4. Method to identify high probability groundwater dependent ecosystems

Groundwater dependent vegetation

Groundwater dependent or phreatophytic vegetation (Naumburg *et al.*, 2005) does not rely on the surface expression of water for survival (SKM, 2001). It instead depends on the subsurface presence of groundwater, often accessed via the capillary fringe or vadose zone (i.e. the subsurface water just above the water table that is not completely saturated (Eamus *et al.*, 2006b). The soil water in this zone is readily available to plant roots. As water is removed by transpiration it is continually replenished from the water table through capillary rise.

Phreatophytes are therefore plants that meet their water requirements by water uptake from the groundwater or its capillary fringe. Terrestrial vegetation will extract water from:

1) The saturated zone below the water table by direct uptake
2) Indirectly from the water table via the capillary effect
3) The soil profile immediately above where groundwater has moved upwards by capillary rise (i.e. the unsaturated (moist) soil above the water table).

Vegetation will extract water from those sources where the combination of soil moisture content, root density and hydraulic connectivity requires the least amount of energy. This means that vegetation will use shallow soil water before seeking deeper soil water or groundwater (Eamus and Froend, 2006). Trees mostly take up groundwater from the capillary fringe. Direct uptake from the water table is not thought to be common as it is difficult for roots to grow and function under saturated conditions, as oxygen is required for plant respiration.

Groundwater dependent wetlands

Although rainfall is the dominant source of water for nearly all wetland systems (Hancock *et al.*, 2009), groundwater plays a role in most of Australia's wetlands (Hatton and Evans, 1998). This role can vary from minor to essential (Hatton and Evans, 1998) but is not well understood (Ramsar Convention Kampala, 2005; Howe *et al.*, 2007). Although many wetlands can be hydrologically and ecologically linked to adjacent groundwater bodies, the degree of interaction can vary. Some wetlands may be completely dependent on groundwater discharge under all climatic conditions, whilst others may have very limited dependence, such as only under dry conditions (Thorburn *et al*., 1994a&b; Ramsar Convention Kampala, 2005; Mudd, 2000).

4.1. Depth to groundwater

It is a fundamental tenet of ecology that ecosystems will generally use resources in proportion to their availability and the availability of different resources will be a significant determinant to their structure, composition and dynamics (Eamus et al 2006a&b). It is therefore assumed that if groundwater can be accessed, ecosystems will generally develop some degree of dependence and that dependence will likely increase with increasing aridity (Hatton and Evans, 1998).

For many communities, depth to groundwater is an important parameter controlling the availability of groundwater to a plant (Hatton and Evans 1998; Eamus *et al.*, 2006a&b; Froend and Loomes, 2006). The identification of high probability GDEs was therefore based on the question "how likely is the community able to access groundwater?" The depth to which roots must grow to access groundwater is a key constraint to their ability to exploit that resource. Although the majority of root biomass occurs in the top 50cm of the soil profile (Cannadell *et al.,* 1996), it is well established that plants have the capacity to explore soil profiles to greater depth. Canadell *et al*., (1996) reviewed rooting depth of vegetation world wide and concluded that the average root depth for sclerophyllous forest trees was approximately 4m and between 3 to 5m for grasslands and herbaceous plants. The literature indicates that root depths on sand-plains can reach depths that exceed 10m. Griffith (2004) recorded roots up to 15m deep and root to shoot ratios of 5:1 for plants less than 1.5 metres tall on high sand dunes. This means that a 1 metre shrub is capable of extending root growth to 5 metres. Phreatophytes include both deep and/or shallow rooted vegetation communities.

Most wetlands are dependent on the watertable being at or near the ground surface. Many of the species common in wetlands have shallow roots and are relatively intolerant of drying out, other species with deeper roots require a waterlogged substrate to be able to absorb nutrients. A strong relationship exists between the distribution, growth and reproduction of wetland vegetation and the depth of ground/surface water (Brownlow *et al.*, 1994). Groundwater dependent wetlands require that groundwater levels be episodically or periodically within their root zone for use when soil water availability is low. Wetlands usually have shallow groundwater, allowing plant roots to reach the groundwater, if necessary, and satisfy demands for water and nutrients (Hattermann *et al.,* 2008; Groom *et al.*, 2000). However, little is known about the rooting depths of wetland plants and reliance on groundwater when surface water is unavailable. To identify groundwater dependent wetlands within the Coastal Burnett Groundwater Area for example, SKM (2005) assumed shallow rooted plants (approx.0.5 and 2m) would access groundwater where the depth to the watertable was within 2-3m.

A depth to water table rule was applied to highlight those communities with the potential to access groundwater. In principal, the greater the depth to groundwater the less the dependence will be on that groundwater. Available data suggests that at depths greater than 10m, groundwater dependency decreases and/or is minimal (Eamus *et al.,* 2006a). It can therefore be assumed that in those areas where the watertable is less than 10m below the surface, terrestrial and wetland will be groundwater dependent. In those areas where watertable levels exceed 10m (areas of high dunes and hills) vegetation is less likely to be dependent on groundwater.

Monitoring of water levels by NSW Office of Water indicates that the nearly all the coastal plains aquifers have a depth to water table of less than 10m from ground surface. There are just a few locations such as the elevated sand dunes near the townships of South West Rock and Hat Head where water table depths can exceed 10m. As part of the broader National Water Commission project, assessment of health of vegetation communities at such locations as compared with the same vegetation community types at nearby locations but with shallow water tables was included in the University of New England study (Warwick et al 2011).

4.2. Location in the landscape

Groundwater dependency can be inferred for many parts of the landscape. The literature has established that there is a strong association between floristic composition, topography and groundwater. Water table depth, in combination with landscape location and plant characteristics, can be used to determine which areas can support ecosystems that depend on groundwater. Depressions and swamp landscapes for example tend to support obligate wetlands where as dunes/hills that are typically associated with much deeper water table depths would support facultative or non-GDEs.

The literature indicates that vegetation and wetlands located within coastal sand aquifers is likely to be dependent on groundwater. Coastal dunes and sand masses are an important groundwater source and most coastal dune lakes (particularly window lakes) are dependent on groundwater for their formation. The source of this groundwater is the dunes and sand masses themselves, which hold vast quantities of freshwater (from rain) in groundwater aquifers.

Within alluvial aquifers, groundwater is stored in the pore spaces in the unconsolidated floodplain material in which floodplain vegetation grows. Significant interaction between ground and surface water can occur where alluvial aquifers occur in up-river situations and that are made from coarse materials such as sand and gravel. In the lower catchment areas (i.e. coastal floodplain alluvium), where alluvial materials tend to be finer, there is generally only moderate inter-play between ground and surface water.

Shallow alluvial groundwater systems are associated with coastal rivers and the higher reaches of rivers west of the Great Dividing Range. These groundwater systems are often in direct connection with surface water bodies such as rivers and wetlands. The importance of groundwater to vegetation located on the floodplain therefore depends on the nature of underlying soils and aquifer. The presence or absence of a uniform clay cover in a floodplain determines whether or not a flood will recharge groundwater and if the shallow aquifer is confined or not (Rassam and Werner, 2008). Roberts *et al.,* (2000) notes that unlike many coastal wetlands or wetlands on sandy soils, groundwater exchange is rarely dominant on floodplains and it is surface flows, as well as losses via evaporation and plant water use, that dominate the water balance. However, many floodplain wetland systems can have significant groundwater inflows and may be surface expressions of the groundwater system and groundwater can be critical for vegetation, with groundwater inflows maintaining floodplain wetland vegetation during dry periods (Roberts *et al.,* 2000).

Some phreatophytes will only inhabit areas where they can access groundwater to satisfy at least some proportion of their water requirement. Other phreatophytes will only use groundwater if it is available i.e. inhabit areas where their water requirements can be met by soil moisture reserves. In these circumstances, the dependence of the species on groundwater is therefore a function of the hydrogeologic setting of the ecosystem which determines whether or not a shallow water table exists that species can access. These plants will therefore be groundwater dependent in some environments (i.e. locations), but not in others.

Groundwater dependent wetlands occur where geology, topography and landform allow groundwater discharge to concentrate (Stein *et al,* 2004). They are typically in hydraulic connection with shallow (unconfined) aquifer systems (Bish and Gates, 1997) and commonly occur where the water table intersects the land surface. Wetlands not dependent on groundwater, on the other hand, overlie impermeable soil or rock where there is little (if any) interaction with groundwater (Rassam and Werner, 2008). Wetlands that depend on groundwater can be either ephemeral or permanent systems that have a continuous or seasonal connection with groundwater (Howe *et al.,* 2007). Surface water levels and underlying groundwater levels can change over time in response to climate, catchment, river management and groundwater extraction (McEwan *et al*., 2006). Site-specific investigations are therefore essential to identify and confirm local interactions.

4.3. Degree of groundwater dependence

The degree of groundwater dependence can vary, the literature indicating seasonal variability in both the quantity of groundwater used and the relative importance of groundwater as a water source (Zencich *et al*,. 2002). The dependency of and the degree of adaptation of phreatophytes to using groundwater is directly related to the security of the resource i.e. the permanence and ease of access to the water source. For many plant species, groundwater use is highest during dry seasons when alternative water sources are depleted and transpirational demands are high. Groundwater dependency can range from total reliance to a proportional, opportunistic use of groundwater. In many cases, plants that have an opportunistic dependence will be groundwater dependent in some environments, but not in others.

