlies a less permeable rock layer. The layers are commonly Tertiary- Quaternary basalt or sediments overlying older rocks. 'Watertable' or 'groundwater salinity' is when the groundwater is saline.

Salt Material that forms cations and anions when dissolved in water. See 'cation', 'anion' and 'salinity'. The most common salt in Australian soils and waters is sodium chloride or table salt (NaCl).

Salt flat Saline area associated with saline watertable that is close to or above the surface for some or all of the year.

Salt marsh A periodically inundated salt flat carrying salt-adapted vegetation.

Salt pan See 'salt flat'.

Salt scald See 'scald'.

Scald An area where erosion of the surface soil has exposed soil that remains bare of vegetation. Scalds can be saline or non-saline, sodic or non-sodic, depending on the properties of the exposed soil.

Secondary salinity See 'salinity' and 'salinity type'.

SLATS Statewide Landcover and Trees Study

Sodic Soil or water is sodic when sodium constitutes a high proportion of the cations (mostly calcium, potassium, magnesium, sodium and aluminium) that are present. The more sodic a soil, the poorer its physical properties tend to be; sodic soils tend to set hard when dry, be sloppy when wet and have low permeability to water, air and roots. The most commonly used definition of a sodic soil is one with an exchangeable sodium percentage (ESP) > 15 somewhere in the top metre. For more recent and comprehensive definitions of sodic soil, see Isbell (1996) and Isbell et al. (1997). Sodic soils may or may not be saline. See 'exchangeable sodium percentage' and 'saline'.

Sodosol A 'Soil Order' of the 'Australian Soil Classification'. Sodosols are a specific kind of 'sodic' soil, having a clear or abrupt textural B horizon, the upper 0.2 m of which has an exchangeable sodium percentage of 6 or greater, and a pH of 5.5 or more. See Table 4.

Soil Order See 'Australian Soil Classification'.

Solodic One of the 'Great Soil Groups'. Solodic soils are the same as Solodized Solonetz, except that their B horizons have coarse blocky structure, without evidence of the characteristic columnar structure. See Table 4.

Solodised Solonetz One of the 'Great Soil Groups'. Solodised Solonetz soils are similar to Solonetz soils, except that they tend to have a thicker A horizon, with well developed A2 horizon, and the A horizon and upper part of the B horizon is acid. The B horizons have coarse columnar structure with clearly defined domes on top of the columns, and exchangeable sodium contents are less than that of the Solonetz. See Table 4.

Solonchak One of the 'Great Soil Groups'. Solonchaks are saline soils. See Table 4.

Solonetz One of the 'Great Soil Groups'. Solonetz soils have an abrupt texture contrast between loamy A horizons and clay B horizons. The A horizon is fairly thin, has a bleached A2 horizon and has neutral to alkaline pH. The B horizon is strongly alkaline (pH>9) and exchangeable cations are dominated by sodium and magnesium in the lower part. See Table 4.

Soloth One of the 'Great Soil Groups'. Soloths are similar to Solonetz, Solodised Solonetz and Solodic soils, except that they are acid throughout the profile. The texture contrast also tends to be less abrupt and the B horizon is not as tough or hard. See Table 4.

Tenosol A 'Soil Order' of the 'Australian Soil Classification'. Tenosols have weak development of soil horizons. See Table 4.

Tertiary See 'Geological era'

Texture The range of particle sizes of which a soil consists, that is largely responsible for its feel and structure. All soil particles are either clay (0-2 µm diameter), silt (2-20 µm diameter), fine sand (20-200 µm diameter), coarse sand (200-2000 µm diameter) or gravel (> 2000 µm diameter, with upper limit depending on situation). "Light" or "sandy" soils contain a high proportion of sand, whereas "heavy" or "clayey" soils contain a high proportion of clay. "Loams" generally contain similar proportions of clay, silt and sand.

Transpiration Movement of water through plants and into the atmosphere, mostly through stomata in the leaves.

Uniform See 'Factual Key'.

Vertosol A 'Soil Order' of the 'Australian Soil Classification'. Vertosols have 35% or more clay throughout the profile. See Table 4.

