

Overview of the Project Area

This chapter provides an overview of the location and setting of the Tillegra Dam Project including relevant environmental characteristics. A summary of the potential environmental and social considerations relating to the Project is also included. A detailed assessment of the impacts of the Project on the environment is addressed in later chapters.

5.1 Location and setting

The Project is located within the Williams River catchment, a subcatchment of the Hunter River catchment. The Williams River rises in the Barrington Tops National Park and flows to meet the Hunter River estuary at Raymond Terrace. The Chichester River joins the Williams River near Bandon Grove. The Project is located in the Dungog LGA within the Hunter region of NSW, approximately 74 kilometres north of Newcastle. The Project area covers the immediate localities of Tillegra and Munni along the Williams River but also the broader Dungog area (and part of the Port Stephens LGA). The local setting of the Project is illustrated in Figure 5.1.

5.2 Climate and weather

The two closest Bureau of Meteorology stations are Chichester Dam (elevation 194 mAHD) and Lostock Dam (elevation 200 mAHD). Summary details for monthly rainfall and temperature meteorological parameters for these two stations are presented in Table 5.1.

Distinct seasonal patterns in rainfall are apparent with the wetter months occurring from December through to March at both sites. This is reflected in both average monthly rainfall totals and the mean number of rain days. The difference between maximum and minimum temperatures does not vary overly from month to month but is greatest in summer months.

Annual rainfall varies across the catchment with about 650 mm/year in Scone (in the Upper Hunter) and over 1,100 mm/year at Williamtown (in the Lower Hunter). Rainfall peaks between January and March and the variability of rainfall from year to year is high.

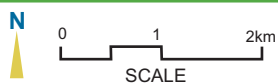
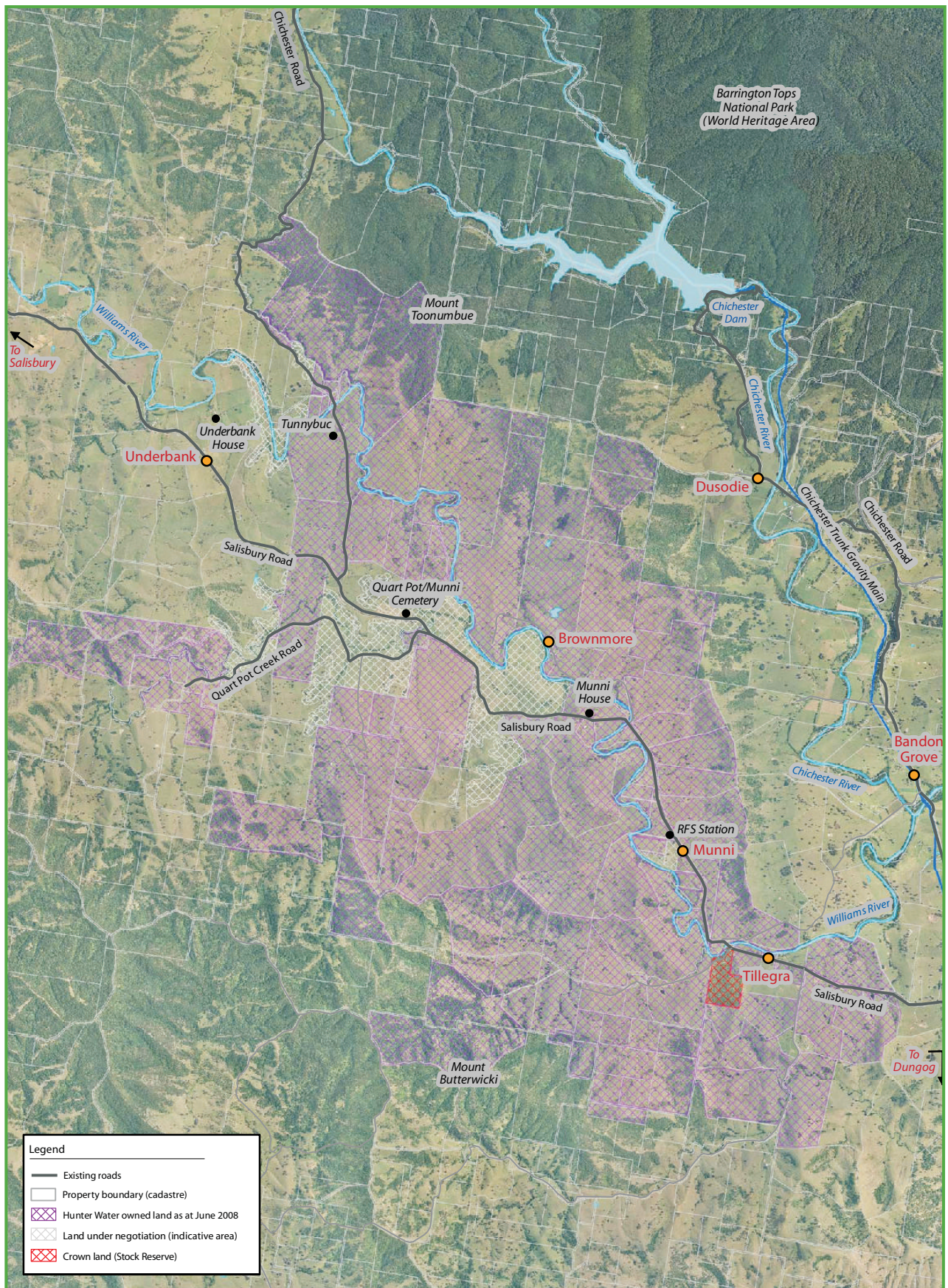


FIGURE 5.1 EXISTING ENVIRONMENT

TABLE 5.1 MONTHLY RAINFALL AND TEMPERATURE FOR CHICHESTER AND LOSTOCK DAMS

	MEAN RAINFALL (mm)		MEAN NUMBER OF RAIN DAYS >1 mm		MEAN MAXIMUM TEMPERATURE (°C)		MEAN MINIMUM TEMPERATURE (°C)	
	CD	LD	CD	LD	CD	LD	CD	LD
Jan	169.8	131.3	10.8	10.0	26.2	29.2	16.7	17.2
Feb	177.2	122.9	11.4	9.6	24.9	28.3	16.7	17.2
Mar	173.9	126.3	11.2	9.5	23.3	26.5	16.2	15.4
Apr	94.4	64.6	8.2	7.1	20.2	23.6	12.7	12.7
May	97.9	76.1	8.6	7.8	17.4	19.9	9.7	10.2
Jun	103.6	60.3	8.9	7.3	14.2	16.9	7.0	7.7
Jul	53.0	38.4	7.4	6.1	13.7	16.4	6.2	6.5
Aug	60.0	35.3	6.9	5.5	15.5	18.3	6.9	6.9
Sep	61.9	50.1	7.1	6.7	19.1	21.4	9.8	9.3
Oct	93.1	67.0	8.8	8.0	21.4	24.5	12.1	11.9
Nov	101.4	84.3	9.4	9.6	24.1	26.3	14.9	13.9
Dec	124.7	90.8	10.1	8.5	26.6	28.9	17.2	16.1
Annual	1,311.5	947.7	108.8	95.7	20.6	23.4	12.2	12.1

CD = Chichester Dam, LD = Lostock Dam

Source: Climate Statistics 2007 – Bureau of Meteorology website (<http://www.bom.gov.au>)

5.3 Geology, landforms, and soils

5.3.1 Regional geological setting

The Dungog area is contained within the Tamworth Synclinorial Zone which forms part of the New England Fold Belt. The belt extends from Newcastle to North Queensland and is a major structural component of Australia's geology on the East Coast.

The 1:100,000 Dungog, Geological Series Sheet 9233 notes an overlying regional geology consisting of Carboniferous Age marine deposited conglomerates, sandstones, siltstones and mudstones with minor limestone and calcareous deposits (Coffey Geotechnics 2008). The Carboniferous Age began approximately 350 million years ago. It is characterised by a time of low sea level, tectonic movement, mountain building and later in the period, global cooling and glaciations.

