West Kimberley Water for Food Project
GoGo Station & lower Fitzroy River scan of surface water-dependent values

Securing Western Australia’s water future

Department of Water
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1 Introduction

1.1 Background

The Water for Food initiative is a key state government investment designed to increase economic growth and employment in regional communities. To help meet these goals, Water for Food is assessing water resource availability and land tenure pathways to facilitate new irrigation areas and increase the size and water efficiency of existing irrigation districts.

Several focus areas where irrigated agricultural may be developed have been identified throughout the Fitzroy valley (Figure 1). The subject of this environmental values scan is GoGo Station and lower Fitzroy River. The station is located in the middle of the Fitzroy Valley.

![Figure 1 Locations of Water for Food Fitzroy focus areas](image)

The initial stage of the GoGo development aims to extract water from Blue-bush Creek and Margaret River, modify Mt Pierre and Blue Bush creeks at the intersection (diverting flow from Mt. Pierre to Blue Bush) and capture overland flow. Stage 1 of the GoGo development involves 5000 ha of irrigated agriculture in the north-east of GoGo station. Future development (stage 2 and 3) for 10 000 ha of irrigated land is also proposed for GoGo station (DoW 2015). Total estimated surface water extraction to support stage 1 is 50 GL yr\(^{-1}\). Diversions have the potential to impact
downstream river flow and, as such, the surface water dependent values of the lower Fitzroy River. These are also considered here.

Future development may target groundwater abstraction from aquifers which may include the Devonian, Poole sandstone and Grant group (Harrington and Harrington 2015).

Water allocation planning will work with the broader Water for Food team to set allocation limits and/or licensing rules for GoGo Station.

1.2 Approach

This environmental scan is chiefly a first-pass, GIS-based review of state, nationally and/or internationally recognised/ listed environmental, cultural or social assets. It does not consider broader literature related to research or survey results. This issue is also highlighted in the Kimberley Regional water plan, from the Department of Water (2010).

“The lack of inclusion of many of the Kimberley’s high-value ecosystems into national and international listings stems from the low level of knowledge about these systems.”

As such, in addition to the environmental values documented here additional work will be required to identify currently unmapped parts of the environment that are of high social and ecological value and also at high risk from any water extraction activities.

We have followed a risk based approach to identify water-dependent values and assess potential risks from surface water extraction. This will help define allocation limits and/or licensing rules for the GoGo development.

Risks are likely to be associated with;

1. local scale direct impacts from the irrigated development area and associated earthworks to divert surface flows
2. impacts on environmental values of the lower Fitzroy River from the diversion and extraction of 50 GL yr⁻¹
3. impacts of water diversion on water dependent social and cultural values (i.e. within a 10 km buffer for mapping purposes) (e.g. rivers, vegetation, pools and dependent biota)
4. impacts from groundwater abstraction on GDEs and water dependent assets connected to certain aquifer(s).

In this review we focus on environmental impacts associated with 1 and 2 above, as for 3 and 4 there is currently little information on the nature of surface flow diversion and how this may impact groundwater.

The document assesses two separate areas - GoGo Station with 10 km buffer and the lower Fitzroy River from Fitzroy Crossing to Wilare with a 10 km buffer. For each area we;
• map and describe available spatial information on the environmental, cultural and social values
• rank the values and the risks from groundwater abstraction
• define and map value-risk categories
• recommend further work and management actions regarding water use and values and risks.

Environmental, cultural and social values

We conducted a desktop review to identify environmental, cultural and social values that may be impacted in each area.

The desktop scan used satellite imagery and datasets held by DoW and other state and federal agencies. These datasets were used to identify ecosystems that may be impacted by potential development(s). A list of available literature and databases utilised in this environmental scan is given in Appendix A.

Some listed values are also recognised as ‘matters of national environmental significance’. These are:

• world heritage properties
• national heritage places
• wetlands of international importance (listed under the Ramsar Convention)
• listed threatened species and ecological communities
• habitat for migratory species protected under international agreements (JAMBA, CAMBA, ROKAMBA).

Datasets included existing mapping of water-dependent ecosystems, wetlands and other hydrographical features (e.g. rivers, creeks, springs). Other layers were then used to describe the ecological and cultural values of the wider area and to identify high priority ecosystems (Appendix A). Satellite imagery (Geoscience Australia 2015) from 1987-2014 was used to determine the frequency of inundation of wetlands and river/creek systems and to map this as a percentage of surface water observations.

The desk top review follows on from a recent review of environmental values in the Fitzroy Valley (Pusey and Kath 2015).

Intended use of the document

Information within this environmental scan is intended to be used to;

1. inform licensing recommendations at the local development scale (e.g. direct modifications and take impacts).
2. provide information that DoW can use as advice for EPA requests in responses to proponent referrals (and pre-referrals) for development(s).
3. make recommendations about how to further investigate and manage environmental values that may be impacted by potential developments.
4. identify any constraints to development posed by environmental values.

5. inform decisions related to trade-offs between socio-economic benefits from development and environment values.

6. identify links between environmental constraints to (i) National Environmental Science Program (NESP) research projects in the Fitzroy Valley, (ii) Proposed pilot/preliminary GDE investigations in the lower Fitzroy and (iii) hydrogeological / water resource investigations.
2 GoGo Station - environmental, cultural and social values

2.1 Environmental values

Wetlands of international or national importance

Geikie Gorge, on the Fitzroy River within 2 km of the northern boundary of the focus area, is listed in the Directory of Important Wetlands of Australia (Environment Australia 2001). It is listed as a ‘permanent river’ which plays an important ecological or hydrological role in the natural functioning of the broader Fitzroy River and has outstanding historical or cultural significance (Environment Australia 2001).

Threatened or priority ecological communities (TEC and PEC)

There are no threatened or priority ecological communities mapped in GoGo area.

Other wetlands

Rivers, creeks and wetlands are concentrated in the northern and eastern parts of GoGo Station (Figures 2 and 3) including the Fitzroy and Margaret rivers and numerous smaller creeks. The majority of these riverine water courses are non-perennial, with perennial sections, or pools, restricted to small sections of the river and creek system.

Wetlands also occur off-stream. Palustrine wetlands are those with significant vegetation cover (>30 % cover), are smaller than 8 ha in area and shallower than 2 m. Lacustrine wetlands have less vegetation cover but are larger than 8 ha and deeper than 2 m. There are 13 palustrine wetlands (billabongs) mapped in the GoGo area. Of these, two are classified as perennial and 11 as non-perennial. There are also six lacustrine (lakes) wetlands, of which two are classified as perennial and four as non-perennial. There are 16 mapped springs on GoGo Station (Figure 3).
Figure 2  Extent of GoGo focus area and buffer zone scan
Figure 3  Wetlands mapped in the GoGo focus area and buffer zone
Native vegetation

Native vegetation currently covers the majority of the GoGo area (Figure 4). Nine broad vegetation types were mapped in the area by Fox et al. (2001) at a scale of 1:1 000 000. These are;

- *Acacia* spp. shrublands on sandplains (vegetation category 18).
- Tussock grasslands (vegetation category 23).
- Hummock grasslands (vegetation category 24).
- Monsoon woodlands to low open-woodlands dominated by *Corymbia dampieri* and *Eucalyptus tectifica* (pindan woodland) (vegetation category 6).
- Monsoon low open-woodlands dominated by *Eucalyptus brevifolia* or *E. leucophloia* (vegetation category 7)
- Open-forests and woodlands dominated by *Eucalyptus* spp. and *Corymbia* spp. on drainage lines and alluvial plains (vegetation category 3)
- Monsoon low woodlands to low open-woodlands dominated by *Corymbia dichromophloia* or *C. capricornia*. (vegetation category 10)
- Monsoon mixed species woodlands to low open-woodlands (vegetation category 21)
- Monsoon woodlands dominated by *Eucalyptus pruinosa* and *Lysiphyllum cunninghamii* (vegetation category 9).