The literature suggests (see Griffith *et al.*, 2003; Griffith and Wilson, 2007; Griffith *et al.*, 2008) that vegetation sub-formations can be roughly divided into facultative and obligate GDEs based predominantly on their generalised topographic location and depth to water table. For example, dry sclerophyll tree mallee, dry sclerophyll shrubland and dry heathland occurring on beach ridges and dunes and subject to deeper water table levels can be classified as facultative GDEs. Swamp sclerophyll shrublands, wet heathlands and sedgelands growing in swales and swamps and subject to shallow water table levels, on the other hand can be classified as obligate GDEs.

Driscoll and Bell (2006) established that facultative and obligate species can be correlated with various water table levels. Four potential levels of dependence were determined, being:

- 0 – 1m Obligate wetland or seasonal inundation
- 1 – 2m Obligate
- 2 – 3m Obligate/Facultative mixed
- >3m Facultative

The classification of vegetation sub-formations into facultative and obligate GDEs is a useful starting point. It is important however that depth to water table be incorporated into the analysis, and, where possible, geological, topographic and climatic data. The incorporation of depth to water table can result in facultative' GDEs being reclassified as 'obligate' or vice versa (Gow 2010).

5. Location of high ecological value GDES on the coastal plains within the study area

To identify the ecological value of GDEs, a core set of criteria, derived and adapted from Dunn (2000) and Bennett *et al.* (2002) were developed and applied. These criteria are presented in Appendix 10. Only those to which a GIS decision rule could be applied were used in the determination of ecological value. Refer to section 6.1 for details on the GIS rules that were applied to available data sets.

5.1. Northern Rivers Region

The amount (percentage) of high ecological value GDEs (includes vegetation and wetland communities) within each groundwater source is presented in Table 7.

Table 7: Percent of high ecological value (HEV) groundwater dependent vegetation (GDE) within each groundwater source in the Northern Rivers CMA.

Groundwater Source	% of HEV GDE within GWS
Bellinger - Nambucca Coastal Sands	31.74
Brunswick River Alluvial	10.52
Clarence and Coffs Harbour Alluvial	12.61
Clarence Coastal Sands	24.87
Coffs Harbour Coastal Sands	42
Hastings Coastal Sands	45.53
Hastings River Alluvial	32.22
Hydes Creek Water Source	0.79
Macleay Coastal Sands	42.86
Macleay River Alluvial	8.99
Nambucca Alluvial	30.10
Richmond Coastal Sands	27.25
Richmond River Alluvium	10.81
Stuarts Point	28.50
Tweed - Brunswick Coastal Sands	24.86
Coastal Bellinger Water Source	15
Tweed River Alluvium	1.45

5.1.1. High ecological value groundwater dependent vegetation

The location of high ecological value groundwater dependent vegetation within the Northern Rivers Region is shown in Figure 11. High probability groundwater dependent vegetation determined to be of high ecological value for each groundwater source is presented in Appendix 11.

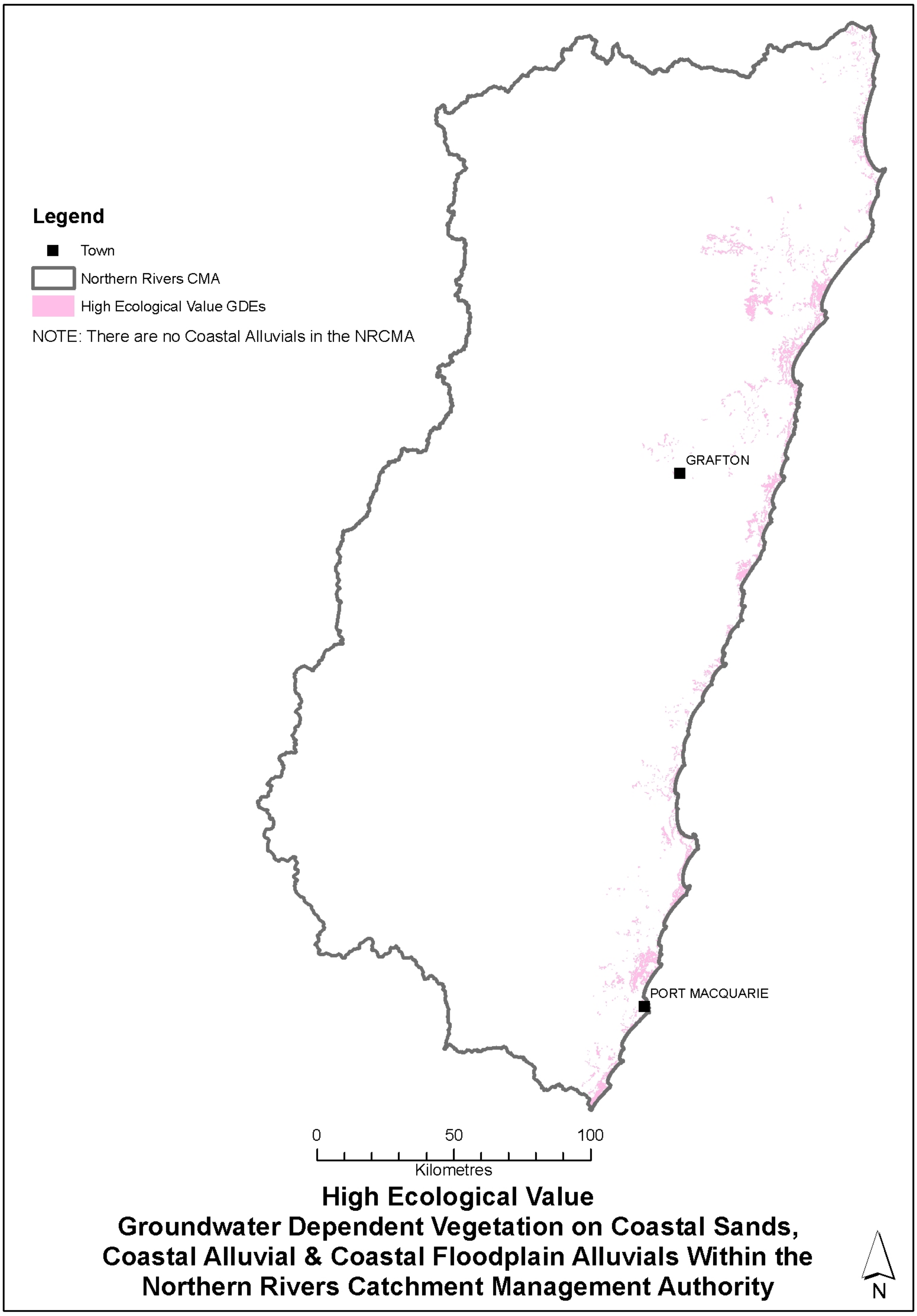

Figure 11: Location of high ecological value groundwater dependent vegetation within the Northern Rivers CMA.

5.1.2 High ecological value groundwater dependent wetlands

The location of high ecological value groundwater dependent wetlands within the Northern Rivers Region is shown in Figure 12. High probability groundwater dependent wetlands (by type and community) determined to be of high ecological value for each groundwater source is presented in Appendix 12.

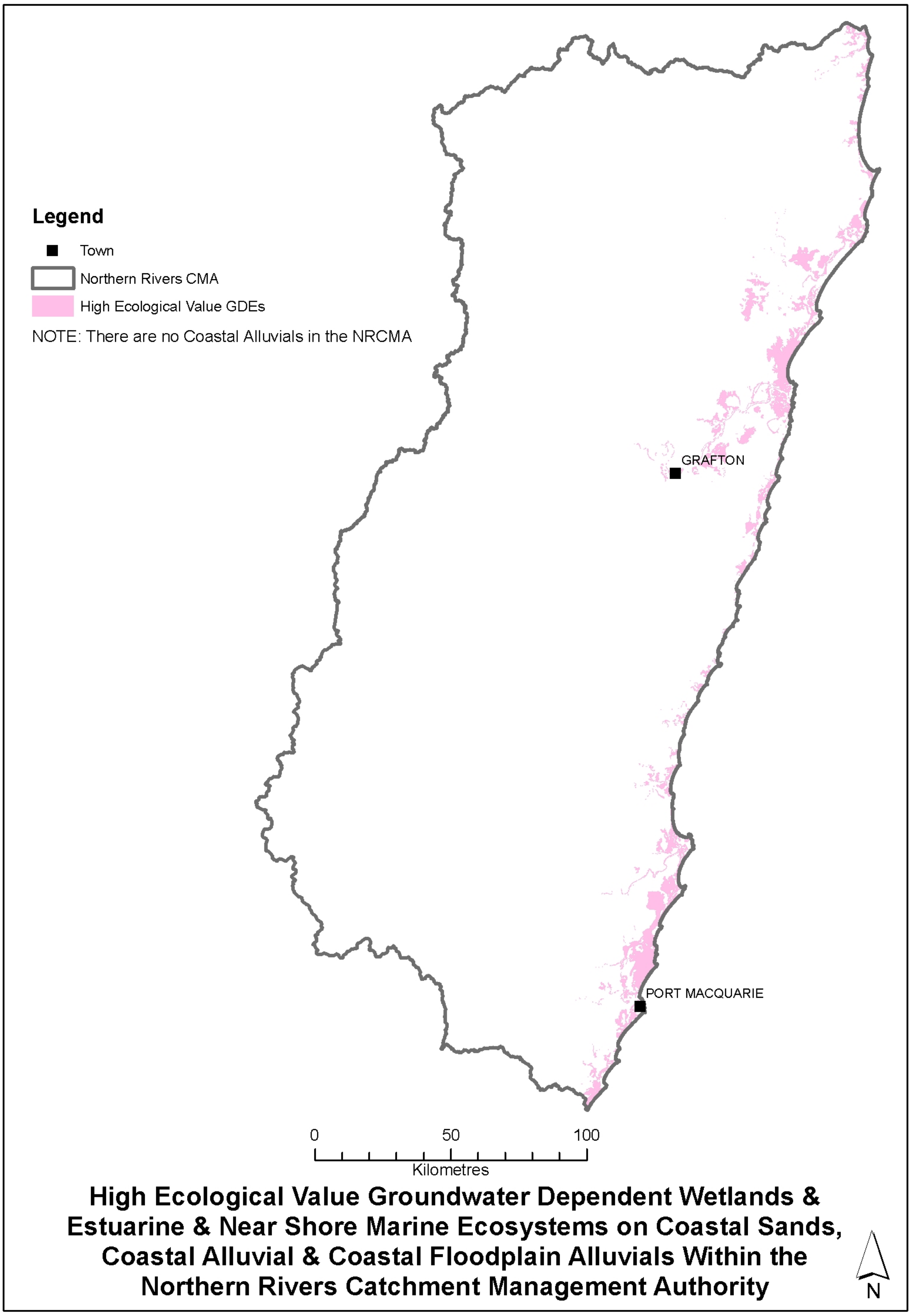

Figure 12: Location of high ecological value groundwater dependent wetlands, including estuarine wetlands within the Northern Rivers CMA.

