GROUNDWATER AVAILABILITY IN THE TWEED-BRUNSWICK CATCHMENT

Published hydrogeology maps cover large areas of the Gwydir River Basin. These maps cover the Narrabri 1:250,000 (DWR, 1988) and Moree 1:250,000 (DWR, 1988) sheets and were used as a guide for the development of the Basin wide availability map.

The following discussion of groundwater characteristics is based on information contained in the "Groundwater in New South Wales" 1984 report, hydrogeologic experience as well as public domain data (Department's Groundwater Data System (GDS)) used to publish the above mentioned hydrogeology maps.

GEOGRAPHICAL SETTING

The Tweed Valley catchment area is located approximately 800 km north of Sydney in the north-eastern area of New South Wales, and lies between latitude's 153^{o}07' and 153^{o}36', and longitude's 28^{o}11' and 28^{o}34'. The Tweed Valley catchment is primarily drained by the Oxley, Rous, and Tweed Rivers, the upper reaches of which originate in the Ranges surrounding Mount Warning. The catchment has an area of approximately 1300 km^2, and a population of approximately 62 000, with the major centres being Murwillumbah and Tweed Heads.

The Brunswick Valley catchment is located approximately 700 km north of Sydney, south-east of the Tweed Valley Catchment, and lies between latitude's 153^{o}26' and 153^{o}39', and longitude's 28^{o}18' and 28^{o}42' as shown in Figure 1. The Brunswick Valley catchment is primarily drained by the Brunswick River, Marshalls and Simpsons Creeks. The catchment has an area of approximately 550km^2 with the main centres of population located at Brunswick Heads, Mullumbimby and Byron Bay.

The Tweed and Brunswick Valley catchments lie within the subtropical maritime region of the eastern coast of Australia. This leads to the summer months being predominantly warm and humid, while the winter months are mild. The average annual rainfall for the area is approximately 1700 mm, of which 60% falls during months from January through April. The highest precipitation occurs on the coastal and northern extremities of the catchments. Cyclonic events can cause intense rainfall during the months from December to April, which can result in flooding during the wet season.

The average annual evaporation for the region is 1600 mm, with December being the peak month of 189 mm and June having the lowest monthly figure of 78 mm.

The topography of the Tweed and Brunswick Valley catchments is quite varied. The majority of the terrain in the catchments can be classed as hilly to mountainous. Land slopes in excess of 8 degrees cover about 60% of the valley, with extensive flood plains being located around the lower reaches of the rivers (Beale, J.G. 1968).

The most predominant physical features within the Tweed Valley catchment have been carved by the major rivers and their tributaries. Over time they have sculptured a large erosional caldera from what was once a shield volcano. Mount Warning is the remnant of the former shield volcano, rising to a present day height of approximately 1150m. The weathering and erosion of the volcano, as well as sea level fluctuations, have created the floodplains of the Tweed River Valley.

Mountainous areas in the Brunswick Valley are located along the central western boundary of the valley in the headwaters of the Brunswick River and Burringbar Creek. The Brunswick River drains a reasonably steep catchment, with elevations of up to 600m, before entering the flat coastal valley near Mullumbimby. The north arm (Marshalls Creek) commences at an elevation of about 450m and initially flows in an easterly direction, finally turning due south, near the coast, before joining the Brunswick River. The south arm (Simpsons Creek) flows north, parallel to the coast, and drains the predominantly marshy coastal strip between Byron Bay and Brunswick Heads.

The catchments are both situated in a sub-tropical zone and therefore have a wide diversity of vegetation. Areas of rainforest and wet sclerophyll forest in the hinterland are particularly significant. These are listed as World Heritage areas and are on the Register of the National Estate. Wetland vegetation communities, including mangroves, saltmarsh, and seagrass have developed on floodplain soils, within tidal influences, of the major rivers.

SOILS

There are two major soil types within the Tweed and Brunswick Valley catchments. These are:

- basalt derived soils (kraznozems, chocolate basalts) resulting from the erosion of the tertiary volcanic flows from Mount Warning. These soils occur throughout the catchments and are found in plateau areas and on steeper slopes. They are usually well drained.
- sedimentary derived soils (resulting from the erosion of sandstones and claystones, both metamorphosed and in their alluvial form). These occur on the floodplain and along the coastal strip. Their drainage depends on their location.

Floodplain soils are composed of estuarine sediments and alluvium.

Problems arise with the formation of acid sulfate soils. These are defined as soils in which, as part of a development or ripening process involving bacterial action and aeration, sulfuric acid is produced in amounts that have a pronounced effect upon the main soil characteristics.