Of these categories 3, 9 and 21 are associated with riparian zones, floodplains and/or shallow groundwater. A full description of all broad vegetation groups is given in Fox et al. (2001).

Although not mapped by Fox et al. (2001), drainage lines and alluvial plains with riparian vegetation dominated by *Melaleuca sp.* are likely to be found in riparian zones and floodplains (Figure 4).
Figure 4  Vegetation of the GoGo focus area and buffer zone
Threatened and priority flora and fauna

**Commonwealth (EPBC Act) listed fauna**

Nine fauna species listed under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) are likely to occur in the GoGo area - six birds, two mammals and a shark. The habitat requirements of four birds - *Erythrotriorchis radiates* (red goshawk; vulnerable), *Erythrura gouldiae* (Gouldian Finch; endangered), *Rostratula australis* (Australian Painted Snipe; endangered) and the purple-crowned fairy wren (*Malurus coronatus coronatus*) – include permanent freshwater and/or fringing woodlands along watercourses and *Melaleuca* swamps (Skroblin and Legge 2012; Department of Environment 2015; Pusey and Kath 2015). The Northern quoll may also be at times dependent on these habitats, as in parts of Queensland it has been noted that it is more likely to be present near permanent water sources (Department of Environment 2015). *Pristis pristis* (freshwater sawfish; vulnerable), a shark species, is found in the Fitzroy River.

**State (EP Act) listed species**

There are numerous different priority or threatened fauna and flora species listed within the GoGo focus area (Table 1, Figure 5). Assessment of possible water dependence of these species are based on the habitat requirements of fauna and flora as described by the Department of Environment (https://www.environment.gov.au), and the Department of Parks Wildlife, Western Australia’s (DPaW), FloraBase website (https://florabase.dpaw.wa.gov.au) (Table 1)

Of the listed fauna species, four are threatened (Table 1). This includes the Australian Painted Snipe (discussed above) and Purple-crowned Fairy-wren and its western sub-species (discussed above). All are possibly reliant on wetlands and riparian vegetation (Skroblin and Legge 2012; Department of Environment 2015). Potential riparian habitat was surveyed and mapped by Skroblin and Legge (2012) (Figure 4).

**Special species**

The freshwater crocodile is listed as a special species within the GoGo area. The saltwater crocodile was listed as ‘other protected fauna’ in Western Australia in the 2015 Wildlife Conservation Act list. It is also listed as a migratory species. Both species are likely to rely on permanent pools within the focus area during the dry season (Department of Environment 2015).

**Species covered by international agreements**

There are numerous bird species covered by international agreements (Table 1). The majority of these, with the exception of the Rainbow Bee-eater, may be dependent on wetlands or riparian vegetation within the Gogo area (Department of the Environment, 2015).

**Priority species**
Priority land snails (*Westraltrachia recta* and *Prymnbriareus nimberlinus*) and plant species may be groundwater dependent, but there is little information on their habitat requirements to date (Table 1). The priority fish species, the Prince regent hardyhead (*Craterocephalus lentiginosus*), is likely to be highly dependent on permanent sections of rivers and creeks in the area. *Cayratia cardiophylla* (plant species) is also found in seepage areas amongst rocks, which may be at risk from water regime change.

**Conservation reserves**

There are no conservation reserves mapped within the GoGo area. However Geikie Gorge National Park occurs to the north within the 10 km buffer and Brooking Gorge just beyond (Figure 5).

**High conservation value aquatic ecosystems in northern Australia**

Drawing on a large amount of biodiversity data Kennard et al. (2010) mapped six criteria that characterise high value aquatic ecosystems (HCVAE) in northern Australia: diversity, distinctiveness, vital habitat, evolutionary history, naturalness and representativeness. Kennard et al. (2010) also mapped areas where these criteria are there highest in northern Australia (i.e. meet 99th percentile threshold) at the planning unit scale. There are no HCVAE areas mapped within the GoGo area.
### Table 1  GoGo area and buffer zone - listed threatened and priority species