5.2. Hunter-Central Rivers Catchment Management Area

High probability groundwater dependent vegetation determined to be of high ecological value for each groundwater source is presented in Appendix 13.

The location of high ecological value groundwater dependent vegetation, selected freshwater and estuarine wetlands within the study area is shown in Figure 13.

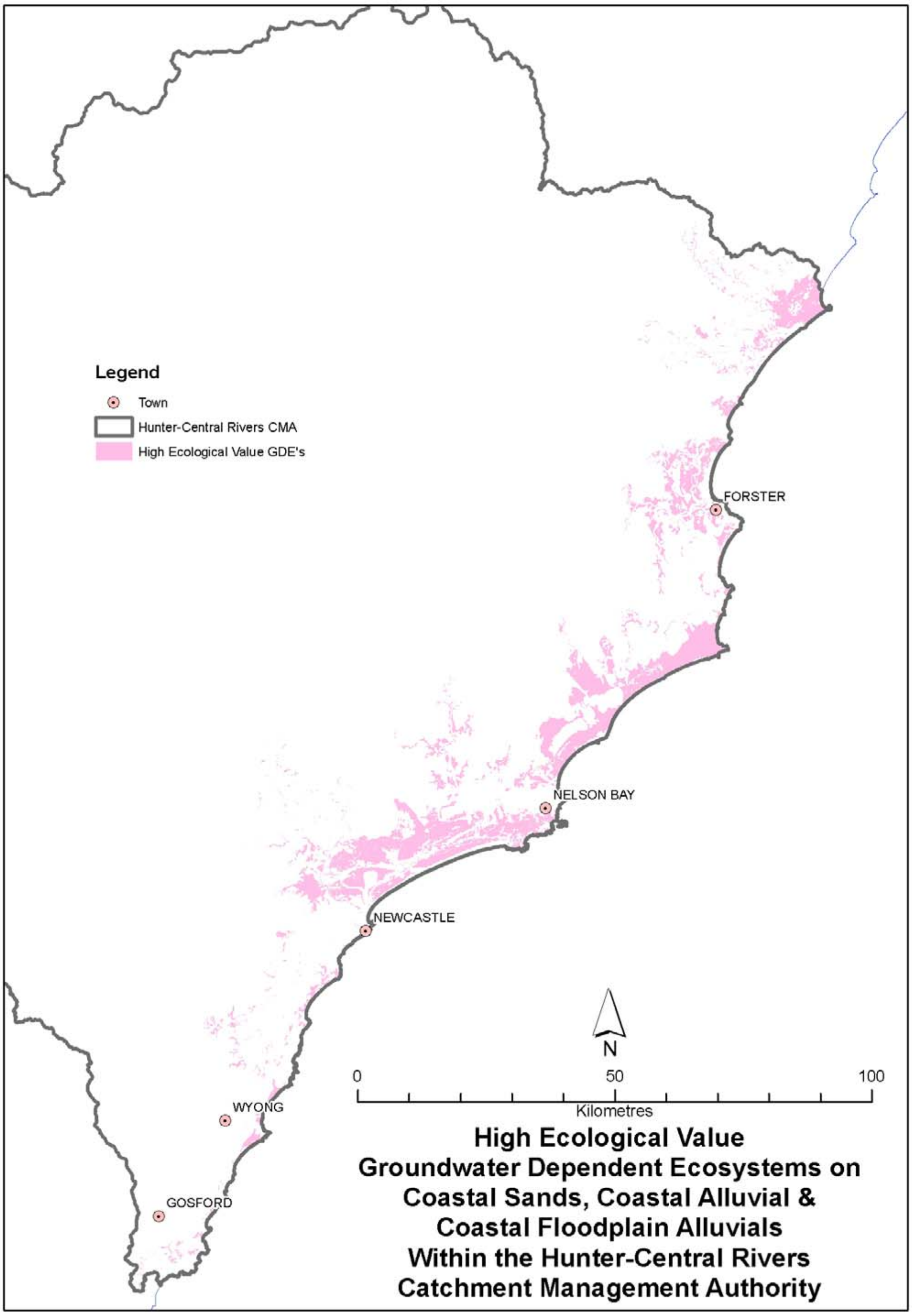

Figure 13: Location of high ecological value groundwater dependent ecosystems within the Hunter – Central Rivers CMA.

The amount (percentage) of high ecological value GDEs (includes vegetation and wetland communities) within each groundwater source is presented in Table 8.

Table 8: Percentage of HEV GDEs within each groundwater source in the Hunter – Central Rivers CMA.

Groundwater Source Name	% of HEV GDEs within GWS
Great Lakes Coastals Sands	73.84
Hawkesbury to Hunter Coastal Sands	39.55
Hunter Regulated River Alluvium	5.93
Karuah Alluvial	91.08
Manning - Camden Haven Coastal Sands	56.56
Manning River Alluvial	10.91
Newcastle	22.22
Paterson/Allyn Rivers	3.91
Sydney Basin - Lower Hunter/Central Coast	57.05
Tomago Tomaree Stockton Coastal Sands (Stockton)	46.68
Tomago Tomaree Stockton Coastal Sands (Tomago)	63.46
Tomago Tomaree Stockton Coastal Sands (Tomaree)	67.13
Wallis Creek	0.30
Williams River	4.39

5.3. Hawkesbury-Nepean, Sydney Metro and Southern Rivers Catchment Management Authority areas

High probability groundwater dependent vegetation determined to be of high ecological value for each groundwater source is presented in Appendix 14.

The location of high ecological value groundwater dependent vegetation, selected freshwater and estuarine wetlands within the Hawkesbury Nepean, Sydney Metro and Southern Rivers CMA areas is shown in Figure 14.

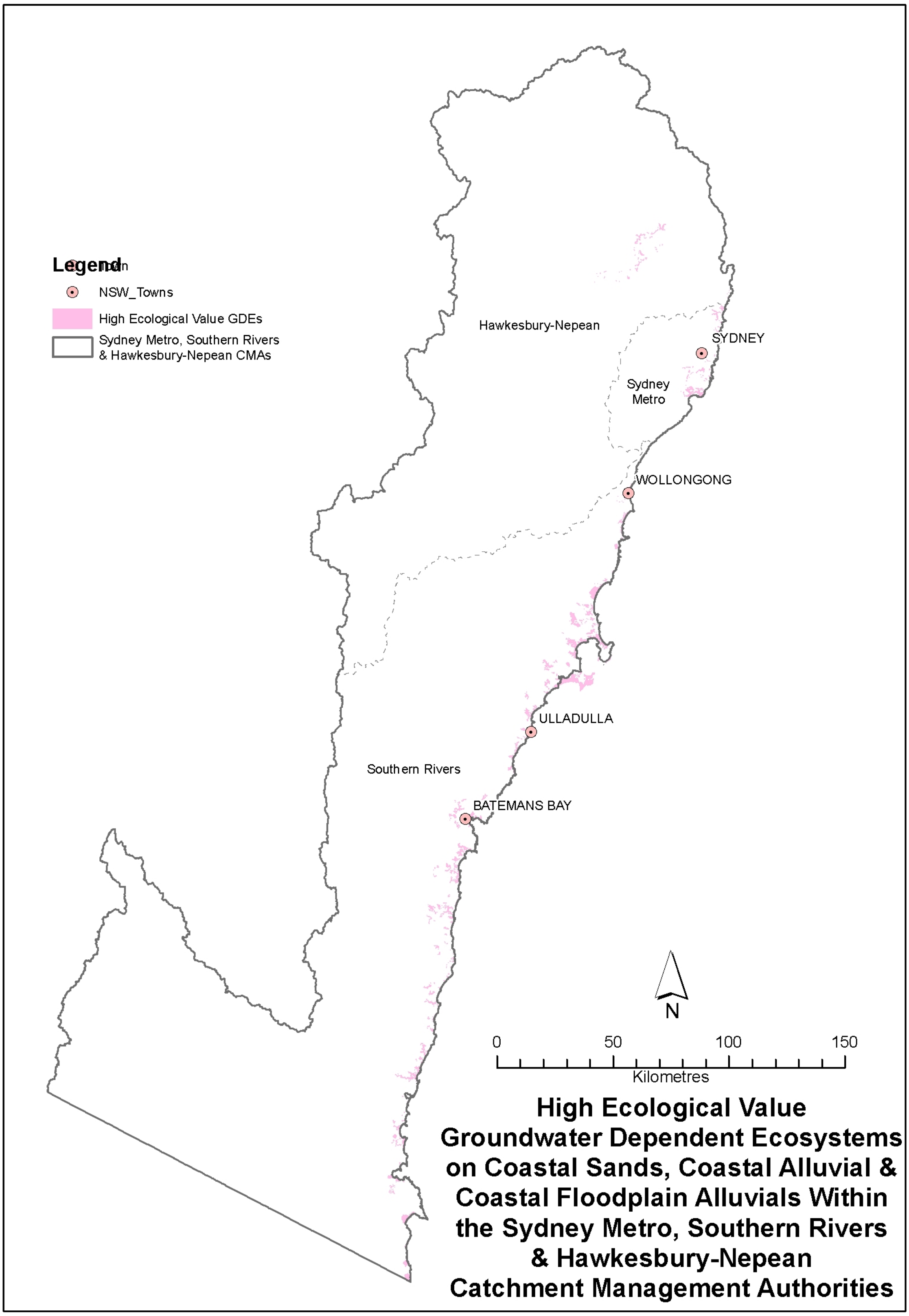

Figure 14: Location of high ecological value groundwater dependent ecosystems within the Hawkesbury – Nepean, Sydney Metro and Southern Rivers CMA areas.

