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TABLES

FIGURES

12. AQUATIC FLORA

12.1. Description of environmental values

This section addresses **Section 3.3.4.1** of the ToR, describing the aquatic flora present or likely to be present at any time during the year in the areas potentially affected by the Project.

12.1.1. Regulatory framework

12.1.1.1. Environment Protection and Biodiversity Conservation Act 1999

The Project has been declared a 'Controlled Action' under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Controlling provisions for the Project relate to aquatic flora in both freshwater and downstream marine environments.

Relevant freshwater-related issues include:

- the aquatic macrophyte *Myriophyllum artesium* is known to inhabit a mound spring on Sandy Creek (a small tributary of Cockatoo Creek; Wandoan Coal Project EIS, 2008). This species is located approximately 20 km upstream (east) of the proposed water storage area, 12 km from the pipeline corridor and is not located within the dam and surrounds or pipeline study areas. It is listed as 'endangered' under the EPBC Act.

Relevant marine-related issues include:

- the Great Barrier Reef World Heritage Area (GBRWHA) (also a National Heritage Place and a Commonwealth Marine Area). The Fitzroy Basin drains to the GBRWHA. World heritage values protected under the EPBC Act that relate to the aquatic flora of (downstream) marine habitats include extensive *Halimeda* beds, a large diversity of flora and habitats for species of conservation significance including seagrasses (15 species covering over 5, 000 km^2) and mangroves (37 species covering over 2, 070 km^2). The potential impacts of the Project on the aquatic flora of the GBRWHA are discussed in **Section 12.2**.; and
- the ecological character of the Shoalwater and Corio Bays Area Ramsar site is protected under the EPBC Act. Environmental values that contribute to the ecological character of the site include the diverse wetlands, which contain both tropical and subtropical flora species, and half of the wetland types found in Queensland. The potential impacts of the Project on the aquatic flora of the site are discussed in **Section 12.2**.

12.1.1.2. Queensland Environmental Protection Act 1994

The objective of the *Queensland Environmental Protection Act 1994* (EP Act) is to protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (ecological sustainable development) (Queensland Government, 1994). The EP Act is the overarching legislation under which the *Environmental Protection (Water) Policy 2009* (EPP(Water)) was developed.

12.1.1.3. *Environmental Protection (Water) Policy 2009*

In Queensland the environmental values of waterways are protected under the EPP (Water). Environmental values include the biological integrity of a modified aquatic ecosystem, which as discussed in the Queensland Water Quality Guidelines (EPA 2009) include biodiversity, plants and ecological interactions. The aquatic flora of the Project area and downstream waters contribute to the biological integrity and ecological interactions in these waterways.

12.1.1.4. *Queensland Nature Conservation Act 1992*

Myriophyllum artesium is also classified as 'endangered' by the *Queensland Nature Conservation Act 1992* (NC Act) (as listed under the *Nature Conservation (Wildlife) Regulation 2006* (NC Reg) – subordinate legislation under the NC Act). *Eleocharis blakeana* (family *Cyperacea*) has been identified in the database search results for the study area and is classified as 'near threatened' under the NC Act.

12.1.1.5. *Queensland Water Act 2000*

The *Queensland Water Act 2000* is the overarching piece of legislation under which the *Water Resource (Fitzroy Basin) Plan 1999* is implemented.

12.1.1.6. *Water Resource (Fitzroy Basin) Plan*

The Fitzroy WRP was under review at the time of drafting the EIS and therefore *Water Resource Plan (Fitzroy Basin) Plan 1999* (WRP) has been used in the assessment of potential impacts and associated compliance. The revised WRP was approved on 8 December 2011 and will be assessed prior to the Project's approval. The *Water Resource (Fitzroy Basin) Plan 1999* (WRP) makes provision for 'environmental water requirements for natural ecosystems'. No specific reference to aquatic flora is made, however, aquatic flora plays an integral role in maintaining the health and ecosystem function of aquatic ecosystems. The WRP has a 10 year review cycle and is currently under revision by DERM. Further information on the review process including objectives and timeline is provided in Section 14.

12.1.1.7. *Queensland Land Protection (Pest and Stock Route Management) Act 2002 (LP Act)*

No declared noxious aquatic flora under the *Queensland Land Protection (Pest and Stock Route Management) Act 2002* (LP Act) have been identified within the Project area, though they are known to be present throughout the Fitzroy Basin.

12.1.1.8. *Weeds of National Significance*

The Australian Government and the State and Territory governments have endorsed a framework to identify which weed species could be considered Weeds of National Significance (WONS) within an agricultural, forestry and environmental context. The WONS provides a framework to prioritise weed management at the state, regional and local levels. Listed WONS that may be of concern in the study areas include:

- *Alternanthera philoxeroides* (alligator weed);
- *Hymenachne amplexicaulis* (hymenachne or olive hymenachne); and
- *Salvinia molesta* (salvinia).