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>Conservation code</th>
<th>Possible water dependence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Goshawk</td>
<td>Erythrotriorchis radiata</td>
<td>EPBC</td>
<td>Moderate</td>
</tr>
<tr>
<td>Purple-crowned Fairy-wren (western ssp)</td>
<td>Malurus coronatus coronatus</td>
<td>EPBC, T</td>
<td>High</td>
</tr>
<tr>
<td>Gouldian finch</td>
<td>Erythrura gouldiae</td>
<td>EPBC</td>
<td>Moderate</td>
</tr>
<tr>
<td>Night parrot</td>
<td>Pezoporus occidentalis</td>
<td>EPBC</td>
<td></td>
</tr>
<tr>
<td>Princess parrot</td>
<td>Polytelis alexandrea</td>
<td>EPBC</td>
<td></td>
</tr>
<tr>
<td>Australian Painted Snipe</td>
<td>Rostratula benghalensis australis</td>
<td>EPBC, T, A</td>
<td>High</td>
</tr>
<tr>
<td>Northern quoll</td>
<td>Dasyurus hallucatus</td>
<td>EPBC</td>
<td>Moderate</td>
</tr>
<tr>
<td>Greater bilby</td>
<td>Macrotris lagotis</td>
<td>EPBC</td>
<td>Low</td>
</tr>
<tr>
<td>Freshwater Sawfish</td>
<td>Pristis pristis</td>
<td>EPBC, P3</td>
<td>High</td>
</tr>
<tr>
<td>Purple-crowned Fairy-wren</td>
<td>Malurus coronatus</td>
<td>T</td>
<td>High</td>
</tr>
<tr>
<td>Freshwater Crocodile</td>
<td>Crocodylus johnstoni</td>
<td>S</td>
<td>High</td>
</tr>
<tr>
<td>Saltwater Crocodile</td>
<td>Crocodylus porosus</td>
<td>OS</td>
<td>High</td>
</tr>
<tr>
<td>Prince Regent Hardyhead</td>
<td>Craterocephalus lentiginosus</td>
<td>P2</td>
<td>High</td>
</tr>
<tr>
<td>Barking Owl</td>
<td>Ninox connivens subsp. connivens</td>
<td>P2</td>
<td>Low</td>
</tr>
<tr>
<td>NA (Plant species)</td>
<td>Cayratia cardiophylla</td>
<td>P2</td>
<td>High</td>
</tr>
<tr>
<td>NA (Land snail)</td>
<td>Westraltrachia recta</td>
<td>P1</td>
<td>Moderate</td>
</tr>
<tr>
<td>NA (Land snail)</td>
<td>Prymnbriareus nimberlinus</td>
<td>P3</td>
<td>Moderate</td>
</tr>
<tr>
<td>NA (Plant species)</td>
<td>Cullen candidum</td>
<td>P1</td>
<td>Low</td>
</tr>
<tr>
<td>NA (Plant species)</td>
<td>Heliotropium foveolatum</td>
<td>P1</td>
<td>Low</td>
</tr>
<tr>
<td>NA (Plant species)</td>
<td>Triodia pascoana</td>
<td>1</td>
<td>Low</td>
</tr>
<tr>
<td>Orange leaf-nosed bat</td>
<td>Rhinonicteris aurantia</td>
<td>T</td>
<td>Low</td>
</tr>
<tr>
<td>NA (Plant species)</td>
<td>Goodenia sepalosa var. glandulosa</td>
<td>3</td>
<td>Low</td>
</tr>
<tr>
<td>Letter-winged Kite</td>
<td>Elanus scriptus</td>
<td>4</td>
<td>Low</td>
</tr>
<tr>
<td>Rainbow Bee-eater</td>
<td>Merops ornatus</td>
<td>IA</td>
<td>Low</td>
</tr>
<tr>
<td>Barn swallow</td>
<td>Hirundo rustica</td>
<td>IA</td>
<td>Moderate</td>
</tr>
<tr>
<td>Pacific Golden Plover</td>
<td>Pluvialis fulva</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Eastern Great Egret</td>
<td>Ardea modesta</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Common Sandpiper</td>
<td>Actitis hypoleucos</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Long-toed Stint</td>
<td>Calidris subminuta</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Wood Sandpiper</td>
<td>Tringa glareola</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Glossy Ibis</td>
<td>Plegadis falcinellus</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Oriental Plover</td>
<td>Charadrius veredus</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Cattle Egret</td>
<td>Ardea ibis</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Fork-tailed Swift</td>
<td>Apus pacificus</td>
<td>IA</td>
<td>High</td>
</tr>
</tbody>
</table>

**IA** = international agreements, **S** = special, **P1, P2 & P3** = maybe threatened or near threatened but are data deficient, have not yet been adequately surveyed to be listed under the Schedules of the Wildlife Conservation (Specially Protected Fauna) Notice or the Wildlife Conservation (Rare Flora) Notice, are added to the Priority Fauna or Priority Flora Lists under Priorities 1, 2 or 3, **P4** = Rare, Near Threatened and others in need of monitoring, **T** = Threatened, **NA** = unknown or no common name, **OS** – other special protected, **EPBC** – listed the Environment Protection and Biodiversity Conservation Act 1999
Figure 5  GoGo - threatened or priority species and national heritage areas
2.2 Cultural and social values

Social values

The federal environment minister announced the inclusion of the west Kimberley on the National Heritage List in August 2011. This listing recognises the outstanding heritage values of 19 million hectares of the west Kimberley, including Aboriginal, historic, aesthetic, cultural and natural heritage values. It also recognises and celebrates the pastoral history of the region. The west Kimberley national heritage values are now protected by national environment law (Environment Australia 2001). A large part of the southern GoGo area and all of the Fitzroy River itself are covered by the West Kimberley National Heritage listing (Figure 5).

The National Heritage values of Mardoowarra (Fitzroy River) were stated as:

“The Fitzroy River and a number of its tributaries together with their floodplains and jila sites (waterholes) of Kurrpurrngu, Mangunampi, Paliyarra and Kurungal, demonstrate four distinct but complimentary expressions of the Rainbow Serpent (Yoongoorrookoo) tradition associated with indigenous interpretations of the different ways in which water flows within the catchment and are of outstanding heritage value to the nation under criterion (d) for their exceptional ability to convey the connectivity of the Rainbow Serpent tradition within a single freshwater hydrological system”. – Commonwealth of Australia 2011.

Cultural values

Sites in the Aboriginal system register that may be related to water could include, amongst others, Margaret River, Pillara spring and the Fitzroy River. There could be other sites of cultural importance that are not mapped here that could also be water dependent. Consultation with traditional owners is likely needed to identify these sites.

Further details on socio-cultural values in the Gogo area, and the Fitzroy Valley more generally are reviewed in Jackson (2015).
3 Lower Fitzroy River - environmental, cultural and social values

In addition to the lower Fitzroy we have assessed sections of other rivers, including the Margaret (also discussed in the previous section), Leopold and Cunningham, as their values may be directly or indirectly impacted by water diversion. We incorporated a 10 km buffer into the assessment to ensure all potential water-dependent features were captured including those related to the extensive flood zone of the river.

![Figure 6 Extent of lower Fitzroy River and buffer zone scan](image)

3.1 Environmental values

Wetlands of international or national importance

Camballin Floodplain (Le Lievre Swamp System) is listed in the Directory of Important Wetlands of Australia (Environment Australia 2001)(Figures 6 and 7). The wetland is a riverine floodplain associated with the Fitzroy River floodplain between Mount Wynne Creek and Liveringa Station homestead. Distinct wetlands on the floodplain are Le Lievre Swamp (1300 ha), Moulamen Swamp (300 ha), 17 Mile Dam (700 ha – 13 km long, 100-1000 m wide) including Lake Josceline, several unnamed swamps and Uralla/ Snake Creek (10 km long x 50-100 m wide)(Department of Environment 2000)(Figure 4). Geikie Gorge, discussed earlier in the GoGo section, is
also a DIWA wetland. McJannet et al. (2009) also identified the Camballin floodplain as a high value ecological asset in the Northern Australian Sustainable Yields project.

**Other wetlands**

Near permanent wetlands (inundated 80% of the time from 1987-2014) (Geoscience Australia 2015) are mapped next to the development area and in both upstream and downstream sections of the river (Figure 8). These are likely to be important dry season and drought refugia for water dependent species. Permanent wetlands also occur on both the Margaret and Fitzroy Rivers within Gogo station and on some smaller tributaries and creeks (Figure 9).

Wetlands also occur off-stream. Palustrine wetlands are those with significant vegetation cover (>30% cover), are smaller than 8 ha in area and shallower than 2 m. Lacustrine wetlands have less vegetation cover but are larger than 8 ha and deeper than 2 m. There are approximately 400 lacustrine and palustrine wetlands mapped in the lower Fitzroy river area. Both perennial and non-perennial wetlands are well represented. Off stream wetlands include Lake Alma, Lake Daley, Troys Lagoon, Ligligin Waterhole and Junedella Waterhole.

There are also a range of perennial and non-perennial rivers and creeks within the 10 km buffer area of the lower Fitzroy.