As noted by Gibson and Dimas (2009), the topography of the region shows many lineations and scarps, created by faulting and folding, as does the majority of the Eastern Highlands of Australia. According to Henderson (2000), a major east-west compressive event formed the Stroud-Gloucester Syncline in the early Permian (about 299 million years ago). This was followed in the latter part of the early Permian by northwest/southeast faulting, uplift of the Gloucester Tops and intrusion of the Barrington Tops Granodiorite. This rock type is basically a darker than normal form of granite. Subsequently, a major compression event produced several major folds in the region.

East-west tension during the late Permian led to high angle faulting which created horsts, grabens and step-faults. These areas subsequently experienced additional compression after formation. Horsts, grabens and step faults are, in simple terms, large blocks of land where the earth's crust has uplifted or remained stationary while other areas of land have sunk. They can create valleys with distinctive scarps on either side. These faults are often also arranged parallel to the axes of folds. They are quite common.

The Project area is located within the Gresford Block. Within this block, the Brownmore fault to the west and the Majors Creek and the Williams River Faults to the east of the Project area are the dominant structural geological features of the region (Roberts *et al* 1991, Department of Commerce 2009). The Tillegra Fault occurs downstream of the proposed dam site (Department of Commerce 2009).

The faults mapped within the regional area, including in close proximity to Tillegra, are considered to have been active between 310 million and 200 million years ago. Gibson and Dimas (2009) note that geological studies to date have not discovered any evidence that any of these faults have been active in recent geological time (generally within the last million years).

5.3.2 Site-specific geological investigations

Preliminary geotechnical investigations were undertaken at the dam site in 1952. These were followed by more specific investigations in 1970 and 1985 comprising:

- A regional survey of the area was undertaken by the Geological Survey of New South Wales (Hall 1952)
- Hunter Water Board, 1952. Investigation included geological mapping and 35 percussion boreholes, 27 of which were extended with diamond coring. Drilling was mostly on the left alluvial terrace, upstream of the site, the right bank, upstream of the embankment footprint, and the lower left abutment.
- Snowy Mountains Engineering Corporation, 1970. Investigation included additional mapping, a seismic traverse in the riverbed and two inclined, diamond cored boreholes across the valley floor.
- Water Resources Commission of New South Wales, 1985. Predominantly aimed at assessment of earth fill borrow sources and involved the drilling of mainly shallow auger bores with associated material testing.

Additional specific work has now been completed for both the dam and proposed relocation of Salisbury Road by Coffey Geotechnics, Douglas Partners Pty Ltd and the NSW Department of Commerce. This work has included:

- a review of regional geology
- topographic surveys
- interpretation of aerial photography
- geomorphological mapping of surface features
- geological mapping
- core drilling and logging of cores
- permeability testing of drill holes
- strength testing of drill cores
- excavation of test pits, test trenches and general sampling
- seismic refraction survey
- soil testing
- petrographic analysis of rock samples
- aggregate testing
- unconfined compressive strength testing
- production of plans and logs of all activities

- assessment of seismic hazards
- landslide risk assessment
- peer review.

The work has been undertaken to understand and assess foundation conditions for the dam, its abutments and associated structures, the need for any works to stabilise the rim of the reservoir or to prevent leakage, and sources of material for construction of the works. This understanding has been used to develop the general arrangement of the structures associated with the dam such as the spillway, river diversion works and offtake tower and foundation treatments such as grouting.

Test pits, boreholes, seismic refraction surveys and other field testing have also allowed HWC to understand the extent of work involved for construction of the new Salisbury Road, volumes of rock and soil in cuts and fills, slope stability and angle of repose on road batters.

5.3.3 Geology of the dam site

The dam site consists of an interbedded sequence of sandstone and shale belonging to the Flagstaff formation. These rocks have been subjected to low grade regional metamorphism and are alternatively referred to as 'tuffaceous sandstone' and 'meta-shale'. Across the wider reservoir area, a range of additional geological formations occur (Department of Commerce 2009). The geological formations present in the Project area are summarised in Table 5.2.

TABLE 5.2 GEOLOGICAL FORMATIONS WITHIN PROJECT AREA

GEOLOGICAL FORMATION	GEOLOGICAL FORMATION
Salisbury Sandstone (Dewrang Group)	Predominately in the south western part of the Project area
Chichester Formation (Dewrang Group)	Occurs in the ridge line to the north of the proposed dam area and in the northwest corner of the Project area
Flagstaff Formation (undifferentiated) (Gilmore Volcanic Group)	Predominant rock type found in the north eastern half of the Project area
Flagstaff Formation (Gilmore Volcanic Group)	Occurs in the southwest part of the Project area and is predominately sequential bedded as follows: <ul style="list-style-type: none"> • Lostock Member • Bandon Grove Limestone Member • Brownmore Sandstone Member • Underbank Mudstone Member • Allyn River Member • Bonnington Siltstone (Gilmore Volcanic Group) – occurs in the centre and to the north of the Project area

5.3.4 Folds and faults

The Project area is known to be subject to regional folding and faulting with a northwest to southeast trend. There are three main folds within the Project area, namely the Lewinsbrook Syncline to the southwest of the proposed inundation area; the Brownmore Syncline, which crosses the proposed inundation area; and the Main Stroud-Gloucester Syncline which is located approximately 27 kilometres to the northeast of the proposed inundation area (Coffey Geotechnics 2008).

A series of continuous faults trend through the region including the Brownmore Fault (associated with the Brownmore Syncline) which crosses the proposed inundation area, and the Major's Creek

Fault and Williams River Fault well to the east of the proposed dam site. A number of less continuous local faults occur in the vicinity of the proposed dam site.

Investigations undertaken in 1970 (Snowy Mountains Engineering Corporation 1970) identified a 2.1 metre wide shear zone (an area of disturbed rock) in the valley floor parallel to the river. Shear zones are quite common and can range in size from several centimetres to several kilometres wide. The identified shear zone comprises altered tuffaceous material with a defect spacing of extremely close/very close. It is assumed that the zone is controlling the orientation of the river at the site. As a result of regional folding, shear zones are also expected to occur in finer-grained rock types, parallel to bedding.

The Tillegra Fault lies outside the rim of the proposed reservoir and approximately 500 metres downstream of the proposed dam site. The fault dips away to the east at an approximate 35 degree angle.

A number of other minor faults have been identified in the proposed storage area. None of the folding and faulting is considered significant or unusual in terms of its impact on the design of the proposed works.

5.3.5 Lithology, strength and weathering

Recent geological investigations (as described in Section 5.3.2) have shown that the various beds or layers of sandstone and shales strike in a north-south orientation across the orientation of the Williams River and beds also dip moderately upstream (west). The ridges on either side of the valley are controlled by this strike.

The various rock types found in the Project area are expected to weather at different rates. Outcrops of tuffaceous sandstone are generally slightly weathered. Although finer-grained rock types (shale) are not generally exposed at the surface, exposures at roadside cuts are generally moderately weathered near the surface. Weathering is most intense at and near the surface and decreases, usually gradually, with depth. Weathering across the Project area depends on a number of factors with the most dominant factors of joint spacing, bedding thickness, topography and mineralogy having the greatest influence. Weathering is expected to be the greatest in areas of low lying topography, on shallower ridge tops and in rock masses with larger joint spacing.

Effectively the upper sandstone and shale layers are moderately weathered between 5-15 metres below the surface of the ground. Below this depth, fresh rock which has considerable strength is commonly found.