Acid sulfate soils are primarily derived from the drainage of parent marine and estuarine sediments that are rich in reduced sulfur compounds, mainly pyrite (FeS_2). Pyrite accumulates through geological time in soil that is rich in organic matter and flushed by dissolved sulfate, usually from sea water. When drainage brings oxygen into the previously saturated soils, the pyrite is oxidised to form sulfuric acid. Acid sulfate soils develop where the production of acid exceeds the neutralising capacity of the parent soil material, so that the soil pH falls below 4. In there oxidising acidic state, the soils contain concentrations of aluminium and iron that are toxic to many plants. Acid runoff or seepage waters from these aerially exposed soils may be detrimental to aquatic life in receiving soils.

SOCIO-ECONOMIC DEVELOPMENT

The first European settlement, within the Tweed / Brunswick area, was attributed to the vast number of timber cutters that arrived in search of Red Cedar. The harvesting of Red Cedar trees continued for many years until the trees were decimated and the community turned to agriculture.

The lush green fields that occur as a result of the high rainfall and mild temperatures of the region made the area ideal for dairying. During the 1950's, farmers began to branch out into other industries, including bananas on areas with steep slopes, and sugar cane on the river flats.

Since then, primary industry in the region has become wide and varied, including:

Sugar Cane	Oysters	Macadamias
Timber	Beef Cattle	Fishing (recreational & commercial)
Dairy Cattle	Tea Tree	Horticulture
Vegetables	Bananas	Crayfish, Perch (aqua culture)
Oil Tree Production	Stone Fruit	Avocados
Prawns	Bush Foods	Pork / Bacon

Residential areas are concentrated at: Tweed Heads, Terranora, Terranora Heights, Fingal, Chinderah, and Banora Point in the Tweed Valley, and, Brunswick Heads, Byron Bay, Mullimbimby, Hastings Point, and Kingscliff in the Brunswick Valley.

Undisturbed or pastoral lands are concentrated at: Cobaki, Broadwater, and west of Terranora in the Tweed Valley, and, west of the coast and Mullumbimby in the Brunswick Valley.

Commercial / Industrial zones are concentrated at: Tweed Heads and areas south of Tweed Heads.

Agricultural lands (non pastoral) are concentrated at: east of the residential area of Terranora, Sugar cane farming occurs mostly on the floodplain upstream of Chinderah and is the regions most important agricultural activity.

Dredging of the Tweed River and broadwaters, for navigation, has occurred since early in the century and more recently for commercial sand and gravel extraction. The coastal dune system was extensively mined for mineral sands during the 1960's and 1970's.

Tourism is also a major industry in the Tweed and Brunswick Valley catchments. With its beautiful beaches and areas of rainforest, many tourists visit the region. More and more visitors are coming for the ecotourism experience, and this segment of the industry is expanding rapidly in response to this specific demand.

SURFACE WATERS

The average yearly discharge of the Tweed River is 418 000 megalitres. It is tidal to Bray Park Weir, while the Rous River is also influenced by the tide to Kynnumboon. The average yearly discharge of the Brunswick River is 52 000 megalitres. Its tidal range is to the west of Mullumbimby.

Runoff as a percentage of rainfall within the Tweed catchment is 23% (Ross, J.B. & McKibbin, D. 1992), which is just above the average for coastal rivers. The Clarrie Hall Dam is the major storage in the catchment. Runoff as a percentage of rainfall within the Brunswick catchment is 29% (Beale, J.G. 1968), which is also above the average for coastal rivers.

The quality of stormwater runoff from a catchment undergoing the transformation from undisturbed / rural to residential / commercial, i.e., an urbanising catchment, is typically of poorer quality than that from the catchment of both the undisturbed and the completely urbanised / established land. This is due to two major attributes, being:

- occurrence within the catchment of considerable areas of exposed and / or disturbed soils.
- frequent over application of fertilisers to encourage vegetation growth.

The main source of sediment inflow into the major rivers is through agricultural runoff. This runoff can occasionally cause non-point source pollution, such as from nitrogen, while point source nitrogen pollution can occur from sewage treatment discharges.

Significant surface runoff also occurs in the development of urban areas that, in turn, affects stream hydrology and morphology. As urbanisation increases, the percentage of catchment surfaces impervious to rainfall also increases leading to a decrease in groundwater recharge rates and therefore groundwater storage is affected. Urban surface runoff is also a source of pollution of the rivers. Typical materials present in urban runoff are: dust and soil, litter, animal wastes, fertilisers, oil and grease, and particles derived from corrosion and abrasion, spillage's to land surfaces, and illegal waste discharges.