There are two springs and six named pools mapped within a 10 km buffer of the lower Fitzroy. Pools include Chestnut, Tragedy, Woolabudda, Yallamungie, Manaroo and Lulika pools.

**Threatened and priority ecological communities (TEC and PEC)**

There are no threatened ecological communities mapped within the Lower Fitzroy focus area. However two priority ecological communities (PEC) are mapped across the area;

- Beard’s vegetation complex 67 - grasslands, tall bunch grass savannah, sparse low tree; ribbon grass (*Chrysopogon* spp.) paperbarks (*Melaleuca* spp.)
- Beard’s vegetation complex 759 - Grasslands, tall bunch grass savanna woodland, coolabah (*Eucalyptus* sp) over ribbon/blue grass (*Botriochloa* spp.)

PEC are possible threatened ecological communities that do not meet survey criteria or that are not adequately defined.

It is likely that the vegetation complex 67 is dependent on surface flows to some extent.
Four broad vegetation types were mapped in the area by Fox et al. (2001) (Figure 8). These are:

- spp. on drainage lines and alluvial plains (vegetation category 3)
- monsoon mixed species woodlands to low open-woodlands (vegetation category 21)
- communities of the littoral zone (vegetation category 26)
- sedgelands, lakes and lagoons and ephemeral herblands and grasslands (vegetation category 25).

All four vegetation types are likely to be water dependent. Vegetation in categories 3 and 26 are likely to need permanent access to either surface or groundwater as well as occasional inundation. Monsoon vine thickets (category 21) generally require permanent access to shallow groundwater and vegetation from category 25 is probably dependent on seasonally high water levels. A full description of all broad vegetation groups is given in Fox et al. (2001).

Although not mapped by Fox et al. (2001), drainage lines and alluvial plains with riparian vegetation dominated by *Melaleuca sp.* are likely to have the same types of water-dependence as that described for categories 3 and 26 above (Figure 8).
Skroblin and Legge (2012) mapped the condition and characteristics of riparian vegetation in the area and its habitat suitability for the Purple-crowned-fairy wren (a listed threatened species). Of 62 sections of riparian vegetation surveyed 28 were rated as high habitat quality and 34 as low quality habitat. Classification of habitat values is based on models that used the quality of river fringing vegetation to predict Purple-Crowned Fairy-Wren occurrence. Areas where the probability of Purple-Crowned Fairy-Wren occurrence is $\geq 75\%$ are classified as high quality habitat (Skroblin and Legge 2012). Further details of Purple-Crowned Fairy-Wren relationship with riparian vegetation are given in Skroblin and Legge (2012).

**Threatened and priority flora and fauna**

Many of the species listed here are discussed in the previous section on GoGo values.

**Federally (EPBC Act) listed fauna**

Ten fauna species listed under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) are likely to occur in the Lower Fitzroy area - six birds, three mammals and a shark. The habitat requirements of two birds - *Erythrotiorchis radiates* (red goshawk; vulnerable) and *Erythrura gouldiae* (Gouldian Finch; endangered) – include permanent freshwater and/or fringing woodlands along watercourses and *Melaleuca* swamps (Department of Environment 2000). The Northern quoll may also be at times dependent on these habitats, as in parts of
Queensland it has been noted that it is more likely to be present near permanent water sources (Department of Environment 2015). *Pristis pristis* (freshwater sawfish; vulnerable), a shark species, also occur in the Fitzroy River itself.

**State (EP Act) listed fauna**

Two threatened species - Curlew Sandpiper and Purple-crowned Fairy-Wren (including the western ssp.) - have been observed in the lower Fitzroy and both are likely highly water dependent (Figure 9, Table 2).

One priority 4 bird species, the Gouldian finch, may also be water dependent as it inhabits riparian and riverine vegetation areas (Department of Environment 2015). The fish species, Prince Regent Hardyhead, Dwarf Sawfish and Greenway's Grunter are also listed as priority species (Table 4). The habitat and water requirements of fish species in general for the lower Fitzroy are reviewed in Pusey (2015).

There is little known about the priority plant species listed and so it is difficult to assess their dependence on either surface or groundwater regimes at this time. Current assessments of flora have been made on habitat descriptions given in FloraBase the Western Australian Fauna [https://florabase.dpaw.wa.gov.au/](https://florabase.dpaw.wa.gov.au/)

**Special species**

There are two listings of special species - freshwater crocodile and peregrine falcon - within the lower Fitzroy area. The saltwater crocodile was listed as ‘other protected fauna’ in Western Australia in the 2015 Wildlife Conservation Act list. It is also listed as a migratory species. Both crocodile species may be reliant on permanent pools on the lower Fitzroy during the dry season (Department of Environment 2015).

Twenty bird species known from the area are covered by international agreements (i.e. migratory birds) (Table 2).
Table 2  Lower Fitzroy area - listed threatened and priority species

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>Conservation code</th>
<th>Likely water dependence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curlew Sandpiper</td>
<td>Calidris ferruginea</td>
<td>EPBC, T</td>
<td>High</td>
</tr>
<tr>
<td>Purple-crowned Fairy-wren</td>
<td>Malurus coronatus</td>
<td>EPBC, T</td>
<td>High</td>
</tr>
<tr>
<td>P-C Fairy-wren (western ssp)</td>
<td>Malurus coronatus coronatus</td>
<td>EPBC, T</td>
<td>High</td>
</tr>
<tr>
<td>Northern Quoll</td>
<td>Dasyurus hallucatus</td>
<td>EPBC</td>
<td>Moderate</td>
</tr>
<tr>
<td>Freshwater Crocodile</td>
<td>Crocodylus johnstoni</td>
<td>S</td>
<td>High</td>
</tr>
<tr>
<td>Saltwater crocodiles</td>
<td>Crocodylus porosus</td>
<td>OS</td>
<td>High</td>
</tr>
<tr>
<td>Common Sandpiper</td>
<td>Actitis hypoleucos</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Glossy Ibis</td>
<td>Plegadis falcinellus</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Eastern Great Egret</td>
<td>Ardea modesta</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Oriental Plover</td>
<td>Charadrius veredus</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Little Curlew</td>
<td>Numenius minutus</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Common Greenshank</td>
<td>Tringa nebularia</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>White-bellied Sea-Eagle</td>
<td>Haliaeetus leucogaster</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Whimbrel</td>
<td>Numenius phaeopus</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Pacific Golden Plover</td>
<td>Pluvialis fulva</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Red-necked Stint</td>
<td>Calidris ruficollis</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Sharp-tailed Sandpiper</td>
<td>Calidris acuminata</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Broad-billed Sandpiper</td>
<td>Limicola falcinellus</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Long-toed Stint</td>
<td>Calidris subminuta</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Wood Sandpiper</td>
<td>Tringa glareola</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Cattle Egret</td>
<td>Ardea ibis</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Eastern Reef Egret/ Heron</td>
<td>Egretta sacra</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>White-winged Black Tern</td>
<td>Chlidonias leucopterus</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Grey Plover</td>
<td>Pluvialis squatarola</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Marsh Sandpiper</td>
<td>Tringa stagnatilis</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Oriental Pratincole</td>
<td>Giareola maldivarum</td>
<td>IA</td>
<td>High</td>
</tr>
<tr>
<td>Australian Painted Snipe</td>
<td>Rostratula benghalensis australis</td>
<td>T/IA</td>
<td>High</td>
</tr>
<tr>
<td>NA (plant species)</td>
<td>Goodenia byrnesii</td>
<td>P3</td>
<td>High</td>
</tr>
<tr>
<td>Freshwater Sawfish</td>
<td>Pristis pristis</td>
<td>EPBC, P3</td>
<td>High</td>
</tr>
<tr>
<td>NA (Land snail)</td>
<td>Prynmbriareus nimberinus</td>
<td>P3</td>
<td>High</td>
</tr>
<tr>
<td>NA (plant species)</td>
<td>Cayratia cardiophylla</td>
<td>P2</td>
<td>High</td>
</tr>
<tr>
<td>Prince Regent Hardyhead</td>
<td>Craterocephalus lentiginosus</td>
<td>P2</td>
<td>High</td>
</tr>
<tr>
<td>NA (plant species)</td>
<td>Triodia pascoeana</td>
<td>P1</td>
<td>High</td>
</tr>
<tr>
<td>Dwarf Sawfish</td>
<td>Pristis clavata</td>
<td>P1</td>
<td>High</td>
</tr>
<tr>
<td>NA (Land snail)</td>
<td>Pilsbycharopa tumida</td>
<td>P1</td>
<td>High</td>
</tr>
<tr>
<td>NA (Land snail)</td>
<td>Westraltrachia recta</td>
<td>P1</td>
<td>High</td>
</tr>
<tr>
<td>Greenway's Grunter</td>
<td>Hannia greenwayi</td>
<td>P1</td>
<td>High</td>
</tr>
<tr>
<td>Fork-tailed Swift</td>
<td>Apus pacificus</td>
<td>IA</td>
<td>Moderate</td>
</tr>
<tr>
<td>Gouldian Finch</td>
<td>Erythura gouldiae</td>
<td>EPBC, P4</td>
<td>Moderate</td>
</tr>
<tr>
<td>NA (plant species)</td>
<td>Heliotropium geocharis</td>
<td>P1</td>
<td>Unknown</td>
</tr>
</tbody>
</table>