The amount (percentage) of high ecological value GDEs (includes vegetation and wetland communities) within each groundwater source is presented in Table 9.

Table 9: Percentage of HEV GDEs within each groundwater source in tne Hawkesbury – Nepean, Sydney Metro and Southern Rivers CMA areas.

Groundwater Source Name	% of HEV GDEs within GWS
Barragoot Lake Tributaries Alluvium	14.96
Bega River Alluvium	31.18
Bermagui River Alluvium	35.60
Bobundra Creek Alluvium	96.12
Botany Sands	9.02
Cuttagee Lake Tributaries Alluvium	40.71
Dignams Creek Alluvium	47.02
Hawkesbury Alluvial	5.99
Maroota Tertiary Sands	2.45
Metropolitan Coastal Sands	17.99
Middle Lagoon Tributaries Alluvium	21.75
Murrah Estuary Tributaries Alluvium	38.77
Murrah River Alluvium	7.55
Narira Creek Alluvium	27.19
Nelson Lagoon Tributaries Alluvium	73.59
South Coast Alluvium	41.40
South East Coastal Sands	49.89
Towamba River Alluvial	29.83
Tuross River Alluvial	13.76
Wallaga Lake Tributaries Alluvium	15.93
Wapengo Lagoon Tributaries Alluvium	39.99

6. Determination of high ecological value ecosystems

Once the GDEs have been identified within a groundwater source and the dependency of the potential or known GDEs inferred (for this report), an assessment of the ecological value of the aquifer and their associated GDEs is required. The assignment of ecological value at the aquifer and GDE scale is essential in determining management actions and priorities such as ranking an aquifer or GDE. The ecological value of a GDE or aquifer is determined using the process described within the Risk Assessment Framework (Serov et al 2012). Full details of the Risk Analysis Framework for Groundwater Dependent Ecosystems can be found in:

Serov, P., Kuginis, L., and Williams, J.P (2012) *Risk Assessment Guidelines for Groundwater Dependent Ecosystems, Volume 1. The Conceptual Framework.* NSW Office of Water and Office of Environment and Heritage. NSW Office of Water (Department of Primary Industries) and Office of Environment and Heritage (Department of Premiers and Cabinet)

The ecological value of groundwater sources on the coastal plains of NSW is detailed in the following document: Kuginis, L., Williams, J.P., Byrne, G and Serov, P. (2012*) Risk Assessment Guidelines for Groundwater Dependent Ecosystems. Volume 4: The Ecological Value of Groundwater Sources on the Coastal Plains of NSW and the Risk from Groundwater Extraction*. NSW Office of Water (Department of Primary Industries) and Office of Environment and Heritage (Department of Premiers and Cabinet).

Presented within this document are the results of a rapid analysis identifying high value environment assets for each groundwater source on the coastal plains. Included also is an analysis of the ecological value of each groundwater source and the risk to that groundwater source from current extraction.

6.1. Identification of high ecological value communities within a groundwater source

Many of the GDE communities within the study area are made up of scattered patches. The ecological value of these individual patches can be determined by applying a number of decision rules to a selected set of criteria. The criteria selected for groundwater sources within the study area are limited to those that can be analysed using available data layers.

Selecting criteria and applying decision rules is difficult because of the complexity of ecosystem functioning. Nevertheless, decision rules are fundamental to any identification of ecological value. DECC (2007; DECCW 2010a&b&c) details a small suite of attributes considered *irreplaceable*:

- Endangered Ecological Communities;
- Highly (>70%) cleared vegetation communities (JANIS – Commonwealth of Australia 1997));
- Areas of old growth vegetation
- All types of rainforest
- Riparian vegetation
- JANIS (Commonwealth of Australia 1997) rare, endangered and vulnerable forest ecosystems; and
- Threatened species, populations or communities that cannot recover from habitat loss at the sub-regional level.
- Coastal Wetlands and estuarine vegetation.

The selected variables to determine ecological value of high probability groundwater dependent vegetation and wetlands within the study area are listed below. A vegetation community or wetland is considered to be of **high ecological value** if it (or part thereof):

- Occurs within:
  - National Park Estate;
  - Declared Wilderness;
  - Designated as SEPP 26 Littoral Rainforest or as Rainforest within vegetation mapping (VIS 524). Most rainforest types are an EEC and due to their support of biodiversity and threatened species, DECCW (2010a&b&c) advocates protection of all rainforests
  - Marine Parks and Aquatic Reserves
  - SEPP 14 Coastal Wetlands;
  - Ramsar/Directory of Important Wetlands; and
- Identified as a rainforest community
- It has threatened/endangered species or communities;
- Is considered to be significant, that is:

- It is identified as Critical Habitat (Office of Environment and Heritage);
- It is identified as <u>Key Habitat</u> under the NSW National Parks and Wildlife Service ”Key Habitats and Corridors Mapping Project (applies to the Northern Rivers Region only)
- It is identified as a high conservation value area within a Regional Conservation Plan. To simplify the many different features of conservation significance, Regional Conservation Plans assigned areas a value of regional, state or local significance. These areas were adopted as having high ecological value.

  The criteria used within all Plans are similar. A twenty five-year planning horizon was adopted for identifying Biodiversity Conservation Lands and opportunities. State, regional and local significance classes for conservation constraints were adopted and spatially delineated: Variables considered in determining state significance included National Parks/Forests NSW estate; SEPP 14, SEPP 26, EEC, Wildlife Corridors of State Significance, Wildlife Habitats of State Significance, highly depleted vegetation communities (less 30% remaining) and rainforest vegetation. Variables considered in determining areas of regional significance included Wildlife Corridors of Regional Significance, Mitchells landscapes (greater than 70% cleared), 100m buffer around areas of SEPP 26, under target vegetation based on JANIS (Commonwealth of Australia 1997) criteria, vegetation on sensitive dune systems, rare vegetation (<1000ha remaining) and a 50 m buffer on all State Significant lands (except corridors and patches <1ha in extent). Variables considered in determining Local Significance included environment protection zones in Local Environmental Plans and all remaining patches of native vegetation. The criteria developed by the Joint ANZECC/MCFFA National Forest Policy Statement Implementation Sub-committee (JANIS) (Commonwealth of Australia 1997) informed the development of the Regional Conservation Plans biodiversity conservation guide and conservation objectives (DECCW 2010a&b&c). JANIS rare, endangered and vulnerable forest ecosystems is considered irreplaceable (DECC 2007; DECCW 2010a&b&c).
- Far North Coast Regional Conservation Plan (DECCW 2010a). The conservation values within the Plan were adopted for the Northern Rivers Region;
- Mid North Coast Regional Conservation Plan (DECCW 2010b). The conservation values within the Plan were adopted for the Northern Rivers and where relevant, the Hunter-Central Rivers CMA areas;
- South Coast Regional Conservation Plan (DECCW 2010c). The conservation values within the Plan were adopted for the relevant areas within the Hawkesbury-Nepean, Sydney Metro and Southern Rivers CMA area. Information on EECs, communities identified as old growth forest/poorly conserved and over-cleared was incorporated into the analysis of high conservation values for Shoalhaven, Eurobella and Bega LGAs.
- Lower Hunter Regional Conservation Plan (DECCW 2009). The conservation values within the Plan were adopted for the relevant areas within the Hunter-Central Rivers CMA area
- It is identified as an area of importance to biodiversity (i.e. priority conserve area) within the Northern Rivers Regional Biodiversity Management Plan (Department

of Environment, Climate Change and Water NSW 2010). The attribute deemed irreplaceable are considered in this Plan. High conservation value areas are in relatively good condition. This rule applies to vegetation and wetland communities identified within VIS 524 (Northern Rivers Region only);

- It is identified as a high conservation value cluster wetland (Department of Environment and Climate Change NSW 2008). This rule applies only to wetlands within the Clarence Lowland IBRA Subregion (i.e. Northern Rivers Region).
- It is identified by the Illawarra Biodiversity Strategy (Illawarra Councils 2010) as priority vegetation 1 and 2 within the Illawarra Sub Region (see Appendix 5).