This pollution can have a significant impact on the aquatic/riparian environment of the water courses as well as extending to the fisheries industries within the estuaries to beyond river mouth entrances.

GEOLOGY

The following geological summary has been extracted largely from Graham (1990).

During the Late Silurian period (400 million years ago), mud and sand were deposited into a marine trough, eventually forming greywacke sandstone and shale. These rocks were, over time,

metamorphosed into what is now known as the Neranleigh-Fernvale Group. This Group forms the basement rocks of the Tweed - Gold Coast region.

During the Mesozoic Era (80 million years ago), giant freshwater lakes formed west of the Mt Warning area into which sediments were deposited from surrounding highlands such as the New England granite area. One of these lakes is now called the Clarence Basin and holds numerous fossiliferous material.

The border between the Neranleigh-Fernvale Group and the two sedimentary basins formed a point of weakness through which, in the Mesozoic Era, there were many volcanic eruptions. These eruptions were composed of rhyolites and other associated volcanic rocks and extended from well south of the Tweed, under the present day Mt Warning and outcropping in the north at Chillingham and Tamborine. These rocks are called the Chillingham Volcanics.

In the Tertiary Period (20 to 60 million years ago), a new series of eruptions started along the line of weakness of the Chillingham volcanics. These eruptions were of low viscosity basaltic lava spreading out relatively flat over vast distances. The main vents were probably in the Mt. Warning area but there must have been many others, perhaps near Point Danger, Cudgen-Fingal, Binna Burra (Qld) and Mullumbimby. These flows formed the base of the growing volcanic complex.

A later Tertiary volcanic phase of less plastic and quicker hardening acidic lavas, such as rhyolite, replaced the basalt. This lava tended to harden in the vents, thus building up the pressure underneath , until eventually, violent explosions released the pressure. This violence at times pulverised the rock into fine ash or larger volcanic bombs or frothed it to pumice. This material, mainly rhyolite, can now be seen as a hard layer resisting erosion in the cliffs of Springbrook and at the edge of the Lamington Plateau and Tweed Range. Due to the fact that the rhyolite is acidic and the water is also acidic, this rock does not weather as rapidly as the basic lava that came later. As a result, the rhyolite forms a barrier to the downcutting highland streams, producing numerous waterfalls and cataracts.

The next stage of the volcanic complex came with a series of outflows of basalt lava. Like the first phase, this was probably a relatively quiet one, with long lava flows coming from a number of vents, but with the Mt Warning vents being the major ones. These basalt flows can be seen on the tops of the Lamington Plateau, the Tweed Range and the Nightcap Range.

Around 10 million years ago, the volcano began its demise. Immobile and very acidic trachyandesite effectively plugged the vents causing acid intrusives, including syenite and trachyte, to upwell in radial cracks. Under the hardening plug, micro-granite began to form, which can now be seen in the Mt. Nullum area. It is this complex of plug and ring dykes, later revealed by erosion, which makes up the present Mount Warning landscape.

Over time, the high rainfall, and thus surface water drainage, caused considerable erosion branching out in a radial form from Mount Warning. Erosion tends to occur more prominently around planes of weakness, such as fractures formed from the great pressure exerted by the upwelling magma and possible collapse of the caldera. Erosion of the inner part of the shield around the volcanic centre occurred, resulting in the present amphitheatre-like structure. Discontinuous alluvial deposits have built up within the drainage channels, becoming more extensive from Murwillumbah to the coast, where surface relief is minimal.

During the Quaternary period aeolian processes formed the sand dunes extending along the east coast from Point Danger to Cudgen Headland.

Over time, this geological provenance has been sculptured by wind and water, weathering and erosion resulting in the present landforms that we see today, producing recent alluvium, sand, and soil.

The geology of the Tweed and Brunswick Valley catchments can be seen in the Aquifer Media vulnerability component map.

GROUNDWATER AVAILABILITY OF THE TWEED-BRUNSWICK CATCHMENT

Groundwater availability maps are an assessment of the expected and dominant groundwater resource for specified areas. They are based on published geologic maps, existing groundwater information and general hydrogeologic principles, and are produced for regional planning purposes. These maps should not be used as a substitute for a detailed hydrogeological assessment where site specific information is required. The following discussion of groundwater characteristics is based largely on information contained in McKibbin (1995).