Water potential Also termed 'pressure' or 'head'. Water has a high potential when it is under pressure, has zero potential when it is pure and at atmospheric pressure, and has negative potential when it is held in small pores by capillary action (matric potential) or contains salts (osmotic potential). The smaller the pores holding the water, or the higher the salt concentration, the more negative the water potential. The more negative the water potential, the more difficult it is for plant roots to take up water. Water potential is usually expressed in terms of pressure (e.g. Pa or bar).

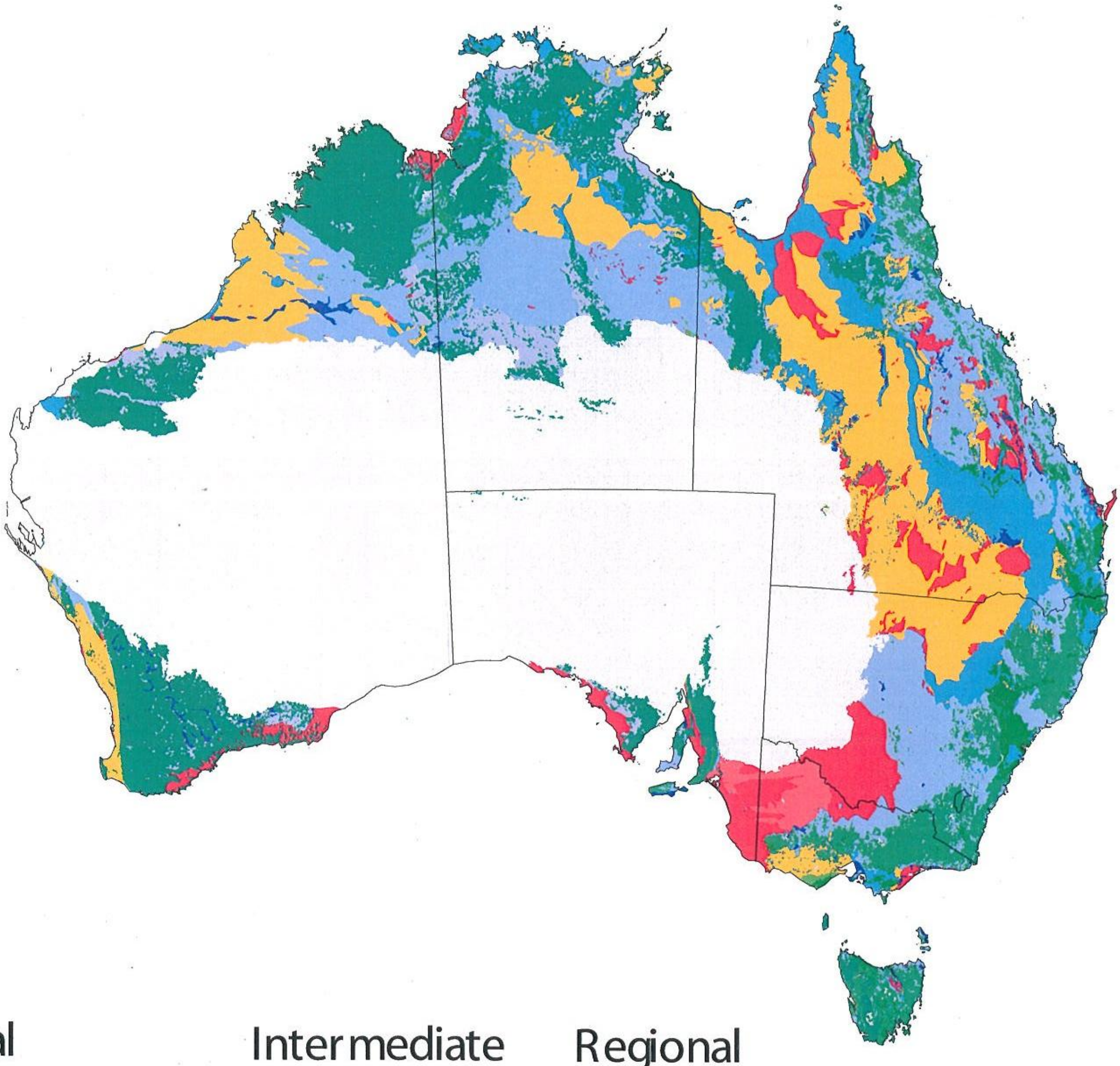
Watertable The top of a groundwater body.