5.3.6 Detailed geotechnical investigations of the dam site, inundation area and relocated roads

Technical consideration of the geotechnical aspects, for the dam, roads and reservoir area are contained within the following technical documents annexed to the EA Report:

- Annexure A – *Tillegra Dam Design Consultancy 361802 – Concept Report*, Dept of Commerce, January 2009
- Annexure B – *Roads Around Tillegra Dam – New Salisbury Road – Concept Design*, Opus International Consultants Pty Ltd, July 2008
- Annexure C – *Tillegra Dam Site Interim Engineering Geological Report Vols 1 & 2*, Dept of Commerce, February 2009

- Annexure D – *Tillegra Dam Design Consultancy 361802 – Storage Rim Stability and Seepage Potential Engineering Geotechnical Report Vols 1-5*, Dept of Commerce, February 2009
- Annexure E – *Interpretive Report on Geotechnical Investigation Vol 4, Concept Design Phase Route Survey Diversion of Salisbury Road Around Proposed Tillegra Dam*, Douglas Partners Pty Ltd November 2008

The reports examine in detail the geological setting, interpreted geological conditions and general foundation suitability for the proposed dam embankment, as well as for spillway, coffer dam and road construction work. The availability of material for construction is also examined. Further information is provided which is of relevance to storage rim geology, seismic hazards, rim stability, seepage potential and general behaviour of the storage area.

In every case, the consulting geologists have noted that there are no impediments that would present as an issue to the proposed construction of the dam. Since production of these studies, additional work has been commissioned to investigate more fully the availability of quarry materials. In this regard suitable material for both fill and concrete aggregate has been shown to exist within the project area.

To ensure geotechnical investigations are of the highest standard, each aspect of the work has been peer reviewed by a panel of experts convened by HWC to provide independent expert advice on suitability of the proposed investigations and final quality of the work. Investigations to date have been carefully scrutinised by the independent expert panel and found to be suitable. These findings have also been accepted by the NSW Dams Safety Committee which has accepted, in principle, findings within the rim stability reports and the overall concept design for the dam.

In summary, there is no geological impediment to the construction of the dam.

5.3.7 Landforms

The Project is located in the North Coast Bioregion, which occupies around seven per cent of NSW landforms (Department of Environment and Conservation 2004). This bioregion covers northern NSW from the shoreline to the Great Escarpment. Typically, there is a sequence from coastal sand barrier, through low foothills and ranges, to the steep slopes and gorges of the escarpment itself.

The Dungog region is divided into a number of physiographic regions (Henderson 2000). The Project falls within the Dungog Hills region, which exhibits rolling to steep hills formed on Carboniferous sediments with the alluvial plains of the Williams and Chichester Rivers and their tributaries. The Williams Range region is located to the immediate west of the Project area, occupying steep mountains and rolling foothills on Carboniferous sediments forming the Williams Range and parts of the Wallarobba Range. The Barrington-Chichester Mountains region is located to the immediate north of the Project area and occupies highly dissected, steep to precipitous terrain on Carboniferous sediments including Chichester State Forest, Barrington Tops National Park and the Chichester Dam catchment.

Catchment runoff and flow of the various tributary streams into the Williams River have been an important factor in shaping natural drainage channels. Major subcatchments of the Williams River are shown in Figure 5.2. The Tillegra subcatchment occupies about 15 per cent of the total Williams River catchment down to the Hunter River confluence. Figure 5.2 also highlights the contributing catchment area between the proposed dam site and the Hunter River.

5.3.8 Soils

Soils associated with the underlying meta-sedimentary rock sequences are generally less than one metre in depth across the landscape. Topsoils include pale brown sandy silts overlaying gravel, sand silts and clay (Department of Commerce 2009). There are, however, a variety of soil landscape types present including alluvial, colluvial, erosional and stagnant alluvial (Henderson 2000).

Overall, soils in the Project area are generally susceptible to localised occurrences of:

- sheet and gully erosion
- acidity (and associated aluminium toxicity)
- high run-on
- sodicity
- mass movement.

Erosion hazard is generally moderate to very high across the Project area. Gully erosion is evident along drainage lines, exacerbated by grazing of livestock, and sheet erosion is common on cleared slopes. Due to the seasonality of erosive rainfall in the Dungog area, adequate ground cover is essential (particularly on steeper slopes) to avoid high rates of soil erosion during high intensity summer storms (Henderson 2000).

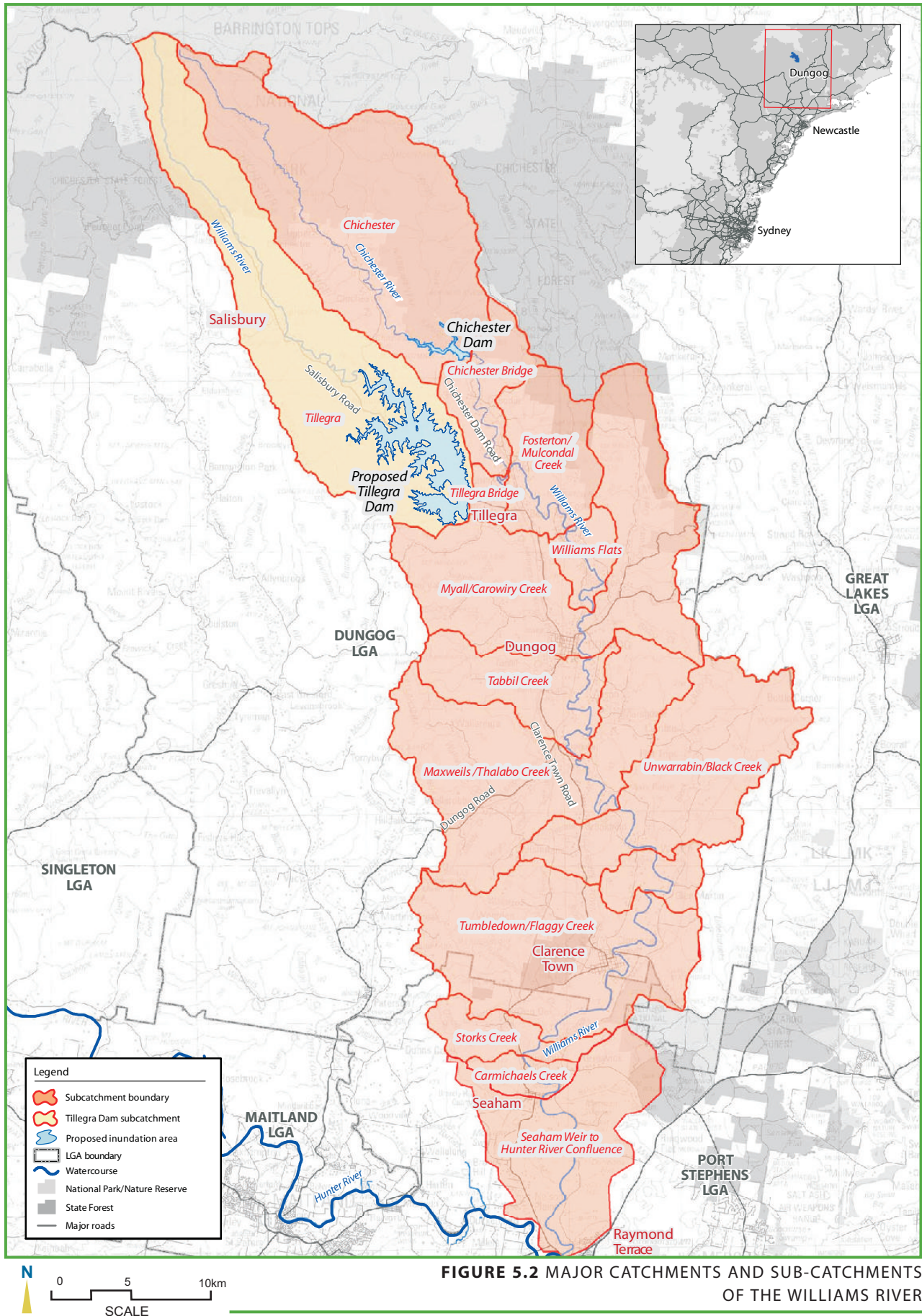
A review of acid sulphate soil risk maps (Department of Natural Resources 2006) indicated no known occurrence of acid sulphate materials in the Project area. The risk of acid sulphate occurrence in the Project area is considered to be low.