A vegetation community is considered to be **of moderate ecological value if:**

- It occurs (only) within a State Forest.
- It is identified as having a moderate conservation value as determined by the Department of Environment and Climate Change NSW 2008): **Moderate values are adopted where applicable and over-ride other existing rules.** For example**,** a number of wetland clusters are identified as being of moderate conservation value despite being identified as SEPP 14 and/or DIWA and/or identified as having conservation value within the Far North Coast and Mid North Coast Regional Conservation Plan. This rule applies only to wetlands within the Clarence Lowland IBRA Subregion (i.e. sections of the Northern Rivers Region)
- It is identified as having a moderate conservation value as determined by the Department of Environment, Climate Change and Water NSW (2010) within the Northern Rivers Regional Biodiversity Management Plan. **Moderate are adopted where applicable and over-ride other existing rules**. This rule applies to wetland communities and vegetation communities identified within vegetation mapping VIS 524 (i.e. Northern Rivers Region)
- It is identified as a seagrass community. Most seagrass communities do not meet the current set of rules determining high ecological value. This is a lack on the part of the current rule set and not because seagrass communities are not considered important. With additional information, seagrass communities maybe reclassified as being of high ecological value. The vast majority (74%) of the Region's seagrass is in the Hastings River catchment, where extensive meadows occur in Queens Lake south of Port Macquarie. Only small areas of seagrass occur in the Northern River Region's other estuaries (Department of Environment, Climate Change and Water NSW 2010). Note that all seagrass and mangrove species in NSW are protected under the *Fisheries Management Act 1994*, and are specifically dealt with as "protected marine vegetation"(Creese et al 2009).

A vegetation or wetland community is considered to be **of low ecological value if:**

- It is identified as having a low conservation value as determined by the Department of Environment and Climate Change NSW 2008): **Low values are adopted where applicable and over-ride other existing rules.** This rule applies only to wetlands within the Clarence Lowland IBRA Subregion (i.e. sections of the Northern Rivers Region);
- It is identified as having a low conservation value as determined by the Department of Environment, Climate Change and Water NSW (2010) within the Northern Rivers Regional Biodiversity Management Plan**. Low values are adopted where applicable**

and over-ride other existing rules. This rule applies to vegetation and wetland communities identified within vegetation mapping VIS 524. (i.e. Northern Rivers Region)

Application of the rules resulted in a list of high, moderate and low ecological value communities. Those communities that could not be classified under the existing GIS rules are classified as having unknown ecological value. Information is insufficient to determine their ecological value as being low, although these communities could be of low ecological value because of a variety of reasons including poor condition. High ecological value GDEs can be considered as potential ecological hotspots.

If additional information is available it can be used to fine tune prioritisation of identified GDEs. For example:

- Habitat condition of the identified GDE (i.e. prioritising less disturbed sites);
- Proximity and connectivity (i.e. prioritising sites that are connected or in close proximity to other high conservation value sites such as EECs, SEPP 14, SEPP 26). This is for example taken into account by the Department of Environment and Climate Change NSW (2008) in determining the conservation value of wetland clusters in the Clarence Lowlands – i.e. sections of the Northern Rivers Region); and
- Patch site vulnerability (to selected activities such as extraction).

Appendices 7 and 15 provides details on high ecological value communities within the Hunter Central Rivers, Hawkesbury Nepean, Sydney Metro and Southern River CMA areas.

7. Development of the GIS layers

Limited time and resources were available for the compilation of datasets. Finer scale datasets were used where available and when time allowed. Limited time and resources were available for the compilation of the datasets. In addition, there is a recognition that for certain features, particularly wetland/vegetation communities, the baseline dataset used was designed for regional scale assessments.

A number of data sets indicating the location and ecological value of groundwater dependent ecosystems were developed through the union of a several data sets.

- Data sets indication the location of vegetation and wetland communities
- Northern Rivers Region
    - o Vegetation and wetland communities covering the Northern Rivers Region as determined by Vegetation Mapping VIS 524. This dataset provides a comprehensive set of characteristics for each vegetation polygon, including Formation Name, Sub-formation and Community;
    - o Wetlands in the Clarence Lowlands IBRA Subregion (Department of Environment and Climate Change NSW 2008);
    - o Estuarine Macrophytes (Saltmarsh/Seagrass/Mangroves) (Northern Rivers Region only)
    - o Kingsford Wetlands
    - Hunter-Central Rivers CMA area

    - Vegetation and wetland communities covering the Hunter-Central Rivers CMA area as per Roff et al (2011);

- Vegetation and wetland communities covering the Hawkesbury Nepean, Sydney Metro and Southern Rivers CMA as determined by vegetation mapping:
    - Illawarra VIS Map 3778, Sydney CMA VIS Map 3817, South Coast SCIVI VIS Map 2230, Baulkam Hill LGA VIS Map 2236, Fe Coast ext VIS Map 3787, Gosford LGA vegetation, Hornsby LGA VIS Map 2292, Stalban rbg VIS Map 2353;
- The location of the National Park Estate, Declared Wilderness; threatened species, threatened communities (Office of Environment and Heritage);
- SEPP 26 Littoral Rainforest and areas mapped as rainforest,
- SEPP No. 14 Coastal Wetlands;
- Important Wetlands- Directory of Important Wetlands and wetlands identified under RAMSAR;
- Northern Rivers Regional Biodiversity Management Plan GIS layers which included areas identified as having a high, moderate or low conservation value; areas indicating candidate EECs;
- Marine Parks and Aquatic Reserves (Marine Parks Authority NSW);
- State Forests (NSW Department of Primary Industries);
- Key Habitat and Corridors (identified under the NSW National Parks and Wildlife Service ”Key Habitats and Corridors Mapping Project);
- High conservation value areas as identified within Regional Conservation Plans - Far North Coast (DECCW 2010a), Mid North Coast (DECCW 2010b), South Coast (DECCW 2010c) and Lower Hunter (DECCW 2009);
- EECs, old growth forests, poorly conserved and over cleared/rare communities as identified for the areas of Shalhaven, Eurobodalla and Bega (undertaken for the South Coast Regional Strategy)
- Critical habitat (Office of Environment and Heritage);
- Groundwater source type, name and boundary information (as determined by the Office of Water);
- Water Sharing Plans as appropriate to each groundwater source (as determined by the Office of Water);
- Major and subcatchments

The data sets were interrogated in an ArcGIs environment to identify locations that were likely to support GDEs (as well as to determine the ecological value of high probability GDEs).

The final data set was checked against Spot 5 to determine if identified GDEs were located within urban, cleared or agricultural land. This resulted in several polygons being reclassified as non GDEs. Field visits and/or additional checking against current imagery maybe required to determine if the community actually exists on the ground (due to the currency of the data layers used to create the GDE data set).

Differences in scale between the various data sets were apparent upon union of the data sets, particularly in the Northern Rivers Region. The “macrophyte” dataset for example is more accurate than the other datasets used to determine the location of wetlands within the Northern Rivers Region (i.e. DIWA, SEPP 14, Kingsford and wetland clusters of the Clarence Lowlands). Where appropriate, the “macrophyte” data set classification of polygons was adopted.

Each potential groundwater dependent ecosystem community was given a GDE name. This name was adopted from the community name as per original vegetation data sets. For vegetation and some wetlands the GDE name was adopted from the community name as per the original vegetation VIS 524 data set (Northern Rivers Data Set). GDE names for wetlands were mostly adopted from the various unioned data sets (i.e. the wetland cluster name was adopted as the GDE name for the Clarence Lowlands; Saltmarsh/seagrass/mangrove habitat was adopted as the GDE name from the macrophyte data set; the feature number was adopted as the GDE name from the SEPP 14 Coastal Wetlands data set or the wetland name where it existed; the wetland name and/or specific name was adopted as the GDE name from DIWA/Ramsar data set and the group name was adopted as the GDE name from the Kingsford data set.

Wetlands, as identified within each data set, were typed as either groundwater dependent wetlands or estuarine and near shore marine ecosystems (i.e. estuarine wetlands). Wetland types were listed where possible (e.g. mangrove, saltmarsh, coastal lakes and lagoons, freshwater wetlands, tidal forests). Each wetland was given a GDE name. This name was adopted from the various unioned data sets. The wetland feature number was adopted as the GDE name or the wetland name where it existed.

GDE probability (high, unlikely/not dependent/unknown/identified/na) and ecological value (high, moderate and unknown) was assigned to each vegetation community. The dependence (obligate/facultative/opportunistic/unknown) of each wetland on groundwater was assessed and a value assigned (obligate/facultative/opportunistic/unknown). The confidence of identification of a vegetation community depending on groundwater was determined and a value assigned (i.e. known – from site specific studies/identified in the literature/WSP or derived/inferred – from GIS rules; no field validation).

8. Data sets and information

8.1. Location of vegetation and wetland ecosystems

8.1.1. Vegetation communities

Groundwater dependent vegetation was identified using the following vegetation datasets:

- Northern Rivers Region

  Groundwater dependent vegetation was identified using mapping of the Northern Rivers Region as determined by VIS 524.

- Hunter-Central Rivers CMA area

  Groundwater dependent vegetation was identified using Roff, A., Sivertsen, D., Somerville, M and Denholm, B. 2011 Hunter Native Vegetation Mapping. Geodatabase Source Book. Office of Environment and Heritage, Department of Premier and Cabinet, Sydney, Australia

The Greater Hunter Mapping Geodatabase builds on previous information mapping that exists within the Hunter Region. Existing field data, mapping, classification and remote sensing interpretation were augmented with new data to produce the final vegetation community classification (adopted as the GDE name) used in the project.

- Hawkesbury-Nepean, Sydney Metro and Southern Rivers CMA areas
  - Illawarra VIS Map 3778;
  - Sydney CMA VIS Map 3817;
  - South Coast SCIVI VIS Map 2230;
  - Baulkam Hill LGA VIS Map 2236;
  - Fe Coast ext VIS Map 3787;
  - Gosford LGA vegetation;
  - Horsby LGA VIS Map 2292; and
  - Stalban RBG VIS Map 2353.