IA = international agreements, S = special species, P1, P2 and P3 = Species that maybe threatened or near threatened but are data deficient, have not yet been adequately surveyed to be listed under the Schedules of the Wildlife Conservation (Specially Protected Fauna) Notice or the Wildlife Conservation (Rare Flora) Notice, are added to the Priority Fauna or Priority Flora Lists under Priorities 1, 2 or 3, P4 = Rare. Near Threatened and other species in need of monitoring, T = Threatened species, NA = unknown or no common name, EPBC – listed the Environment Protection and Biodiversity Conservation Act 1999
High conservation value aquatic ecosystems in northern Australia

Drawing on a large amount of biodiversity data Kennard et al. (2010) mapped six criteria that characterise high value aquatic ecosystems (HCVAE) in northern Australia: diversity, distinctiveness, vital habitat, evolutionary history, naturalness and representativeness. Kennard et al. (2010) also mapped areas where these criteria are there highest in northern Australia (i.e. meet 99th percentile threshold) at the planning unit scale. There are five significant HCVAE areas mapped in the lower Fitzroy (Figure 7).

3.2 Cultural and social values

Social values
The federal environment minister announced the inclusion of the west Kimberley on the National Heritage List in August 2011. This listing recognises the outstanding heritage values of 19 million hectares of the west Kimberley, including Aboriginal, historic, aesthetic, cultural and natural heritage values. It also recognises and celebrates the pastoral history of the region. The west Kimberley national heritage values are now protected by national environment law (Environment Australia 2001). Part of the GoGo focus area and all of the Fitzroy River is within the listed area (Figure 5).

The National Heritage values of Mardoowarra (Fitzroy River) were stated as:
“The Fitzroy River and a number of its tributaries together with their floodplains and jila sites (waterholes) of Kurrpurrngu, Mangunambi, Paliyarra and Kurungal, demonstrate four distinct but complimentary expressions of the Rainbow Serpent (Yoongoorrookoo) tradition associated with indigenous interpretations of the different ways in which water flows within the catchment and are of outstanding heritage value to the nation under criterion (d) for their exceptional ability to convey the connectivity of the Rainbow Serpent tradition within a single freshwater hydrological system”. – Commonwealth of Australia 2011.

Cultural values

There are a large number of sites in the Aboriginal sites system register associated with the Fitzroy River, some that are likely be related to water. There could be other sites of cultural importance that are not mapped here that could also be water dependent. Consultation with traditional owners is likely needed to identify these sites.

Further details on socio-cultural values in the Fitzroy Valley are reviewed in Jackson (2015).
4 Environmental, cultural/ social values checklist

A high proportion of the significant ecological, cultural/social values we consider when assessing/ defining allocation limits (DoW 2011) occur within the GoGo and lower Fitzroy areas. Overall the in-situ values of the areas are high and should be afforded a high level of protection from surface water extraction/ diversion.
Table 3  Summary of ecological, social and cultural values

<table>
<thead>
<tr>
<th>Values</th>
<th>GoGo</th>
<th>Lower Fitzroy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Native vegetation and fauna</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Conservation reserves and land recommended for conservation reserves</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Listed WA threatened ecological community</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Habitat for WA threatened fauna or flora</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nationally listed threatened ecological community</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Any native vegetation associated with a wetland or watercourse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Habitat for nationally threatened fauna</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2. Wetlands and watercourses</strong></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>*Wetlands and watercourses listed of national importance</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Wetlands and watercourses to which an international agreement applies (e.g. Ramsar)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wetlands or water courses where management category has not been assigned but may be of high conservation priority for any reason.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>3. Sites of heritage, cultural or social significance</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aboriginal heritage sites associated with any of the above categories</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Heritage sites associated with any of the above categories</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Indigenous protected area</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Recreation or tourism sites associated with any of the above categories</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td><strong>4. Matters of National Environmental Significance</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>World heritage properties</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>National heritage places</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wetlands of international importance (listed under the Ramsar Convention)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Listed threatened species and ecological communities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Habitat for migratory species protected under international agreements (JAMBA, CAMBA, ROKAMBA)</td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>

*Geikie Gorge is within 2 km of focus area’s northern boundary*
5 Value and risk matrix mapping of values

Key considerations in assessing environmental and social assets include their value and the risk to them from any prospective development. Here we assess the values of environmental and social values within the GoGo focus area and lower Fitzroy. Then, based on their likely dependence on surface water, we estimate the likelihood of them being impacted by water diversion or abstraction.

The approach is derived from the groundwater-risk allocation planning process (DoW 2011) used by the Department of Water when information is limited. Similar approaches are also utilised in other areas of Australia to manage water dependent environmental assets, such as GDEs (Serov, Kuginis et al. 2012).