UNCONSOLIDATED SEDIMENTS

Beach and Dune Sands

These aquifers have the greatest potential for groundwater resources.

The coastal sandbeds of the Tweed and Brunswick Catchments form an important aquifer system because they catch and store a significant proportion of the rain that falls on them. Moreover, as they consist mostly of sand deposited mainly by wind action, the permeability of the aquifer system is generally high. However, thin discontinuous clay, silt and peat deposits are often interspersed throughout the sand bed formation. These horizons are generally of low permeability and thus occasionally produce lower than expected yields.

Water tables are generally shallow; often they are only a few metres below the natural surface level. Consequently, freshwater lagoons, lakes and freshwater wetland habitats within the sand beds are common features and they represent “windows” to the water table.

Groundwater salinity within the beach and dune sands of the Tweed / Brunswick area is quite variable. Department records show that the groundwater is of low salinity along the beaches (<500mg/L) but typically grades into a higher salinity within the dunes (1500-5000mg/L). This high salinity is possibly due to the high frequency water courses within the catchments running parallel to the beach therefore increasing the likelihood of salinisation of the dune sediments. Water quality problems occur in some areas with the presence of iron or hydrogen sulfide causing discolouration.

The beach and dune sands are recharged by direct infiltration of rainfall with the fresh water body overlying the denser salt water. Yields of up to 40L/s can occasionally be obtained from individual bores within the sand dunes. However, because of their hydraulic connection with bodies of saline water, careful extraction and management techniques are necessary to avoid saline intrusion.

Little use is made of these resources within the catchments for agriculture. However, large numbers of spear-points and bores are used to obtain water for seaside homes, tourist resorts,

caravan and camping areas.

Alluvial Sediments

Alluvium between 7 and 10 metres thick occurs in the upper reaches of the major rivers within the Tweed and Brunswick catchments. This increases to about 25 to 35 metres towards the downstream limits where there is a transition into the estuarine environment due to the “drowning” of the lower reaches by a sea level rise of some 80 metres after the last major ice age. A sea level fall of about 5 metres some thousands of years ago has left low level estuarine flats exposed which were formerly extensive silt and mud flats in the tidal zone.

Groundwater investigations undertaken by DLWC and bore records have shown that the Tweed River alluvium and similar environments do not contain any significant low salinity groundwater resources on the flats such as downstream of Murwillumbah. The sediments deposited in the estuaries of all the coastal rivers have similar characteristics. They form low lying flats that are often extensive.

Groundwater in these deposits is often only suitable for stock from the top 5 to 6 metres due to the higher salinity derived from sediments of marine origin. Yields of 1-5 L/s are possible from the main alluvial flats which are generally fine grained sediments. This finding relates to the predominant estuarine origin of the sediments over much of the lower Tweed Valley, however, fresh quantities of water are obtainable along the northern edge of the Tweed Valley alluvium and its tributary alluvium due to recharge from the fresher basement rocks.

In the Tweed River upstream of Murwillumbah, and in other similar major tributaries, bore records show that the groundwater potential is much better; with the thickness of alluvium ranging up to 20 metres on the Tweed River. Yields of over 2.5L/s (some ranging up to 20L/s in the coarser gravels) with salinities <500mg/L are obtainable in the Oxley River up from Murwillumbah with lower yields and similar salinities found in the other major tributaries to where the fluvial deposits occur.

TERTIARY BASALTS AND ASSOCIATED VOLCANICS

Basaltic lavas of Tertiary age are widespread within the catchments and comprise the Mount Warning Shield Volcano. The shield volcano is believed to have an age of 20 to 23 million years before present. Its larger acidic bodies caused a profusion of sills, dykes and plugs mainly in the older Mesozoic sedimentary strata that are part of the Clarence-Morton Basin.

Tertiary basalts and their associated volcanic rock formations are one of the most important aquifer systems of the study region. They are a very reliable aquifer system for bore water supplies containing low salinity groundwater that is suitable for most urban and rural purposes although the water is typically hard. Yields within the basalts and associated rocks of the Tweed/Brunswick Valley catchments are generally between 0.5 and 1.5L/s although individual yields as high as 15L/s have been recorded. The depths for supplies are on average 30 metres.

The permeability of the rock formation is generally high due to the consistent secondary porosity features such as joints and fractures as well as some primary features such as vesicular zones (gas bubble voids trapped when the rock cools and solidifies) within the lava as well as weathering profiles between volcanic layers. Groundwaters discharging from the basalt terrain feed numerous springs and significantly maintain some wetlands and the baseflow of streams that drain such areas.