5.4 Fluvial geomorphology

The Williams River is a relatively steep, large-capacity, gravel bed channel with in-channel benches and various types of gravel and bedrock bars (Erskine 1986, 1998, 2001; Erskine and Livingstone 1999). Brooks *et al* (2004) classify the river near Munni as 'discontinuous floodplain river style' which is typical of many coastal gravel-bed rivers in eastern Australia. As such, it exhibits alternating reaches of close bedrock confinement and unconfined floodplains. Significant lateral migration is restricted to unconfined bends. The resistance of the channel boundary is also enhanced by dense bankside vegetation, coarse bed material and bedrock bars in the bed (Erskine 1998, 2001).

The floodplains and hillslopes of the Williams River have been cleared since first European settlement in the early 1800s (Erskine 2001). Both Erskine (2001) and Brooks *et al* (2004) assumed that widespread forest clearance during the initial settlement phase increased runoff and flood peak discharges. Erskine (1998) was of the view that improved pastures, which have been in extensive use since the 1960s would have decreased runoff since then.

River stability is a function of both resistance (offered by large woody debris and riparian vegetation) and fluvial energy. Significant geomorphic change results when the energy or shear stress of the flow exceeds the resistance of the channel boundary. This is more likely in extremely large flood events. Brooks *et al* (2004) were of the view that the present channel size reflects riparian zone disturbance since European settlement, and that channel expansion accelerated with the onset of desnagging in the 1960s coincident with a series of large floods.



The volume of material delivered to the channel system from sediment sourced from the channel itself (ie bed and bank erosion) appears to have increased since the 1940s (Erskine 1998). The National Land and Water Resources Audit estimated the average annual suspended sediment transported by the Williams River upstream of the Chichester River confluence to be 4,600 t/yr (Australian Government 2001).

Erskine (1998) concluded from an analysis of flood variability that the Williams River is likely to be more stable than other Hunter Valley rivers. The relatively low flood variability and relatively low flood magnitudes, combined with the relatively dense riparian vegetation, presence of rock bars and bedrock valley walls, and coarse bed material particle size (which offer resistance to erosion and degradation), mean that the Williams River has relatively good prospects for physical rehabilitation (stabilisation) compared to most other Hunter Valley rivers.

5.5 Water resources

5.5.1 Hydrology

The Williams River catchment is approximately 1,300 km² in area at its confluence with the Hunter River. The steep upper catchment and frequent rainfall result in a river hydrology characterised by relatively short-lived flow events and significant baseflow during the wetter months. The interannual variability is marked by wet/dry periods in which the river can completely cease to flow for short periods during droughts but also maintain large flows during the wet cycles. The average recorded streamflow at the lower end of the Williams River is about 321,000 ML/yr.

The Tillegra Dam subcatchment is approximately 194 km² in area and accounts for around 15 per cent of the total Williams River catchment area. The subcatchment is characterised by steep vegetated slopes, rising to 1,500 metres above sea level in the northern elevated region, and cleared agricultural land in the southern area of the subcatchment declining to around 87 metres above sea level at Tillegra Bridge.

The flow regime at the proposed dam site is influenced by the steep upper catchment and rolling hills around the dam site as well as rainfall variation across the catchment. Flows at Tillegra Bridge over the 77 years of daily observations vary from nil to a flood peak of 54,488 ML/d. The average flow is 261 ML/d with a median inflow of 51 ML/d.

Other than the steep slopes of the upper areas, most of the Williams River catchment has been cleared of vegetation over the past 200 years (Healthy Rivers Commission 1996). Land clearing typically changes the hydrology by increasing runoff characteristics, particularly for storm events, with increased baseflows. Dry weather low flow periods are evident in the flow records (1931 to 2007) at Glen Martin (some 60 kilometres downstream of the Tillegra gauge) for the periods 1964/65, 1979/81 and 1990/91. The recent period of dry weather from 1997 to early 2007 that affected most of the southeast coast of NSW was not evident in flow records until 2005. As a result, the duration of the longest drought on record is 18 months.

Flows in the Williams River downstream of the proposed dam site increase as tributary inflows contribute to the main channel flow. Observed flows at Glen Martin range from nil to a flood peak of 137,448 ML/d. The catchment area at Tillegra represents approximately 20 per cent of the catchment at Glen Martin, and contributes approximately 40 per cent of the flow. The average flow is 881 ML/d and median inflow is 118 ML/d.

5.5.2 Water quality

In 1996, the Department of Urban Affairs and Planning concluded that the Williams River catchment was reasonably healthy, able to support diverse ecosystems and a range of land uses such as national parks, agriculture and human development. The 1997 Healthy Rivers Commission Inquiry into the Williams River formed a similar conclusion for the river following a review of water quality monitoring data, scientific studies and community consultation. However, results from recent studies along the Williams River provide evidence of declining water quality.

Water quality above Glen Martin is considered excellent within the vegetated upper slopes of the catchment, excellent to good in the cleared agricultural areas of the proposed inundation area, fair between the proposed dam site and Dungog and poor downstream of Dungog (Chessman and Growns 1994).

The results of water sampling conducted as part of the EA investigations within the same reaches generally agreed with these findings. However, it was found that zinc concentrations and total phosphorus concentrations generally exceeded the ANZECC (2000) guidelines. Dissolved oxygen levels were also below the lower guideline limit at the majority of sampling locations. Downstream of the proposed dam site, faecal coliform concentrations were found to be higher than primary contact guidelines at all sites sampled. Total nitrogen, nitrate and nitrite concentrations were above guideline levels at a significant portion of sampling locations.

The 23 kilometre reach of the Williams River from Glen Martin to Seaham Weir (known as the Seaham Weir pool) originally formed the freshwater pool of the tidal estuary prior to construction of Seaham Weir in the 1960s. At mean sea level the pool volume is about 9,600 megalitres increasing to 12,100 megalitres at one metre AHD.

Water quality in the pool is affected by inflows and internal processes such as thermal stratification during low flow periods in the warmer months. The weir pool regularly experiences outbreaks of blue-green algae during the spring and summer months when temperatures are high and flows are decreased. Recent sampling found that dissolved oxygen concentrations were below the ANZECC guideline limit, while total phosphorus exceeded guideline levels. Nitrogen, nitrate and nitrite concentrations exceeded the guideline levels for bottom waters of the pool. Surface waters were also found to contain elevated levels of chlorophyll-a.

The estuary reach of the Williams River between Seaham Weir and its confluence with the Hunter River at Raymond Terrace is approximately 15 kilometres in length and about six metres deep with a series of slightly deeper sections, with the deepest of 14 metres near the weir. Water quality in this reach of the river is influenced by surface warming and the formation of a density gradient downstream of the Seaham Weir which results in thermal and oxygen stratification of the water column. The frequency, magnitude and duration of the stratification are dependent on a combination of solar radiation, catchment rainfall and flow over the weir. The potential for these anoxic conditions to develop can extend for several kilometres downstream of the weir (Sinclair Knight Merz 2005).

5.5.3 Water resource management

The DWE is responsible for managing water access and trading in NSW. While rural land holders have access to water for basic purposes such as for stock and domestic uses, licences and/or approvals are required for extracting water from rivers or aquifers for commercial purposes. The Hunter catchment represents 80 per cent of the irrigated area in the NSW mid-coast region (Water Use Efficiency Advisory Unit 2002). The majority of irrigation industries in this region are wine grapes and dairy cow pastures.

Irrigation licences are administered by the DWE. Along the Williams River, management of licences is facilitated using the Glen Martin gauging station. Currently, there are 177 licences which can take up to 8,300 ML/d. Irrigation demand is highest in summer when it can reach 62 ML/d (Department of Natural Resources 2007). The difference between the total licence allocation and observed peak irrigation demand reflects that not all licences issued have been acted on (these are referred to as 'sleeper' licences). Additional demands are placed on the water resource by HWC (approximately 60,000 ML/yr or 164 ML/d) and stock and domestic uses.