Yellow earth One of the 'Great Soil Groups'. Yellow earths are similar to Red Earths, but predominantly yellow in colour, and sometimes with a more pronounced texture gradient down the profile. See Table 4.

Table 4. A list of the 'Soil Orders' of the 'Australian Soil Classification' that occur commonly in the Northern Gulf region, and approximate correlation with their 'Great Soil Group' and 'Factual Key' names. See Glossary for definitions of the names. Taken from Isbell (1996).

Soil Order (Isbell, 1996)	Great Soil Group (Stace et al., 1968)	Factual Key (Northcote, 1979)
Chromosol	Non-calcic brown soils, some Red-brown earths, some Podzolics	Many Duplex (D) soils
Dermosol	Prairie soils, Chocolate soils, some Red and Yellow Podzolic soils	Wide range of Gn3 soils, some Um4
Ferrosol	Krasnozems, Euchrozems, Chocolate soils	Gn3, Gn4, Uf5, Uf6 soils
Hydrosol	Humic gleys, Gleyed podzolic soils, Solonchaks, and some Alluvial soils	Wide range, some Dg and Uf6 soils most common
Kandosol	Red, Yellow and Grey earths, Calcareous red earths	Gn2, Um5 soils
Rudosol	Lithosols, Alluvial soils, Calcareous and Siliceous sands, some Solonchaks	Uc1, Um1, Uf1 soils
Sodosol	Solodized solonetz and Solodic soils, some Soloths and Red-brown earths, Desert loams	Many Duplex (D) soils
Tenosol	Lithosols, Siliceous and Earthy sands, some Alluvial soils	Many Uc and Um classes
Vertosol	Black earths, Grey, brown and red clays	Ug5 soils

Australian groundwater flow systems



Local

- deeply weathered rocks
- fractured rocks or weathered fractured rocks
- fine-grained sediments
- sand dunes

Intermediate

- sedimentary sequences
- layered sedimentary sequences or fractured basaltic rocks
- fractured rocks
- deeply weathered rocks

Regional

- alluvial sediments
- shallow marine and other sediments
- layered sedimentary or fractured basaltic rocks
- (less than 300 mm annual rainfall zone)

National Land & Water Resources Audit
A program of the Natural Heritage Trust

Sources: AUSLIG: Coastline/State Boundaries
AUSLIG: 9 Second Digital Elevation Model
AGSO: BMR Record 1986/27 Regolith Terrain Map Australia (1: 5 000 000)
AGSO: BMR 1976 Geology of Australia (1: 2 500 000)