5.1 Ranking values

Ranking of mapped environmental, cultural and social values is based upon DoW (2011) which asks,

“How significant are the water-dependent ecosystems in terms of socio-cultural/environmental value?”

We adapted this question to cover all mapped socio-cultural and environmental values, because we do not know which values are and are not definitively water-dependent. We ranked values from 1-5 (low to high) reflective of the scale and legislative importance of socio-cultural and environmental values. The rankings are described below (Appendix B details how values were ranked);

1. Locally significant (i.e. within the catchment)
2. Regionally significant (i.e. in the Kimberley)
3. Significant environment asset in Northern Australia (HCVAE scores from Kennard et al. 2010)
4. State significant
5. Federally/Internationally significant.

5.2 Ranking likelihood of impact from surface water diversion

The potential for ecosystems to be impacted by surface water diversion or abstraction is based on our knowledge of how dependent a particular ecosystem. This approach was also used in DoW (2011), which asked;

“What is the likelihood that water-dependent ecosystems would be impacted if water was abstracted, i.e. how sensitive are they to abstraction?”

We assessed all mapped socio-cultural and environmental values on the likelihood they could be impacted by groundwater abstraction. This was based on our current knowledge of the relationship between ecosystems in the study area and groundwater. In our assessment if a GDE is highly groundwater-dependent we make
the assumption that there is high likelihood that it will be impacted by groundwater abstraction. We present the rankings for this assessment below in Table 4.

1. Unlikely to be impacted by water diversion or abstraction because the ecosystem is probably not connected or directly/indirectly dependent on surface water.

2. Likely to be impacted by water diversion or abstraction because the ecosystem is likely to be dependent on surface water or indirectly dependent on the habitat that the surface water supports (e.g. riparian vegetation).

3. Very likely to be impacted by water diversion or abstraction because the ecosystem is directly and frequently connected/dependent on surface water (e.g. springs, permanent stream pools, aquatic vegetation species).

5.3 Describe and map value and likelihood of impact categories

To ensure we considered both value (5.1) and the likelihood of impact from groundwater abstraction scores (5.2) we developed four categories to classify and map high priority areas (Table 4). In figures 10 & 11, points represent individual species (flora or fauna) of high value and polygons are areas of potentially water-dependent vegetation or areas mapped as HCVAE. Where species likely to be groundwater-dependent (red or yellow points) occur in areas of less likelihood of groundwater-dependence (green or blue polygons) further investigation is required (see recommendations) to determine whether to impact specific habitat is likely (see recommendations for each category).

Once mapped we described the environmental values in the GoGo and Lower Fitzroy areas (and buffer zones) that may be impacted by water extraction/diversion for the GoGo development. We then made broad management recommendations. Specifically, recommendations relate to EPA guidelines on;

- Hydrological processes - To maintain the hydrological regimes of groundwater and surface water so that existing and potential uses, including ecosystem maintenance, are protected

- Inland Water Environmental Quality - To maintain the quality of groundwater and surface water, sediment and biota so that the environmental values, both ecological and social, are protected.
Table 4  Value-risk categories

<table>
<thead>
<tr>
<th>Categories (colour)</th>
<th>Category description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 4 (red)</td>
<td>High value social and environmental assets (e.g. EPBC act, state/federal threatened species, international agreements) (value ranking 3, 4 and 5) that are very likely or likely to be impacted by surface water development? (likelihood rankings 2 &amp; 3).</td>
</tr>
<tr>
<td>Category 3 (yellow)</td>
<td>Locally and regionally significant social and environmental values (value ranking 1 &amp; 2) that are very likely or likely to be impacted by surface water development (likelihood rankings 2 &amp; 3).</td>
</tr>
<tr>
<td>Category 2 (green)</td>
<td>High value social and environmental assets (e.g. EPBC act, state/federal threatened species, int. agreements) (value ranking 3, 4 and 5) unlikely to be impacted by surface water development (likelihood ranking 1)</td>
</tr>
<tr>
<td>Category 1 (blue)</td>
<td>Locally and regionally significant social and environmental values (value ranking 1 &amp; 2) that are unlikely to be impacted by surface water development (likelihood ranking 1)</td>
</tr>
</tbody>
</table>

GoGo values-likelihood of impact category mapping

Category 4 assets (red)

There are several EPA and EPBC listed species we classified as category 4 assets within the GoGo area that may be affected by water abstraction (Table 1). For example, there are bird species that rely on riparian vegetation that may be affected (e.g. the threatened Purple-crowned fairy-wren). Priority fish species and any fresh and salt water crocodiles in the area may be particularly dependent on pools that may be affected by abstraction (Table 1). There are also numerous water bird species that are threatened and covered by international agreements that may be dependent on wetlands in the GoGo area (Table 1).

Although Geike Gorge is upstream of the proposed development, its proximity to GoGo and its very high environmental, social and cultural values make it imperative that any potential for impacts to the system are carefully considered.

We recommend that further work be undertaken by proponents to demonstrate that water extraction (and diversion) does not influence hydrological processes and inland water environmental quality important for maintaining:

- in-stream and aquatic habitat for high risk, high value species likely to threatened and priority species.
- Geike Gorge’s environmental, cultural and social values.
Figure 10  Value-likelihood of impact categories for the GoGo focus area and buffer zone
Category 3 assets (yellow)

There are many category 3 assets (e.g. streams, wetlands and riparian vegetation) within the GoGo focus area and buffer zone (Figure 10). Permanently inundated areas of rivers or creeks that fall into Category 3 are of particular value and at greater relative risk from changed water regimes.

While, there is little information on surface-groundwater connectivity for the focus area there is flood/inundation mapping (Figure 5) that highlights areas that are frequently / permanently inundated. These areas are likely to be pools on rivers or creeklines, which are important drought refuges for freshwater species and also likely to be at high risk from changed water regimes.

It should be noted that, as this inundation mapping is of coarse resolution (25 m resolution gridded dataset, Geosciences Australia 2015), smaller pools may not be captured.

Figures 4 and 10 show areas of riparian vegetation (Fox, Neldner et al. 2001). Again, because of the coarse resolution of this mapping some riparian vegetation may not be represented. The accuracy of mapping of these vegetation communities has also not been assessed on ground.

We recommend that further work be undertaken by proponents to demonstrate that water extraction (and diversion) does not influence hydrological processes and inland water environmental quality important for maintaining:

- riparian and/or groundwater-dependent vegetation
- values associated with aquatic habitats, including; rivers, creeks, pools, wetlands, billabongs and springs on Gogo station.

Category 1 (blue) and 2 (green) assets

There are numerous category 1 (blue) and category 2 (green) assets mapped in the GoGo focus area and buffer zone. These are a combination of vegetation types with a low likelihood of surface water-dependence and various threatened and priority species that are unlikely to be impacted by changed water regimes.

Despite the low likelihood of impact, there are legal obligations (e.g. EPBC act) covering listed species and communities and riparian vegetation (RIWI Act) and further work may be needed to confirm that these species/communities will not be impacted by water abstraction. Therefore it is still important to confirm the accuracy of mapping and we recommend further analysis and ground-truthing to avoid any issues associated with abstraction impacts.