8.1.2. Wetland ecosystems

8.1.2.1. Northern Rivers Region

<u>Wetland clusters within the Clarence Lowlands IBRA subregion (Clarence Lowlands)</u>

Wetland clusters within the Clarence Lowlands IBRA subregion (Clarence Lowlands) were identified by the Department of Environment and Climate Change NSW (2008). The Clarence Lowlands stretches from Ballina in the north to Coutts Crossing in the south, and is located within the Northern Rivers Catchment Management Authority area. The Clarence Lowlands spans the local government areas of the Clarence Valley, Richmond Valley, Lismore, Ballina, Kyogle and Byron Shire councils.

The Clarence Lowlands contains a wide variety of wetland vegetation communities including Swamp Oak Forests, Coastal Saltmarsh and Mangrove Forests on the estuarine plain, Swamp Sclerophyll Forests and Freshwater Wetlands, Lowland subtropical and dry ‘gallery’ floodplain rainforest on the alluvial plain, and Wallum heaths, Swamp Sclerophyll Forests, and Sedgelands on the coastal barrier sand systems (The Department of Environment and Climate Change, NSW, 2008). The area also supports saline basins, swamps and tidal delta flats in the main estuaries and meander plains, and backswamps, levees and terraces along the major drainage lines of the alluvial plain. Periods of heavy rainfall often result in the many wetland depressions on the Clarence and Richmond floodplain becoming inundated, particularly during summer months (Department of Environment and climate change NSW 2008).

The Department of Environment and Climate Change, NSW (2008) investigated 19 wetland clusters in the Clarence Lowlands of which 17 are relevant to study area (i.e. the coastal plains). These wetland clusters represent groups of inter-related wetlands and adjacent riparian habitat<u>. National parks and reserves were not included in defining the wetland clusters.</u> The wetland clusters were defined by their similarity in terms of:

- Hydrology (are hydrologically connected or associated to same river or creek system);
- Spatial proximity (are located close to one another, ‘in a cluster’);

- Ecological similarity (support similar ecological communities); and
- Geomorphological similarity (have formed due to similar geological processes).

The wetland clusters as defined by the Department of Environment and Climate Change, NSW (2008) are listed and described in Appendix 2.

Kingsford wetlands

Kingsford *et al.* (2003) conducted an inventory of wetlands in NSW. The spatially derived wetland groups of relevance to this project included:

- Freshwater lakes – naturally occurring drainage basins of open water(not estuarine or coastal lagoons and lakes)
- Floodplain wetlands –river and creek channels and adjacent inundated vegetation including swamps, waterholes and shallow depressions
- Estuarine wetlands- open water bodies and adjacent vegetation at the mouth of a river open to the sea where salt and freshwater mix
- Coastal lakes and lagoons – opens bodies of water and adjacent vegetation that were not obviously part of the river and were completely or partly separated from the sea

Rivers that flood were deemed floodplains wetlands. Kingsford *et al.*, (2003) inventory did not include highland rivers, or aquifer ecosystems. Coastal wetlands were mapped using a classification based from satellite imagery and ancillary data. The wetlands mapping is only at a scale of 1:100,000 and did not map some permanent wetlands and many of the temporary wetlands on the coastal floodplain.

Seagrass beds, mangroves and salt marsh

Seagrass, mangrove and saltmarsh communities, collectively known as macrophytes, are mapped along the NSW coast line. The inventory contains a standardised GIS layer for macrophytes in 154 estuaries. The mapping arose from a recognition that seagrasses, mangroves and saltmarshes play an important role in the ecology of estuaries (Creese et al 2009).

Of the 38 estuaries within the Northern Rivers CMA four had no mangrove, saltmarsh or seagrass: Tallow Creek, Broken Head Creek, Jerusalem Creek and Saltwater Creek. Of the remaining estuaries, seagrass was found in 28. The majority of seagrass occur within the Camden Haven River. Mangroves are found in 34 estuaries, the majority in the Clarence River, Richmond River, Macleay River, Tweed River and Hastings River. Saltmarsh occurs in 34 estuaries, the largest areas occurring in Lake Innes/Cathie, Macleay River, Clarence River and Hastings River (Creese et al 2009).

Within the exception of Avoca Lagoon, all 16 estuaries within the Hunter Central Rivers CMA have at least one category of macrophyte habitat. There are no seagrass beds within Black Head Lagoon, the Hunter River or Terrigal Lagoon. Mangroves are absent from four estuaries and saltmarsh from six. The majority of seagrass beds occur within Wallis Lake, Tuggerah Lake, Lake Macquarie and Port Stephens. Mangroves occur within 12 estuaries with the majority being in the Hunter River and Port Stephens. Saltmarsh occurs 10 of the estuaries with 32% of it occurring in Port Stephens (Creese et al 2009).

Despite its large size the amount of seagrass present in the Hawkesbury system is small with the majority occurring in Pittwater. This is because much of the system, in common with other drowned river valleys, is deeper than the normal depth range for the growth of seagasses. Most of the mangrove and saltmarsh habitat in this CMA occurs in the Hawkesbury River (Creese et al 2009).

Some estuarine macrophytes were found in all 11 estuaries of the Sydney Metropolitan CMA except Curl Curl Lagoon. Three estuaries; Dee Why Lagoon, Curl Curl Lagoon and Cooks River do not have any seagrass. The majority of mangroves are found in the Georges River and Botany Bay. Saltmarsh is limited the upper parts of Georges River and the southern part of Botany Bay (Creese et al 2009).

Of the 85 estuaries within the Southern Rivers CMA, seagrass occurs in around 67, mangroves in 34 and saltmarsh in 62 (Creese et al 2009).

8.1.2.2. Hunter Central Rivers, Hawkesbury Nepean, Sydney Metro and Southern Rivers CMA area

Wetland communities listed within vegetation mapping (section 8.1.) were identified, as well as those SEPP 14, Ramsar and DIWA wetlands.

8.2. Location of ecosystems of ecological value

8.2.1. Protected areas

Data sets included mapping of:

- NPWS and Forests NSW estate, including areas identified as Wilderness for the purposes of the *Wilderness Act 1987*;
- Areas identified under the Marine Parks Act 1997 and areas identified as Aquatic Reserves

8.2.2 Critical habitat

OEH is required to identify critical habitat. Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations and ecological communities. Critical habitat is only declared after extensive consultation with the Scientific Committee, public authorities, landholders and the wider community. Information on critical habitat can be sought on the OEH register of critical habitat in NSW website.

8.2.3. SEPP 26 Littoral Rainforests and areas mapped as rainforest

The policy applies to land described in maps administered by the Department of Planning and to land within a distance of 100 metres from the edge of the mapped area except residential land.

8.2.4. Location of SEPP 14 Coastal Wetlands

SEPP 14 Coastal Wetlands aim to protect and preserve coastal wetlands. The areas covered by the SEPP are shown on a series of maps held by the Department of Planning. Over 1,300 coastal wetlands have been mapped under SEPP 14, representing 7% of all coastal wetlands in NSW. SEPP 14 Coastal Wetlands are distributed along the coast with numerous examples in poorly drained coastal areas behind coastal dunes as well on major floodplains (e.g. Tweed and Richmond River systems).

Coastal wetlands protected under SEPP 14 include mangrove, saltmarsh, some *Melaleuca* and *Casuarina* forests, sedgeland, brackish and freshwater swamps, and wet meadow. Swamp forests dominated by eucalypts Swamp Mahogany (*Eucalyptus robusta*), and Coastal Wet Sand Cyperoid Heath are excluded from SEPP 14.

8.2.5. Location of DIWA and Ramsar Wetlands

Wetland classification within *The Directory of Important Wetlands* is based on that used by the Ramsar Convention in describing *Wetlands of International Importance.* The classification of wetlands is based on water regimes, salinity and vegetation type. 40 different wetland types are recognised in three categories: A – marine and coastal zone wetlands; B – Inland wetlands and C- Human made wetlands (not considered in this project). For the most up-to-date list of wetland types defined within the Directory see www.deh.gov.au/water/wetlands/database/index.html.

Although the Ramsar Classification System has value as a basic habitat description, particularly for sites designated for the Ramsar List of *Wetlands of International Importance*, it should be noted that it does not readily accommodate descriptions of all wetland habitats in the form and level of description that are now commonly included in many Australian wetland inventories. As a result of division along biological attributes, there is some overlap between wetland categories and unnecessary division in others. For example, wetlands, currently classified as forested swamp, marshes and meadows due to differences in vegetation could be classed as a single wetland type due to similar landform setting and hydrologic dynamics. Other wetlands types are ill-defined in that they encompass a number of types (e.g. Alpine/tundra wetland encompass bogs, meadows and other mires) while other types are repeated (e.g. repetition of types named as 'marshes") (Semeniuk and Semeniuk, 1995). The Ramsar classification system has recently included non-tidal freshwater forested wetlands, rock pools and inland karst systems (Environment Australia, 2001). For a list of the latest Australian Ramsar wetlands refer to http://www.environment.gov.au/water/publications/environmental/wetlands/ramsar.html

8.2.6. Endangered Ecological Communities

Information on EEC was derived from various sources. The coastal plains landscape supports 12 threatened ecological communities listed as endangered under the NSW *Threatened Species Conservation Act 1995* (TSC Act).