5.5.4 Existing water supply

HWC supplies water to the Lower Hunter region from a number of sources. The main water supply sources are Grahamstown Dam (predominantly supplied by the Williams River) and the groundwater sources of the Tomago and Tomaree sandbeds. Grahamstown Dam has a catchment area of 100 km² and a capacity of 190,000 megalitres, and supplies approximately 40 per cent of the total long-term regional needs (Hunter Water Corporation 2006b).

Approximately half the stored water for Grahamstown Dam is drawn from the Williams River. Water is collected immediately upstream of Seaham Weir and pumped to Grahamstown Dam via the Balickera Canal.

The volumes supplied by the different sources to meet demand in are shown in Figure 5.3. Over the past 25 years, annual demand has varied depending on both residential and industrial needs, the introduction of pay-for-use pricing and general climatic conditions.

Growth in annual household demand is now expected to move steadily with population growth where before over the last decade, growth in household demand was offset by reductions in water volumes supplied to industry.

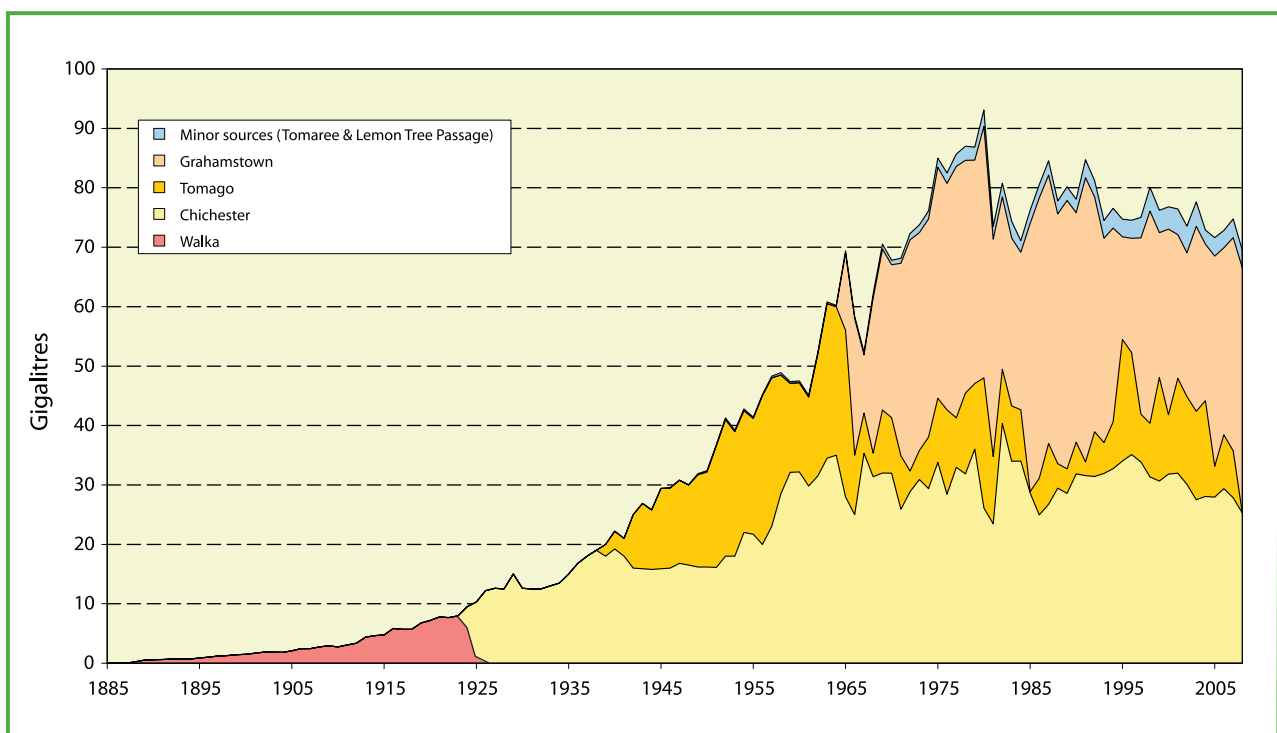


FIGURE 5.3 HISTORIC ANNUAL SUPPLY SOURCES

5.6 Aquatic ecology

The Williams River contains a variety of aquatic habitats. The upper reaches through the proposed Project area contain riffle and pool sequences, gravel bars, bed rock and pools (Department of Primary Industries 2006). Riparian vegetation in this area is confined to the main channel and absent along most tributaries. In-stream, large woody debris is present in places. Further downstream in the lowland reaches, the channel gradually widens forming an unbroken watercourse with deep pools, rock platforms and snags. Macrophyte species such as spike rush (*Eleocharis acuta*), *Vallisneria* sp. and *Phragmites* sp. are common (Department of Primary Industries 2006, Dungog Shire Council 2004a).

The aquatic habitat within the catchment has experienced significant impacts since European settlement. Forest clearing for agriculture during the 19th century increased runoff and flood peak discharges. Increased sediment loads smothered habitats such as gravel beds and shallow holes. Flood mitigation measures implemented in the 1950s and other channel works have changed channel morphology resulting in bed instability, erosion of riffle habitat and infilling of low pools.

Combined AusRivAS analysis undertaken as part of the environmental assessment for both edge and riffle habitat found macroinvertebrate assemblages upstream of the proposed dam site were comparable to reference conditions with good diversity and sensitive species well represented. Sites downstream had significantly fewer taxa than expected, suggesting existing impacts on water quality and/or aquatic habitats. Results from the downstream sites should be interpreted with caution as sampling took place during a time of relatively high flows, potentially under representing the number of taxa present rather than underlying degraded water quality or habitat. Resampling of these sites was not possible due to constant high flows within the Williams River (The Ecology Lab 2008).

Twelve native species of fish have been recorded within the Williams River above Seaham Weir and in sections of the river in close proximity to the Tillegra Dam site. Eight of these species are diadromous and spend part of their lifecycle downstream of the dam in estuarine waters (TEL 2008). Six of these species are also catadromous, meaning that they must migrate to the sea below Seaham Weir to spawn and complete their life cycle. The introduced mosquitofish (*Gambusia holbrooki*) has also been identified above the proposed dam wall site. No fish species recorded above Seaham Weir are listed as threatened under the *Fisheries Management Act 1994* or the EPBC Act.

Seaham Weir is located approximately 10 kilometres upstream of the confluence with the Hunter River and is a tidal barrier that separates freshwater from estuarine habitat. The weir allows downstream fish movement but upstream fish passage is only possible when medium to high flows coincide with high tides and active fish migration (Department of Primary Industries 2006). Seaham Weir has been identified as a high remediation priority by the DPI due to its restriction of fish passage to up to 250 kilometres of upstream habitat including tributaries.

5.7 Terrestrial ecology

Significant changes to the natural ecology of the Williams River catchment have occurred over the past 100 years through clearing of vegetation, abstraction of water for urban and agricultural purposes, the drainage of swamps, the erosion of soils and the introduction of animals (Department of Urban Affairs and Planning 1996). Although much of the native vegetation within the proposed inundation area has been cleared or disturbed to varying degrees through past development, agriculture or poor land management practices, fragmented habitat remnants occur in the area (Dungog Shire Council 2004a, Department of Urban Affairs and Planning 1996). Despite the fragmented nature of the landscape, discontinuous corridors and habitats can often provide important stepping stone links between other areas of more contiguous vegetation. Mapping of key

habitats and corridors across the northeast of NSW undertaken by Scotts (2003) shows several remnants identified as key habitats within subcatchments in close proximity to the Project area.

The region supports a wide range of habitats including rainforests, moist forests, woodlands, riparian vegetation and aquatic ecosystems (Dungog Shire Council 2006). These habitats in turn support a wide range of flora and fauna including threatened fauna species and ecological communities. Such a wide range of habitats indicates a wide range of biodiversity within the existing environment. Pressures on biodiversity within the Dungog area include habitat fragmentation and vegetation clearing, introduced species and fire.