In areas where development proceeds more detailed investigations may be needed to establish that assets are not dependent on river flow (e.g. isotope analysis). We will also need to confirm values with local stakeholders (e.g. aboriginal communities) to ensure no water dependent values have been overlooked. Failure to confirm a lack of water dependent environmental values prior to development runs the risk of future unintended and difficult to redress social and environmental consequences.
Lower Fitzroy value-likelihood of impact category mapping

Figure 11  Value-likelihood of impact categories for the lower Fitzroy River and buffer zone

Category 4 assets (red)

There are numerous EPA and EPBC listed species we classified as category 4 assets within the lower Fitzroy and buffer zone that may be affected by water abstraction (Table 2). For example, there are bird species that rely on riparian vegetation that may be affected (e.g. the threatened Purple-crowned fairy-wren). Priority fish species and any fresh and salt water crocodiles in the area may be particularly dependent on pools that may be affected by abstraction (Table 1). There are also numerous water bird species that are threatened and covered by international agreements that may be dependent on wetlands or pools of the lower Fitzroy (Table 1).

The Camballin Floodplain, a DIWA (Directory of Important Wetlands) listed wetland, is also at risk along with five areas mapped as HCVAE in the lower Fitzroy area.

We recommend that further work be undertaken by proponents to demonstrate that water extraction (and diversion) does not influence hydrological processes and inland water environmental quality important for maintaining:

- in-stream and aquatic habitat for high risk, high value species likely to threatened and priority species.
• the significant environmental values of the Camballin Floodplain
• significant environmental values associated with mapped high conservation value aquatic ecosystems (HCVAEs).

Category 3 assets (yellow)

There are large number of category 3 assets (e.g. streams, wetlands and riparian vegetation) within the lower Fitzroy and buffer zone (Figure 7, 8 and 11). Permanently inundated areas of rivers or creeks that fall into Category 3 are of particular value and at greater relative risk from changed water regimes.

While, there is little information on surface-groundwater connectivity for the Fitzroy there is flood/ inundation mapping that highlights areas that are frequently / permanently inundated. These areas are likely to be river pools, which are important drought refuges for freshwater species and also likely to be at high risk from changed water regimes.

It should be noted that, as this inundation mapping is of coarse resolution (25 m resolution gridded dataset, Geosciences Australia 2015), smaller pools may not be captured.

Figures 8 and 11 show areas of riparian vegetation (Fox, Neldner et al. 2001). Again, because of the coarse resolution of this mapping some riparian vegetation may not be represented. The accuracy of mapping of these vegetation communities has also not been assessed on ground.

We recommend that further work be undertaken by proponents to demonstrate that water extraction (and diversion) does not influence hydrological processes and inland water environmental quality important for maintaining:
• riparian and/or groundwater-dependent vegetation associated with the lower Fitzroy
• values associated with aquatic habitats, including; rivers, creeks, pools, wetlands, billabongs and springs on the lower Fitzroy.

Category 1 (blue) and 2 (green) assets

There are numerous category 1 (blue) and category 2 (green) assets mapped on the lower Fitzroy and buffer zone. These are a combination of vegetation types with a low likelihood of surface water-dependence and various threatened and priority species that are unlikely to be impacted by changed water regimes.

Despite the low likelihood of impact, there are legal obligations (e.g. EPBC act) covering listed species and communities and riparian vegetation (RIWI Act) and further work may be needed to confirm that these species/ communities will not be impacted by water abstraction. Therefore it is still important to confirm the accuracy of mapping and we recommend further analysis and ground-truthing to avoid any issues associated with abstraction impacts.

In areas where development proceeds more detailed investigations may be needed to establish that assets are not dependent on river flow (e.g. isotope analysis). We will also need to confirm values with local stakeholders (e.g. aboriginal communities) to ensure no surface water dependent values have been overlooked. Failure to
confirm a lack of water dependent environmental values prior to development runs the risk of future unintended and difficult to redress social and environmental consequences.
6 Further considerations

6.1 Links to regional licensing and Environmental Protection Authority

Baseline monitoring

We recommend that a monitoring program be implemented by proponents to establish baselines for environmental assets that may be impacted by development (i.e. high risk assets, red and yellow in Figures 10 and 11). Baselines and ongoing monitoring of any environmental values should adhere to the definition of environmental criteria as outlined by the Environmental Protection Authority (2015), namely,

“A numerical value for an environmental indicator and proposal- or site-specific parameters to measure performance relative to the environmental outcome and to instigate management responses to ensure the environmental outcome is met.”

Collection of these data should focus on the flora and fauna of the wetland and vegetation habitats that are at a high risk from water extraction. These could include, but are not restricted to fish and macroinvertebrates of stream and wetland habitats and riparian vegetation composition and condition. Examples of procedures and environmental indicators that may be relevant at Gogo and the lower Fitzroy are outlined in the monitoring programs developed for the Ord River (DoW 2011) and various Pilbara rivers (DoW 2013).

Triggers and thresholds

Baseline and ongoing monitoring data can be used to develop early response criteria, triggers and thresholds. Environmental Protection Authority (2015) definitions for each of these are given below.

Early response criteria

Environmental criteria that provide information on changes, which are precursors to the onset of environmental impact and signal a need for early response actions.

Trigger criteria

Environmental criteria that forewarn of the approach of the threshold criteria and signal the need to undertake trigger level actions to ensure the threshold criteria are not exceeded.

Threshold criteria

Environmental criteria representative of the limit of acceptable impact beyond which indicates that the environmental outcome is not being met.

6.2 Environmental, hydrological and hydrogeological projects in the lower Fitzroy

This section describes possible overlap with other projects in the lower Fitzroy that may be relevant to the assessment of water extraction from Gogo station. Note that these projects are still under development and the timelines and specifics of each may not be directly relevant to assessing the downstream impacts of Gogo water extraction on the environmental values of the lower Fitzroy.

Fitzroy Environmental value review and proposed NESP & NAWRA projects

National Environmental Science Program (NESP) and CSIROs’ Northern Australian Water Resource Assessment (NAWRA) project are undertaking environmental and hydrological investigations in the Fitzroy Valley. Of these potential projects, three may have relevance to assessing water extraction activities proposed at Gogo station, they are:

- The identification of riparian and floodplain vegetation (including GDE vegetation), and their water requirements, of the Lower Fitzroy. Water extraction from Gogo which may influence flood pulses and surface water inundation regimes may be relevant.
- The identification of in-stream pool habitats, including the habitat and water requirements of fish. Water extraction from Gogo which may influence pool hydrology and water quality may be relevant.
- NAWRA surface flow hydrology modelling for the Fitzroy valley (possibility of scenario analysis for different water extraction regimes from Gogo on the hydrology of the lower Fitzroy).

Innovative groundwater solutions (IGS) & DoW sampling in the lower Fitzroy

IGS and DoW surveyed pools in the lower Fitzroy in 2015 to identify those that may be highly dependent on groundwater inputs to remain inundated over periods of low rainfall. Isotopes were sampled to help identify the source of water supporting the river pools. Further sampling will be undertaken by DoW in 2017.