Those identified and of relevance to groundwater dependent communities on the coastal plains of the Northern Rivers CMA area include:

- Littoral Rainforest and Coastal Vine Thickets of Eastern Australia;
- Byron Bay Dwarf Graminoid Clay heath Community. This can include communities of clay heath;
- Coastal Cypress Pine Forest in the NSW North Coast Bioregion;
- Littoral Rainforest in the NSW North Coast, Sydney Basin and South East Corner Bioregions;
- Lowland Rainforest in the NSW North Coast and Sydney Basin Bioregions. This can include communities of Camphor Laurel, Coastal Flooded Gum, Open Coastal Brushbox, Dry Rainforest, Warm Temperate Rainforest, Wattle, Wet Bangalow-Brucshbox, Lowland Rainforest on Floodplains, Northern Wet Brushbox;
- Swamp Oak Floodplain Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions. This includes communities of Swamp Oak;

- Swamp Sclerophyll Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions. This includes communities of Coastal Sands Blackbutt, Swamp Mahogany and Paperbark; and
- Sub-tropical Coastal Floodplain Forest of the NSW North Coast Bioregion. This can include communities of Clarence Lowlands Spotted Gum, Coast Range Bloodwood-Mahogany, Coastal Forest Red Gum, Coastal Swamp Box, Lowland Red Gum, Wet Bloodwood-Tallowwood, Escarpment Redgum, Foothill Grey Gum-Ironbark-Spotted Gum, Scrub, River Oak, Northern Ranges Dry Tallowwood, Red Mahogany, Rough-barked Apple, Open Shrubby Brushbox-Tallowwood, Stringybark-Apple, Dry Heathy Blackbutt-Bloodwood and Wet Bloodwood-Tallowwood
- Coastal Saltmarsh in the New South Wales North Coast, Sydney Basin and South East Corner Bioregions;
- Freshwater Wetlands on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions. This can include communities classified as sedgelands/rushlands, wet heath and freshwater wetlands.

Some of these communities have very restricted ranges whiles others are widespread but fragmented (DECCW 2010a&b) and include floodplains or coastal lowland/wetland communities.

Those identified and of relevance to groundwater dependent communities on the coastal plains of the Hunter Central Rivers CMA area include:

- Swamp Sclerophyll Forest on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions
- River Flat Eucalypt Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions
- Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South East Corner Bioregions
- Littoral Rainforest in the NSW North Coast, Sydney Basin and South East Corner Bioregion
- Swamp Oak Floodplain Forest of the NSW North Coast, Sydney Basin and South East Corner Bioregions
- Lower Hunter Valley Dry Rainforest in the Sydney Basin and NSW North Coast Bioregions

Those identified and of relevance to groundwater dependent communities on the coastal plains of the Hawkesbury Nepean, Sydney Metro and Southern Rivers CMA areas (Department of Environment, Climate Change and Water NSW 2010) include:

- Bangalay Sand Forest (includes communities such as Coastal Sand Forest);
- Dry Rainforest of the South East Forests in the South East Corner Bioregion (includes communities such as Subtropical Dry Rainforests);
- Illawarra Lowlands Grassy Woodland in the Sydney Basin Bioregion and the Illawarra Subtropical Rainforest in the Sydney Basin Bioregion (includes communities such as the South Coast Grassy Woodlands);

- Littoral Rainforest (TSC Act) and Littoral Rainforest and coastal vine thickets of eastern Australia (includes communities such as Temperate Littoral Rainforest and Littoral Thicket);
- Lowland Grassy Woodland in the South East Corner Bioregion (includes communities such as the Far South coast Grassy Woodlands);
- *Melaleuca armillaris* Tall Shrubland in the Sydney Basin Bioregion (includes communities such as Basalt Hilltop Scrub)
- River flat Eucalypt Forest on Costal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions (includes communities such as Floodplain Swamp Forest and South Coast River Flat Forest);
- Swamp Sclerophyll Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions (incorporating the formerly listed Sydney Coastal Estuary Swamp Forest Complex in the Sydney Basin Bioregion). Includes communities such as Coastal Sand Swamp Forest.
- Western Sydney Dry Rainforest in the Sydney Basin Bioregion (includes communities such as Grey Myrtle Dry Rainfroest)
- Swamp Oak Floodplain Forest of the NSW North Coast, Sydney Basin and South East Corner Bioregion. This EEC is not restricted to floodplain areas but includes estuarine habitats as well (includes communities such as floodplain swamp forest)
- Coastal Saltmarsh in the NSW North Coast Sydney Basin and South East Corner Bioregions (includes communities such as Estuarine Saltmarsh)
- Freshwater Wetlands on Coastal Floodplains of the NSW North Coast, Sydney Basin and Southeast Corner Bioregions (includes communities such as Coastal Freshwater Lagoons, Floodplain Wetlands)
- Swamp Oak Floodplain Forest of the NSW North Coast, Sydney Basin and South East Corner Bioregion (includes communities such as floodplain swamp forest, estuarine fringe forest and estuarine creekflat scrub)
- Sydney Freshwater Wetlands in the Sydney Basin Bioregion (includes wetlands such as coastal freshwater lagoons and freshwater lagoons on sandplains)
- Temperate highland Peat Swamps on sandstone (includes wetlands such as Blue Mountains-Shoalhaven Hanging swamps

Although saltmarsh is listed as an EEC under the TSC Act, seagrass, mangroves and macroalgae (seaweeds) are protected under the NSW *Fisheries Management Act 1994* (FM Act).

Note that information on EEC is indicative for many communities and may not represent a definitive location/area of the EEC. Vegetation communities could not always be aligned clearly to EEC determinations.

8.2.7. Flora species of conservation significance-threatened species

In NSW more than 1000 native species, populations and ecological communities are threatened with extinction. As a consequence both the NSW and Commonwealth governments introduced legislation relating to the protection of threatened species:

- The NSW Threatened Species Conservation Act 1995 (TSC Act), and

- The Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)

For more information please visit the Threatened species area of the DECCW website

OEH is responsible for administering the TSC Act, which aims to protect terrestrial threatened species, populations and ecological communities.

8.2.8. Regional Conservation Plans

DECCW (2009, 2010a&b&c) identified high conservation value areas (regional, state and locally significant biodiversity assets) using a variety of single theme datasets such as high conservation value crown lands, JANIS rare and endangered forest ecosystems, JANIS vulnerable forest ecosystems, rainforest, centres of endemism, corridors, Mitchell landscapes greater than 70% cleared and derived datasets such as DECCW's Biodiversity Conservation Lands dataset. Refer to DECCW (2009, 2010a&b&c) for further detail on data sets used. The layer was developed largely for regional scale analyses such as the Comprehensive Regional Assessments and therefore unsuitable for property level assessments

It should be noted that the vegetation map used is a model of vegetation distribution and presents only the probability of a particular vegetation community being present at a particular location. The Regional Conservation Plan dataset is therefore best used at a regional planning level, providing an indication of relative biodiversity value at this scale.

8.2.9. Illawarra Biodiversity Strategy

Given the lack of reliable mapping of the pre-European extent of vegetation communities in the Illawarra, the Illawarra Councils were unable to determine priority vegetation using criteria listed within The Southern Rivers CMA Catchment Action Plan (CAP) (2006). Illawarra Councils (Illawarra Councils 2010) mapped regional biodiversity corridors and prioritised vegetation types using endemism within the region as a key variable. In addition, other variables such as patch size were considered in determination of priority. Patch size classes were defined into three categories, 0-2 hectares, 2-10 hectares, and >10 hectares. This categorisation was based on studies that demonstrated that 2 hectares is the threshold for plants under which biodiversity declines rapidly (Drinnan, 2006). A specific list of vegetation priorities for the Illawarra were defined with most of the Priority vegetation occurring on the Illawarra coastal plains and foothill rainforests south of Wollongong. Priority vegetation included communities such as Basalt Hilltop Scrub, Subtropical Dry Rainforest, Coastal Sand Forest, Coastal Sand Swamp Forest and Coastal Warm Temperate Rainforest (Appendix 5) (Illawarra Councils 2010 –Appendix 12).

8.2.10. Regional wildlife corridors and key wildlife habitat

This applies only to the Northern Rivers CMA area. The regional fauna corridors and key habitats mapping was developed to identify the important fauna habitat and corridor areas on a regional basis. Many of the areas with high fauna habitat value also have high flora habitat values. Rainforest, high senescence forest, wetlands and many coastal communities are examples of communities with both high flora and fauna habitat values (Kendell 2003).

The primary objective of the Key Habitats and Corridors (KHC) Project was to integrate and consolidate regional biodiversity data collected from across north-east NSW in order to develop a framework for conservation planning that can operate on a regional scale. The KHC operates on the premise that planning at the regional scale can provide a framework for localised planning activities, aiming to inform regional conservation planning, assessment and restoration programs by delineation of key habitat areas and linkages in the form of regional and sub-regional corridors. KHC mapping is based on a faunal assemblage approach, relying on the premise that faunal assemblages are ecologically relevant surrogates for conservation planning within a landscape context. Predictive modelling and pattern analysis tools applied to distributions of priority forest fauna resulted in the derivation of species assemblages and their predicted distributions. Key habitats were derived from the overlap of distribution and habitat modelling outputs.

Corridor locations were determined through a complex process of modelling least-cost pathways between areas of key habitat for species assemblages, incorporating assumptions regarding intervening habitat, apparent ease of use of a particular pathway by a biological entity and the effect of distance. Corridor widths were determined through consideration of assemblage species' home range requirements. Final outputs from the KHC project are simplified into two major parts:

- **Key Habitats**, being the modelled output of combined areas of highest quality modelled habitat, species distributions and centres of endemism, and thus potentially identifying those areas most likely to be of importance to the species being considered; and
- **Corridors**, being those areas providing the most likely utilized and best quality habitat between areas of species assemblage habitat

Further details on the methodology for the KHC project can be found in Scotts (2003).