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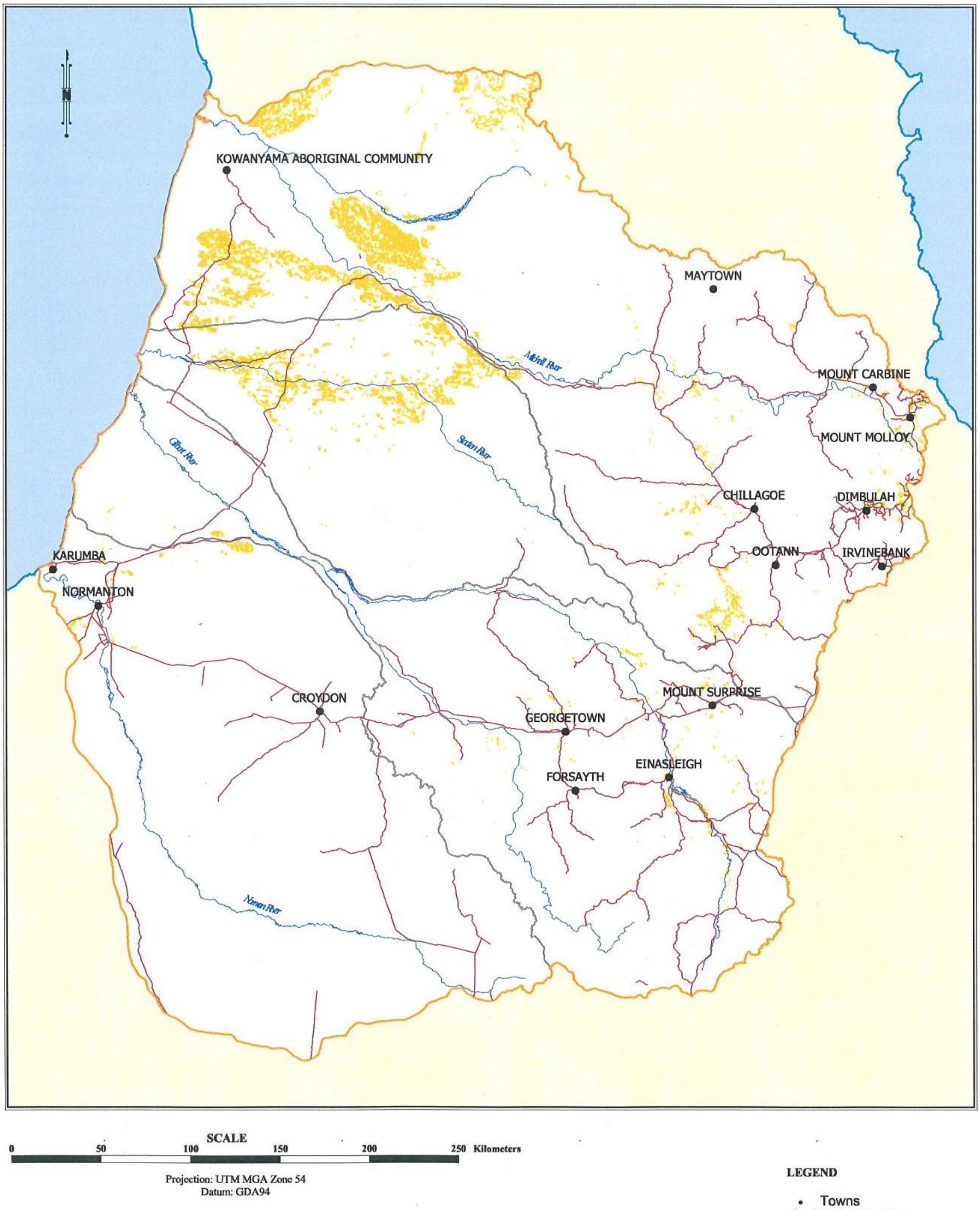

Figure 2. Risk of Dryland Salinity Occuring in the Northern Gulf Region by 2050

From the National Land and Water Resources Audit
Australian Dryland Salinity Assessment (2000)

Queensland Government
Natural Resources, Mines and Energy

This map is a guide for regional planning purposes only.
Estimates of projected dryland salinity hazard in 2050 were based on a map overlay analysis using attributes that drive salinisation such as geology, landscape features, regolith depth and type, land use and climate. Groundwater data for assessing salinity risk in Queensland are extremely limited.
It reflects potential dryland salinity areas related to the extent of land use change.
Information has been prepared at a scale of 1:2 500 000.

Data Sources:
Dryland Salinity data was supplied by the National Land and Water Resources Audit
1:250 000 Drainage data supplied by Geoscience Australia