Permanent pools that have minimal or no inputs from groundwater are likely highly dependent on periods of high surface flows to ‘top-up’ so that they have water to persist through the dry-season. Identifying relationships between surface water regimes, pool persistence (i.e. for non-groundwater fed pools) may be important for developing surface water extraction activities, such as those proposed at Gogo station.

DoW and NAWRA hydrological and hydrogeological investigations

There are 17 bores that are being monitored throughout the Fitzroy Valley, downstream of Gogo. Some of these bores, namely those in shallow alluvial, may provide information that could be linked to proposed surface water extraction at Gogo station. For example, relationships between water extraction at Gogo with recharge...
and shallow groundwater regimes may be important to consider for environmental values of the lower Fitzroy.

The installation of new monitoring bores across Mount Anderson, Liveringa, Kimberley Downs and Brooking Springs stations in the lower Fitzroy region is an essential part of a 2016 project agreement between DoW and CSIRO. These monitoring bores will focus on the outcropping areas of the Poole Sandstone and Grant Group aquifers, as well as the Fitzroy River alluvium.

It is also proposed that new bores be installed in alluvial sediments close to the Fitzroy River channel.

The bores support groundwater investigations and provide monitoring infrastructure to collect baseline information for informing licensing rules, and groundwater allocation statements which balance economic, environmental, cultural and social values of water by:

- Characterising the nature of surface water groundwater interaction between the Poole Sandstone, Grant Group, the Fitzroy River alluvium and the Fitzroy River.
- Characterising and quantifying groundwater recharge to the Poole Sandstone and Grant Group aquifers.
- Characterising aquifer connectivity and regional groundwater flow patterns in the Poole Sandstone and Grant Group aquifers.
Appendices

Appendix A - Spatial layers and datasets

The high priority ecosystems identified below are protected under the following legislation, policy and tools:

- The *Environmental Protection Act 1986*, as listed in *EPA guidance statement 33: Environmental guidance for planning and development*.
- The *Environment Protection and Biodiversity Conservation Act 1999*, identified using the Protected Matters Search Tool at environment.gov.au

<table>
<thead>
<tr>
<th>Ecological components</th>
<th>Spatial layers and datasets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native vegetation and fauna</td>
<td></td>
</tr>
<tr>
<td>Conservation reserves and land recommended for conservation reserves</td>
<td>DPaW Managed Lands and Waters System 1-5 and 7-12 Areas DEP 06/95</td>
</tr>
<tr>
<td>Listed WA threatened ecological community</td>
<td>Threatened Ecological Communities (buffers) - DPaW</td>
</tr>
<tr>
<td>Habitat for WA threatened fauna or flora</td>
<td>Threatened Fauna – DPaW</td>
</tr>
<tr>
<td>Nationally listed threatened ecological community</td>
<td>Protected matters search tool (see also the rows under Matters of National Environmental Significance)</td>
</tr>
<tr>
<td>Any native vegetation not associated with a wetland or watercourse</td>
<td>Native Vegetation Current Extent – DAFWA</td>
</tr>
<tr>
<td>Habitat for nationally threatened fauna (EPBC)</td>
<td>Protected matters search tool (see also the rows under Matters of National Environmental Significance)</td>
</tr>
</tbody>
</table>

| Wetlands and watercourses | |
| Wetlands and watercourses to which an international agreement applies (e.g. Ramsar) | Protected matters search tool - DoE |
### Wetlands or water courses where management category has not been assigned but may be of high conservation priority for any reason, including:
- Occurs within conservation reserves and land recommended for conservation reserves, TEC and buffers, habitat for threatened flora or fauna.
- Provides a dry season refuge for aquatic or terrestrial fauna (e.g. river pools).
- Aquifers (supporting significant stygofauna)

Support species or communities of listed or otherwise recognised high conservation significance

### To find wetland features:
- Rivers – DoW
- Hydrography, linear
- Aerial photography
- GDE atlas - BOM
- Water observations from space (persistence of water bodies) – Geoscience Australia

### To determine conservation priority, use the above, plus:
- DPaW Managed Lands and Waters
- System 1-5 and 7-12 conservation areas DEP 06/95
- Threatened Ecological Communities (buffers) - DPaW
- Threatened Fauna – DPaW
- Threatened and Priority Flora - DPaW
- Wetlands - DIWA
- GDE atlas - BOM

### Sites of heritage, cultural or social significance

<table>
<thead>
<tr>
<th>Category</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aboriginal heritage sites associated with any of the above categories</td>
<td>Aboriginal Sites Register System – DIA</td>
</tr>
<tr>
<td>Heritage sites associated with any of the above categories</td>
<td>Register of Heritage Places</td>
</tr>
<tr>
<td>Recreation or tourism sites associated with any of the above categories</td>
<td>Geographic Names – DLI</td>
</tr>
</tbody>
</table>

### Matters of National Environmental Significance

<table>
<thead>
<tr>
<th>Category</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>World heritage properties</td>
<td>EPBC Protected matters search tool - DoE</td>
</tr>
<tr>
<td>National heritage places</td>
<td></td>
</tr>
<tr>
<td>Wetlands of international importance (listed under the Ramsar Convention)</td>
<td></td>
</tr>
<tr>
<td>Listed threatened species and ecological communities</td>
<td></td>
</tr>
<tr>
<td>Habitat for migratory species protected under international agreements (JAMBA, CAMBA, ROKAMBA)</td>
<td></td>
</tr>
</tbody>
</table>
Appendix B - Classification of assets into value and rank categories

<table>
<thead>
<tr>
<th>Value rankings</th>
<th>Description and justification of values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Locally significant (within the catchment)</td>
<td>All native vegetation, as well as riverine and wetland areas that provide important habitat for fauna and flora and contribute to ecological processes.</td>
</tr>
<tr>
<td>2. Regionally significant (in the Kimberley)</td>
<td>Rare, or uncommon features that may be regionally important for biodiversity (and thus conserving environmental values) – This includes springs, near-permanent or permanent water bodies, such as pools and riparian vegetation.</td>
</tr>
<tr>
<td>3. Significant environment asset in Northern Australia (HCVAE scores from Kennard et al. 2010)</td>
<td>Drawing on a large amount of biodiversity data Kennard et al. (2010) mapped six criteria that characterise high value aquatic ecosystems in northern Australia (these are: diversity, distinctiveness, vital habitat, evolutionary history, naturalness and representativeness).</td>
</tr>
<tr>
<td>4. State significant</td>
<td>Western Australian State legislation - Listed WA priority and threatened ecological communities, flora and fauna.</td>
</tr>
<tr>
<td>5. Federally/Internationally significant</td>
<td>Includes species and communities listed under the EPBC act and International agreements – including Wetlands of international importance (listed under the Ramsar Convention) and habitat for migratory species protected under international agreements (JAMBA, CAMBA, ROKAMBA). Also includes Aboriginal heritage sites, as well as world national heritage listed areas.</td>
</tr>
</tbody>
</table>
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