The KHC study area in northeast NSW incorporates the NSW North Coast Bioregion and the greater proportion of the New England Tablelands Bioregion. The study area was broken into three 'analysis areas', the Upper North Coast from Tweed Heads to Coffs Harbour and approximately 90km inland; the New England Tablelands (NET) including Tenterfield, Glen Innes and Armidale; and Lower North Coast (LNC) commencing south of Coffs Harbour.

8.2.11 Northern Rivers Regional Biodiversity Management Plan Data set

A series of maps are included in the NRRBMP (The Department of Environment, Climate Change and Water NSW (2010), delineating a number of areas of conservation significance (wetland and vegetation communities) within the Northern Rivers region. These were divided into two categories, *priority areas* and *other areas.* Areas of *particular* importance to biodiversity on a regional scale are identified in the plan as *priority areas.* The *Northern Rivers Regional Biodiversity Management Plan* (DECCW 2010) used detailed environmental datasets, computer modelling and expert knowledge to identify 'areas of importance to biodiversity' in the Northern Rivers CMA region.

Management priorities for the conservation and repair of terrestrial vegetation communities were modelled and mapped across the Region using the Biodiversity Forecasting Tool. This tool is a geographic information system-based approach to regional conservation assessment developed within DECCW. The Tool was applied to terrestrial biodiversity in the Region to provide provides regional 'Conserve' and 'Repair' priorities. . *'Conserve' priority areas are those that contain vegetation that, if lost, would have the greatest negative impact on the region's biodiversity.* . Around 500 Conserve priority areas have been identified on private and other Crown lands. Areas on Forests NSW and parks and wildlife estate were not identified.

The biodiversity forecasting approach has been applied to a wide range of assessment and planning activities across NSW during the past five years. The Tool used extent, condition and configuration of vegetation to evaluate the likely persistence of terrestrial biodiversity in the Region. Vegetation structure and condition was used as a surrogate for biodiversity in general, as data on individual species in the Region was not sufficiently comprehensive to apply it for all species.

The areas of *importance to biodiversity* within the Northern Rivers Region as determined by The Department of Environment, Climate Change and Water NSW (2010) were adopted to identify groundwater dependent ecosystems of high, moderate and low ecological value. Note that this rule was adopted for vegetation and wetland communities that were identified within VIS 524).

Mapping outcomes are applicable at the regional level and are thus not necessarily directly applicable to local areas and individual sites. Outdated, incomplete and/or vegetation mapping and species distributional data derived from unsystematic survey methods potentially bias outcomes. Other limitations arise from gaps in knowledge and inconsistencies associated with using multiple data sources.

8.2.12. Conservation value of wetlands in the Clarence Lowlands IBRA Subregion

The conservation value of wetland clusters within the Clarence Lowlands IBRA subregion (Clarence Lowlands) were identified by the Department of Environment and Climate Change NSW (2008). The Department of Environment and Climate Change, NSW (2008) evaluated the conservation values of wetland clusters in the Clarence Lowlands using a variety of ecological and conservation criteria. Conservation values were based on a number of datasets including:

- Presence of terrestrial or aquatic threatened fauna and fauna species
- Migratory Bird Species (JAMBA, CAMBA and ROKAMBA);
- National Importance (DIWA listing);
- SEPP 14 Wetland (SEPP 14 mapping); and
- Adjacency (desktop analysis and mapping).

The spatial data on conservation values were combined with additional expert panel information and used to rank each wetland cluster based on individual criteria. Wetland clusters were assigned into very high, high, moderate and low value groups. Findings from the conservation assessment identified many of the wetland clusters with “very high” conservation values, including Bungawalbin, Everlasting Swamp, Richmond Estuary, Tabbimoble, Clarence Estuary, The Broadwater and Tuckean. Those wetlands generally determined to be of lower conservation value include South Clarence, Alumy Creek/Bunyip Creek and Casino. These wetlands are in landscapes that have been heavily modified and generally isolated (hydrologically and spatially) from other ecosystems.

DECC (2008) noted that the loss of wetlands from the Clarence Lowlands has been significant with the majority of remaining ecosystems listed as EEC under the TSC Act. EECs present within the wetland clusters are shown in Table 10.

Table 10: EEC within wetland clusters

GDE name (wetland clusters)	EEC present
Alumy Creek/Bunyip Creek	Freshwater Wetland and Swamp Sclerophyll Forest on Coastal Floodplains
Chaffin Swamp	Freshwater Wetland and Swamp Sclerophyll Forest on Coastal Floodplains
Clarence Estuary	Coastal Saltmarsh and Swamp Oak Forest
Coldstream	Freshwater Wetland and Swamp Sclerophyll Forest on Coastal Floodplains
Everlasting Swamp	Swamp Sclerophyll Forest on Coastal Floodplains, Freshwater Wetland and Swamp Oak Forest
Mangrove Creek	Swamp Sclerophyll Forest on Coastal Floodplains
Shark Creek	Swamp Sclerophyll Forest, Subtropical Coastal Floodplain Forest, Swamp Oak Forest and Freshwater Wetland
South Clarence	Equivalent to Freshwater Wetland EEC
Tabbimoble	Freshwater Wetland, Swamp Sclerophyll Forest on Coastal Floodplains and Subtropical Coastal Floodplain Forest
The Broadwater	Coastal Saltmarsh , Swamp Oak Forest and Swamp Sclerophyll Forest on Coastal Floodplain, Subtropical Coastal Floodplain Forest and Freshwater Wetland
Bungawalbin	Freshwater Wetlands on Coastal Floodplains and Lowland rainforest and Swamp Sclerophyll Forest on Coastal Floodplains
Casino	Freshwater Wetlands
Evans River/Rocky mouth Creek	Swamp Sclerophyll on Coastal Floodplains and Freshwater Wetland
Newrybar	Unknown
Richmond Estuary	Coastal Saltmarsh and Swamp Oak Forest and Swamp Sclerophyll Forest on Coastal Floodplain and Lowland Rainforest

Tuckean	Swamp Sclerophyll Forest on Coastal Floodplain and Subtropical Coastal floodplain Forest and Coastal Cypress Pine Forest
Wardell	Swamp Sclerophyll Forest on Coastal Floodplains and Lowland Rainforest on Floodplains and Subtropical Coastal Floodplain Forest

There are currently no Ramsar-listed wetlands in the Clarence Lowlands (The Department of Environment and Climate Change, NSW 2008). There are nine wetlands in the Clarence Lowlands that are DIWA listed. These include: Alumy Creek/Bunyip Swamp, The Broadwater, Clarence River Estuary, Bundjalung National Park, Cowans Pond, Everlasting Swamp, Lower Bungawalbin Creek, Tuckean Swamp and Wooloweyah Lagoon (Environment Australia, 2001).

Of the mapped coastal wetlands, 22,754 hectares of SEPP 14 wetlands are located in the Clarence Lowlands with 9,216 hectares of this located within the wetland clusters (The Department of Environment and Climate Change, NSW 2008).

Over 71 plant species within the Clarence Lowlands are listed on the TSC Act, many of which are also nationally listed species on the EPBC Act (The Department of Environment and Climate Change, NSW 2008).

9. Limitations of the data set

There are a number of limitations associated with the adopted mapping approach and include:

- Limited time and resources were available for the compilation of the dataset and not all relevant data sets could be incorporated.
- Datasets used were limited with respect to reliability, accuracy and age. The output therefore is only as accurate and reliable as the quality and detail of exiting data used as inputs. For example the lack of a standardised approach to vegetation and wetland mapping (and condition assessment) in NSW. Within the study area vegetation mapping is inconsistent in terms of classification of vegetation types and quality. The mapping is sometimes of lower quality in coastal lowland and wetland areas compared with forested lands. Although more recent and detailed vegetation has been undertaken by local councils there remains a significant problem with inconsistent classification schemes and mapping scales. Users should therefore be aware that information relating to GDE probability and ecological value is based on data that has limitations in terms of both scale and age. Groundwork may be required to check that mapping of high ecological value areas is accurate and that the delineation of such areas is correct.
- Inherent uncertainty by applying rules across a large area (e.g. a single depth to water table rule). This has implications for the classification of potential GDEs as any variation in this surface may result in a change in the assigned level of groundwater dependence for each wetland/vegetation community. Groundwater dependence is capable of varying not only from community to community but also from tree to tree, and as such, any groundwater dependent dataset produced on a community scale can only by used as a guide and not a absolute GDE rating (Gow 2010);

- Groundwater dependence is assessed spatially. There is no temporal understanding of groundwater dependence;
- Issues arising from using multiple datasets generated at varying scales which has implications for applying a single GDE classification to a polygon, particularly in cases where polygons are relatively large and depth to water table can vary over a short distance (e.g. areas of complex topography).
- Although the layers will generally aid in identification of the potential presence/and or extent of high ecological value areas, the scale of the mapping is such that it is only broadly applicable and cannot be used in isolation to inform planning boundaries or explicitly define ecological constraints at a local scale.
- Decisions about probability and ecological value are limited by the available data (e.g. major gaps in wetland and lowland data for flora, fauna species and ecosystems; issues with the spatial accuracy of existing mapping and modelled predications;
- Spatial datasets are not available for all important biodiversity features
- Lack of information on exact rooting depth for communities.
- The lack of ground truthing of a) interpretation of groundwater dependency b) existence of the community on the ground. Although some checking of communities (presence or absence of vegetation) against latest available imagery has occurred, some communities may or may not exist on the ground (this depends on the age of the available data).

It should be noted that all data used was as provided. Additional quality assurance to verify the accuracy or currency of the data was not undertaken. Users of the data should consult the metadata of both this dataset and the component datasets used to create the new layers for information on reliability before making decisions on its use.

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