Flora and fauna surveys were undertaken within the Project area as part of the environmental assessment. The flora survey identified the following five natural vegetation communities throughout the Project area:

- Subtropical Rainforest
- Moist Gully Blue Gum Wet Sclerophyll Forest
- Spotted Gum–Ironbark Forest
- Forest Red Gum Moist Slopes Forest
- Riparian Forest.

One highly modified community was also identified during the fieldwork. This consisted of predominantly cleared open pasture or derived grassland with sporadic remnant paddock trees.

The overall species diversity within the Project area was found to be high with a total of 314 flora species from 100 families identified. This total includes 21 ferns, 220 dicotyledons and 73 monocotyledons. Of the total species recorded, 78 species of exotic flora were identified, representing approximately 25 per cent of the total species. A total of 157 fauna species were positively identified (comprising 95 bird, 32 mammal, 16 frog and 14 reptile species). A further five species of insectivorous bat were given a probable identification and two species given a tentative (possible) identification based on ultrasonic call analysis.

Eight threatened fauna species (speckled warbler, eastern bent-wing bat, east-coast freetail-bat, southern myotis, squirrel glider, brush-tailed phascogale, koala and grey-headed flying-fox) as well as five migratory species listed under the EPBC Act were positively identified within the Project area during the fauna survey. In addition, calls of the eastern false pipistrelle and greater broad-nosed bat were given a probable identification and calls of the golden-tipped bat were given a tentative (possible) identification based on ultrasonic call analysis. Additional threatened fauna species have potential to occur based on availability of suitable habitat.

Two endangered ecological communities (EEC), Lowland Rainforest in the North Coast and Sydney Basin Bioregion and River-flat Eucalypt Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions were identified within the Project area. Further, in some intersecting gullies and drainage lines intergrading forms of the Subtropical Coastal Rainforest EEC were considered to occur. No endangered flora species were identified.

5.8 Landscape and visual amenity

The landscape in the Project area is dominated by cleared rural land with dispersed residences and various other cultural elements such as sheds, roads, fences, transmission lines and the Chichester Trunk Gravity Main (CTGM). The CTGM is a large grey main that extends above and below the landscape transporting water to Dungog Water Treatment Plant. A number of small church buildings

also occur within the area. The density of development varies throughout the Project area, with closer spaced but still low density settlement along Chichester Dam Road and Salisbury Road. Away from these roads, settlement is more sparsely distributed particularly on the steeper slopes of the Williams and Chichester River catchments. Most of the land has been cleared for grazing purposes and remnant woodland is comparatively rare in the immediate Project area. Some views to more distant elevated upland areas reveal areas of extensive woodlands.

The Project area is mostly free of commercial or industrial development and presents a pleasant rural setting with intrinsic value for tourism in the form of country drives, rural cycling and potentially rural home-stay holidays. The settlement of Salisbury in the upper Williams River catchment provides an example of a small village within a rural setting that includes cabin style holiday accommodation. Most traffic on Salisbury Road is generally associated with local residents, with visitors to the area forming an intermittent presence.

The scale of the topography in terms of height is not such as to be spectacular for its peaks but the relief does present dimension and variety to the local rural landscapes. Views of the local landscape may be considered pleasant and interesting to the casual observer with a variety of examples of steep ridges, streams over gravel-lined river beds and intermittent remnant woodlands and grasslands.

The CTGM is a prominent element alongside much of Chichester Road being very exposed and clearly visible due to being above ground and grey in colour within a grassland landscape. Power lines are generally low voltage local supplies with simple pole structures and lightweight conductors, and are not significant elements in the landscape.

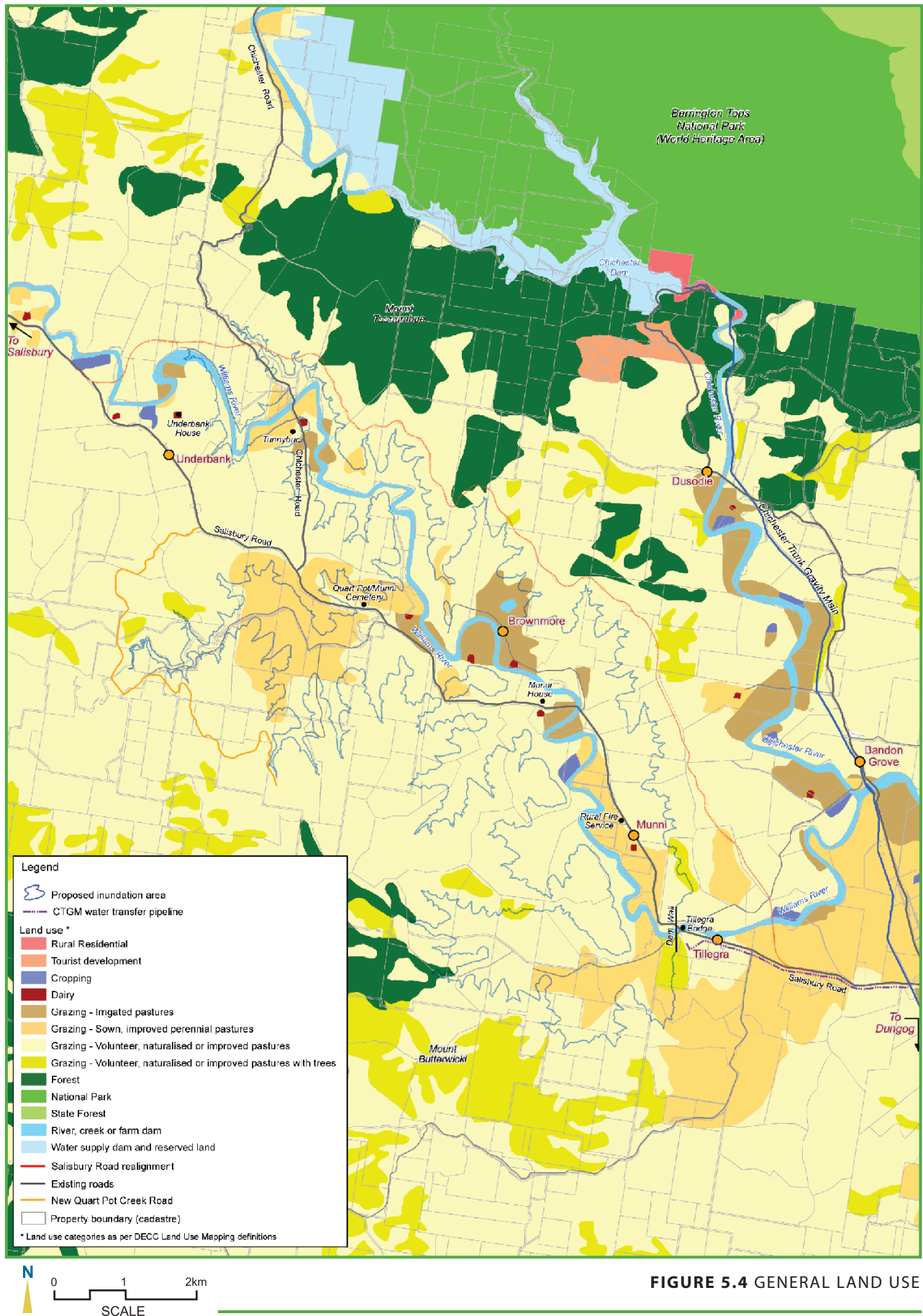
Views of the landscape are obtained from residences in the area, the roads passing through the area and aircraft flying over the area, the latter forming a comparatively minor portion of the observers of the local landscape. Public views of the local landscape from vehicles passing through the area are generally a series of fleeting glimpses of various landscape elements. These give a general perception of the rural character with more prominent features often influencing the experience of the landscape.

5.9 Land use

In the northern part of the Dungog LGA, the headwaters of Chichester River and part of the Williams River form the Barrington Tops National Park. The National Park contains one of the five original cores of rainforest present in NSW before European settlement (National Parks and Wildlife Service 1989).