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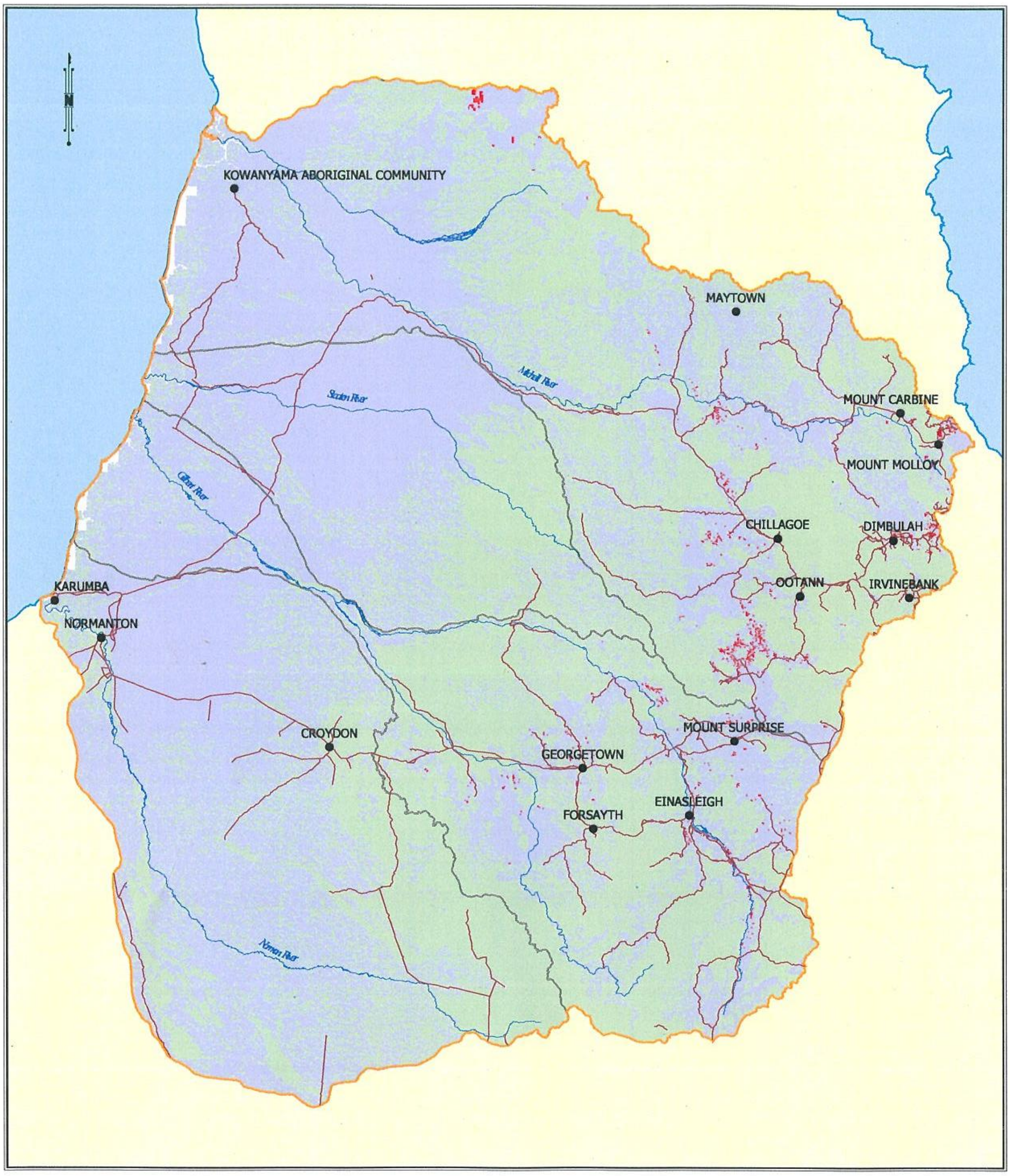

SCALE

0 50 100 150 200 250 Kilometers

Projection: UTM MGA Zone 54
Datum: GDA94

Figure 3. Salinity Hazard in the Northern Gulf Region
From the Queensland Salinity Hazard Map, 2001

LEGEND

- Towns
- Major Roads
- Major Rivers
- NGRMG Boundary
- Catchments

Salinity Hazard
- Low
- Medium
- High

This map is a guide for regional planning purposes only. Queensland Salinity Hazard defines areas in the landscape with potential for mobilization of salt, using attributes that drive salinisation such as geology, landscape features, regolith depth and type, land use and climate.

Queensland Government
Natural Resources, Mines and Energy

NRM&E Ref V:/rvmp/ngrmg

Data Sources:
1:250 000 Drainage data supplied by Geoscience Australia

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