The water is usually of excellent quality with low salt content (<500mg/L), although it is often found to be hard which is characteristic of waters from basaltic terrains.

POROUS SEDIMENTARY ROCKS

The porous rock aquifers, within the area, are associated with the sandstones of the Clarence-Moreton Geological Basin that extends south from the Queensland border to about 50 kilometres beyond Grafton.

The Bundamba Group, situated to the north and south of Mt Warning, consists mainly of Early to Mid Jurassic sandstones, siltstones, and pebble conglomerates. It is a low yielding, variable salinity aquifer system with higher salinities south of Mt Warning and lower salinities north of Mt Warning. However, the resource potential is not yet fully established.

The shale, sandstone, coal, and ironstone of the Jurassic aged Walloon Coal measures occupy much of the area in the Tweed Valley Catchment west of Mt Warning. Bores within this formation usually obtain water within 30 metres of the surface, but have proven to be low yielding and have a salinity of 500 - 1500 mg/L.

Groundwater prospects are mostly poor in terms of both salinity and yield. Yields are generally less than 1 L/s and rarely exceed 2 L/s.

BASEMENT AQUIFERS - *FRACTURED ROCK*

Much of the Tweed Valley catchment is occupied by the basement rocks of the Neranleigh - Fernvale Group. This Group consists of metamorphosed sediments being, greywacke, slate, phyllite, and quartzite and produces yields generally under 1.5L/s. Salinity is generally low (<500mg/L), however, localised hydrogeologic variations may occur giving rise to higher or lower values than expected.

MAJOR LAKE SYSTEMS

The aquifer media of the Tweed Heads lake system and other similar saltwater lake systems along this coast consists mainly of basement rocks and recent alluvium. Departmental records show that bores in the vicinity of these lake systems were of low salinities (<500mg/L) at the time of their construction. This suggests that at this time the lakes were acting as discharge sites for the local groundwater. Due to groundwater level fluctuations occurring from wet and dry periods or from season to season it is possible that the lake system may act as both a groundwater discharge and recharge site, the latter resulting in unexpected saline intrusion. This results from the reversal of the hydraulic gradient causing saline water encroachment in coastal areas destroying much of the aquifer system.

POTENTIAL FOR LAND SALINISATION

There is the potential for land salinisation to occur on the lower slopes of the Tweed and Brunswick catchments. Land salinisation occurs when salty groundwaters rise to or near the ground surface. The rise of groundwaters is caused by the modification of native vegetation by activities such as clearing, grazing, or by cropping to vegetation that uses much less water than the natural vegetation. This results in a more significant amount of surface water recharge to the groundwater. As the water table rises due to excessive recharge, it dissolves and accumulates naturally occurring salts in the soil and brings them towards the surface where the salt is concentrated by soil moisture evaporation. This concentration causes devegetation of the land of all but the most salt resistant plants.

It is recommended that a Dryland Salinity Hazard Map be produced for the Tweed and Brunswick catchments. These maps show areas that have the potential to be affected by land salinisation as well as those that already have been affected.

POTENTIAL ACID SULFATE SOILS

Coastal areas such as the Tweed and Brunswick Catchments contain vast amounts of potential and actual acid sulfate soils due to their close relationship with marine environments.

Acid sulfate soils are acidic soil horizons or layers resulting from the aeration of soil materials that are rich in iron sulfides, mainly pyrite. When drainage or excavation brings oxygen into these previously water logged soils (potential acid sulfate soils), the pyrite is oxidised to sulfuric acid. Should the production of acid exceed the neutralising capacity of the soil so that the pH falls below 4, these soils are known as actual acid sulfate soils.

Potential acid sulfate soils are waterlogged soils rich in pyrite that have not been oxidised. Any disturbance that admits oxygen will lead to the development of actual acid sulfate soil layers. Potential acid sulfate soils are completely innocuous to the environment if kept under water (Soil Conservation Service of NSW, 1995)

Acid sulfate soil risk maps have been produced for the coastal areas of the Tweed and Brunswick catchments by the Soil Conservation Service of NSW. These maps show there is high potential acid sulfate soil development within the soils associated with alluvial flats of the major rivers of the Tweed and Brunswick Catchments. The occurrence of these potential acid sulfate soils means that certain groundwaters that have been classed favourably on the availability map could be destroyed by

the formation of actual acid sulfate soils by lowering of the watertable through, for example, pumping from bores or construction of surface water diversions.

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