For the remainder of the broader Project area (ie south of Barrington Tops), land use is predominately agricultural (refer Figure 5.4). This includes the raising of beef cattle and dairying and occupies the alluvial plains and gently inclined slopes. Goat, deer and horse grazing also occur in the broader Project area on a limited scale (Department of Urban Affairs and Planning 1996). Small pockets of generally undisturbed bushland occur on the footslopes of the Barrington Top ranges. There is also an area of vegetated Crown land (zoned Environment 7 under the Dungog LEP) located near Tillegra Bridge and in the immediate impact zone of the proposed dam wall and spillway.

There is a local swimming hole at the junction of the Chichester and Williams Rivers and the Williams River is occasionally used for canoeing and various other water sports. Other recreational pursuits in the area include horse riding and bush walking, for example in the Barrington Tops and Telegerry State Forest.



5.10 Socioeconomic profile and characteristics

Dungog Shire covers an area of 2,248 km² and had a population of 8,062 persons as recorded by the ABS Census in 2006. Over the decade 1996–2006, the Shire's population increased from 7,720 to the current number representing a total growth of six per cent.

The most significant township in the Project area is Dungog with a population of about 2,500. Dungog has a commercial strip including convenience stores, retail, bakery, hotel and a visitors centre. It also has a hospital, high school and pre-school. Paterson, Clarence Town and Gresford are the three other main townships in Dungog LGA. Other smaller settlements include Stroud, Martins Creek, Vacy and Bandon Grove. There is also a community title tourism development south of Chichester Dam.

There are 477 businesses in Dungog Shire, most of them small and medium size businesses with over 40 per cent in agriculture, forestry and fishing followed by construction (approximately 12 per cent) and property and business services (approximately 10 per cent). Communication services, wholesale trade, cultural and recreational services and education are represented with less than 10 businesses each.

The ABS 2006 Census indicated there were 3,462 persons employed in Dungog Shire. About two-thirds were working full time while one-third worked part time. Unemployment was low with 175 persons looking for either full time or part time work. The level of local part time employment was slightly higher than the national average of around 29 per cent (Australian Bureau of Statistics 2007). The predominant household income in the Shire is in the range of \$41,000 to \$62,000.

The *Strategic Connections: Economic Flows and Industrial Development in Dungog Shire Report* (Dungog Shire Council 2005) indicates that economic turnover in Dungog Shire is driven by household spending and government services provision. An estimated 55 to 60 per cent of household spending by Dungog Shire households leaks from the Shire.

The predominant age group in Dungog Shire is the 30–39 years grouping followed by the 40–49 years and 50–59 years groupings. The Shire is projected to experience a significant increase in the proportion of its elderly population over the next two decades and a significant decline in the younger age brackets exacerbated by continued outflow of young adults and a slowing of in-migration of families with children (Dungog Shire Council 2005). The economic implications of this trend would be to adversely impact on the proportion of a population in receipt of earned income.

5.11 Noise and vibration

Due to the predominantly rural nature and associated lack of development in the Project area, there are generally low levels of noise emissions. This has been confirmed from baseline monitoring undertaken for the environmental assessment which recorded rating background levels (RBL) typically less than 40 dB(A).

Noise sources generally consist of livestock (along with other farm animals), wind noise from rustling leaves, insects and bird life as well as intermittent operation of farming equipment such as tractors or four wheelers. Traffic noise emitted from intermittent vehicle traffic along Salisbury and Chichester Dam Roads dominates the noise environment. During quiet evening and night time periods, water flow was audible from the Williams River.

Existing vibration levels within the Project area are negligible as there are no major sources of vibration within and surrounding the area. The vibration survey conducted for the environmental assessment identified levels less than 0.2 mm/s, these being attributed principally to infrequent traffic. With the exception of a number of residences sited alongside roads, there are not considered to be any sensitive receptors in the Project area.

5.12 Air quality

Air quality within Dungog Shire is primarily influenced by fugitive emissions of particulate matter as PM₁₀. Sources of particulate matter include wind-blown dust, prescribed burning or bushfires, domestic combustion of solid fuel, quarrying and motor vehicle emissions.

The dominant winds surrounding the Project area have predicted wind speeds of less than 5.3 m/s. Summer winds are predominantly easterly, south-easterly and north-easterly while winter winds are predominantly northwesterly. The Project area is dominated by neutral and stable atmospheric conditions due to the low wind speeds in the area. Significant cloud cover in the area resulting in minimal solar radiation also causes reduced heating and cooling of the surface leading to neutral conditions.

The nearest DECC monitoring station is located at Beresfield; approximately 60 kilometres to the south of Tillegra. The maximum daily averaged and annual averaged ground level concentrations of PM₁₀ recorded at Beresfield are 56 µg/m³ and 17 µg/m³ respectively. However, due to the intervening distance and the differing locational contexts, the information from this site is of limited value in assisting to characterise local conditions in the Project area.

As part of the environmental assessment, limited baseline monitoring was undertaken in the Underbank and Tillegra localities, and included recording the ground level concentration profile of PM₁₀. This showed that PM₁₀ levels are maximised early in the morning and in the early evening when temperature inversions inhibit air mixing and results in accumulation of pollutants at ground level. The average PM₁₀ over the day was 21 µg/m³. Both the Commonwealth goal and NSW goal for particulate matter is 50 µg/m³.

5.13 Heritage

5.13.1 Aboriginal heritage

Aboriginal groups were distributed through the district in local groups known as 'Nurra'. Specific groups were recorded in places such as Burnt Gully Creek, Dungog and at Tillegra. Brock (cited in Koettig 1986) notes that Aboriginal campsites were known (near the Dungog showgrounds and rifle range) and that plenty of kangaroos, wallabies, possums and other game were hunted in the area. Shelters or 'mia mias' were constructed using bark sheets against a log or by placing bushes along a large tree.

In the early 1830s, Dr McKinlay, a resident of Dungog, undertook a census of Aboriginal people living in the Williams valley and recorded approximately 230 individuals, however, the spread of white settlement had a great impact on the ability of the local people to gain access to previously abundant resources and Aboriginal population numbers began to dwindle from the 1840s.

The Aboriginal people with modern day association with the Project area are the Gringai clan of the Wonnarua people. Discussions with local residents who have collected stories also suggest Gringai (or Gringhi) people were the group living in the area in the early 19th century.

Koettig (1984) undertook an overview of the region as part of a broad scale archaeological study of the Hunter Valley. The findings of this overview were consistent with previous studies that had shown that the sparsity of sites recorded in the region does not tally with the evidence that relatively large numbers of Aboriginal people are likely to have inhabited the area. A major factor in explaining the sparsity of sites is the lack of areas with suitable ground surface exposure where artefacts would be expected to occur (Koettig 1984).

A search of the Aboriginal Heritage Information Management System (AHIMS) database for sites

within the Dungog LGA generated a list of 33 site features. These comprised one art site, 13 artefact sites, three burials, one ceremonial site, two shell deposit features (associated with middens), two 'earth mounds' (sometimes recorded at midden sites or other areas of deposit), three grinding groove sites, seven scarred trees and one area of potential archaeological deposit. None of the site features or Aboriginal objects on AHIMS are recorded within the Project area.

Investigations undertaken as part of the environmental assessment for the Project examined eight discrete locations deemed as being archaeologically sensitive based on the criteria of lower angle slopes, close proximity to water, and elevation above average flood levels. A total of 34 artefacts were retrieved with the majority recovered from a site adjacent to Munni House.

As very little previous work has been undertaken in the region and only a few sites have been recorded, the rarity value of each of the recorded sites in the Project area is relatively high compared to sites with similar numbers of artefacts in other regions. The site near Munni House is assessed as having high scientific significance, while the other sites are assessed as having moderate scientific significance.

5.13.2 Contemporary heritage

European settlement of land in the Project area commenced during the 1830s. While this proceeded rapidly, services and transportation infrastructure was slow to develop. In the 1830s the Williams River network began to be used for transportation with the purchase of a river boat from England and the launching of the Australian-built paddle steamer William IV (Ford 1995). For some time, ships were independently operated and ran regular services to and from Sydney and Newcastle along the Hunter River.

In the 1850s plans were finally made to improve the road systems within the region. This included the construction of various bridges and punt fordings. A tramway between Dungog and Chichester was mooted but was considered to be too expensive.

In the late 1840s police districts were established for each of the major settlements to increase the capacity of the police force within the area. Plans were also set into action for the conversion of the mounted police barracks at Dungog to a court house and conversion of the present court house to a watch house (Ford 1995).

By the 1840s the reliance on the Sydney and Newcastle markets was beginning to decline with the establishment of settlements at Clarence Town, Dungog and Seaham. Few of the farmers in the area at that time had money and so engaged in a barter system. This system worked well with many of the shopkeepers being happy to accept produce in lieu of payment, until the financial depression of the mid 1840s resulted in the storekeepers being unable to pay the merchants and they were forced into insolvency, effectively ending the barter system.

Dairy farming figures prominently in the local history of post-European settlement. After 1890 dairying spread rapidly in NSW, assisted mainly by changes in technology, land legislation and the development of overseas markets. Companies producing butter were soon established to take advantage of the newly opened railway. Other factors which aided the move into dairying (as well as refrigerated shipping) were the introduction of electricity and the advent of the motor truck, although at this stage most individual dairy farmers still used horses and carriages (Karskens 1988).

The Dungog Co-op Dairy Company was formed in 1905 but moved to Cooree in 1913 to take advantage of the railway siding. The 1920s saw considerable growth in the local population of Munni as the dairying industry technology changed, allowing longer storage and changes to pasteurisation processes. Smallholder participation in the NSW dairy industry appears to have reached its zenith just

after the recovery of business conditions in the mid-1930s. From the 1940s onwards, the number of smallholders in the NSW dairy industry began to decline. Many of those that were left could only make a modest income.

While the bulk of milk production in NSW was still going into butter production in the 1930s, milk production began to tend to divide into a northern NSW butter producing zone (where farmers returns were more meagre) and a southern NSW zone producing milk for householders in the Sydney, Newcastle, Erina, Wollongong and Blue Mountains-Lithgow districts where farmers were guaranteed, by government, somewhat higher prices for their product. In 1967 the Dungog dairy upgraded and extended so that it could also prepare powdered milk.

During the mid-20th century the Commonwealth and NSW governments implemented a series of reforms of the dairy sector by allowing milk producers in the far south and north of the State access to the Sydney metropolitan markets. During the 1980s, at a federal level, the then Hawke government decided both to continue the reduction of government assistance to the dairy industry and to make the industry even more commercially orientated. In 1990 the Dungog dairy factory closed due to declining numbers of farmers.

Other farming activities have also taken place in the district. After a short period of European settlement, various crops were grown in the area including wheat, corn and tobacco. Over a period of time the Dungog district became known for its timber and dairy products reflecting a Hunter Valley trend towards livestock and fodder production in the late 1800s to early 1900s (Karskens 1988).

The contemporary heritage assessment undertaken for the Project considered a total of 50 items and features within the Project area. These include numerous mid-to-late 19th and early 20th century houses and homestead complexes (notably Munni House), extant and former bridges, a former school site, Quart Pot/Munni Cemetery, two possible burial grounds, and the site of Mann's hut and stockyards. Munni House and Quart Pot/Munni Cemetery are listed under the Dungog LEP. Twelve other items were found to have heritage significance at a local level.

The Munni House property is significant in the context of Australian pastoral activities in regional NSW demonstrating early settlement patterns. It has early association with the Mann family followed by the Smith family who owned the property for 140 years and who influenced the development of the region. The house, although demonstrating a sequence of changes to its verandahs, retains its earliest sections substantially intact. The two surviving slab outbuildings are also substantially intact and becoming increasingly rare in rural NSW. Consequently these two buildings also make a strong contribution to the Munni House complex.

Quart Pot/Munni Cemetery is significant to the local community for historical, cultural and spiritual reasons. The cemetery provides an insight into the historical development of the local area, its population, religious beliefs and practices and the health of the local community.

5.14 Traffic and transport

The two principal routes to Dungog from the south are Main Roads (MR) 101 and 301. MR101 links Maitland via Paterson to MR301 a few kilometres south of Dungog. MR301 links Raymond Terrace to Dungog via Seaham and Clarence Town. From Dungog, Chichester Dam Road and Salisbury Road (local roads) provide access to the Project area.

The existing roads within the Project area are in fair to reasonable condition for their current two-way rural road function. However, the narrow, sometimes winding, nature of some sections of various roads is not ideal for larger vehicles and sight distance limitations in some areas are of concern from a road safety perspective.

A recent study by Dungog Shire Council (2008) identified that in general, major access within the Shire is deficient in terms of all major indicators of asset condition. Most roads are excessively rough, narrow and have inadequate shoulder width. Additionally, they have excessive pavement defects such as cracking, potholes, rutting, shoulder drop off and failed patches. They also lack any reasonable level of overtaking opportunities. These findings were confirmed by a road safety audit undertaken as part of the environmental assessment.

Existing traffic volumes on the roads likely to be used during construction are not readily available for the Dungog area, with limited data on the classified roads south of the town. RTA publications provide historical records of daily traffic volumes in key areas on these roads and these are reproduced in Table 5.3. A recent survey undertaken on Salisbury Road near Tillegra is also included in the table.

TABLE 5.3 PUBLISHED AND SURVEYED TRAFFIC VOLUMES

ROAD	SITE	1995	1998	2001	2004	2006
Salisbury Rd	West of Chichester Dam Road	–	–	–	–	279
Chichester Dam Rd ¹	South of Salisbury Road	–	–	–	–	500 ¹
MR101 Dungog Rd	South of Dungog ²	–	3,407	1,963	2,100 ²	
	South of Wirragulla	978	845	835	870	
	South of Paterson	2,577	2,711	2,898	2,815	
	North of Lorn	11,940	13,062	13,112	13,369	
MR301	South of Wirragulla	1,142	1,200	1,239	1,341	
Clarence Town Rd	South of Clarence Town	1,930	1,753	2,157	2,270	
	South of Seaham	4,228	5,080	5,710	6,021	

¹ No traffic count available for Chichester Dam Road - estimated volume only

² Volume on MR101 north of Wirragulla calculated from feeder southern legs of MR101 and MR301

The key points to note from the table are as follows.

- Salisbury Road, west of the intersection with Chichester Dam Road, was the subject of a vehicle classification count by Dungog Shire Council in November and December 2006. Both northbound and southbound traffic movements were included in the count. The results indicated that an average of 279 vehicles used the road per day and less than one per cent of vehicles using the road were heavy vehicles. Traffic flow peaks in the mornings at 8.00 am and in the afternoons between 3.00 pm and 5.00 pm but peak period volumes are only about 20 vehicles per hour. This figure is relatively consistent during daylight hours.
- Chichester Dam Road is located closer to Dungog than Salisbury Road. As such, it is expected the southern portion of Chichester Dam Road would convey higher traffic volumes than Salisbury Road due to the addition of traffic from further north of Chichester Dam Road. However, the additional volume is not expected to be significant; accordingly, volumes on this road have been estimated at 500 vehicles per day.
- MR101 south of Dungog has a daily volume of approximately 2,000 vehicles per day. This has been calculated from the sections of MR101 and MR301 south of Wirragulla. The traffic volume leaving and entering Dungog to/from the south is split approximately 60:40 in favour of the MR301 route to Clarence Town and Raymond Terrace over the MR101 route to Paterson and Maitland. This confirms the distance saving for travel to the Lower Hunter and Newcastle.
- MR101 and MR301 carry more traffic further to the south as the two regional routes pick up additional traffic from towns further south. While MR301 takes the majority of traffic to/from Dungog, MR101 is the most heavily trafficked of the two at the southern end, with 13,000 vehicles per day at Lorn, just north of Maitland.