12.1.2. Methodology

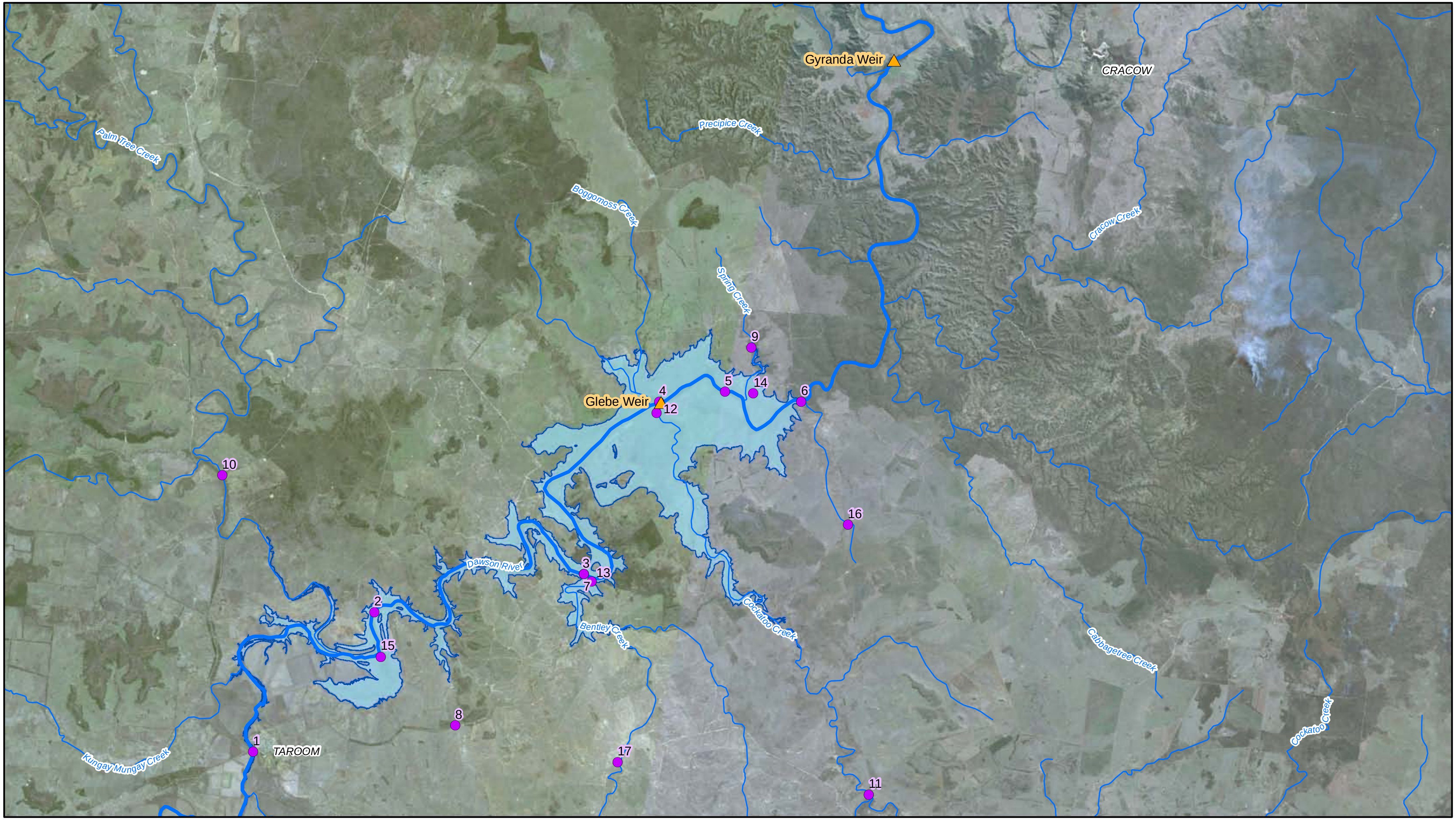
In order to describe the environmental values related to aquatic flora the following activities were undertaken:

- the regulatory instruments noted above were reviewed;
- the literature available on the area and the catchment was sourced and reviewed; and
- baseline surveys were undertaken during the 2007 pre-wet (November) and the 2008 post-wet (June) season's.

Commissioned by SunWater, two baseline field surveys were conducted in the dam and surrounds study area to describe the aquatic flora present in the freshwater habitats that may be affected by the Project (encompassing sites upstream of, within, and downstream of the inundation and buffer). These included a pre-wet season survey (frc environmental Appendix 12-A) and a post-wet season survey (Ecowise 2008a and 2008b; Appendix 12-B and Appendix 12-C). The locations of all sites relative to the proposed water storage are listed in Table 12-1 and displayed in Figure 12-1. For the pipeline study area, one field survey was undertaken (in the post-wet season 2008; frc environmental Appendix 12-D).

Table 12-1 Dam and surrounds sites surveyed for aquatic flora during baseline surveys

Site	Channel name	Location	Survey completed	
			Pre-wet	Post-wet
1	Dawson River	Upstream of water storage	×	✓
2	Dawson River	Within water storage	✓	✓
3	Dawson River	Within water storage	×	✓
4	Dawson River	Within current Glebe Weir pool	✓	✓
5	Dawson River	Within water storage	×	✓
6	Dawson River	Downstream of water storage	×	✓
7	Dawson River	Within current Gyranda Weir pool	×	✓
8	Blackboy Creek	Upstream of water storage	✓	✓
9	Spring Creek	Upstream of water storage	×	✓
10	Palm Tree Creek	Upstream of water storage	✓	✓
11	Cockatoo Creek	Upstream of water storage	✓	×
12	Cockatoo Creek	Within current Glebe Weir pool	✓	✓
13	Bentley Creek	Within current Glebe Weir pool	×	✓
14	Spring Creek	Within water storage	✓	✓
15	Scotchy Creek	Within water storage	✓	✓
16	Price Creek	Downstream of water storage	✓	✓
17	Bentley Creek	Upstream of water storage	✓	✓
18	Cockatoo Creek	Within water storage	✓	×



LEGEND

- Aquatic Flora Site Locations
- Weir
- Major Watercourse
- Watercourse
- Full Supply Level (183.5 m AHD)

Projection: GDA94 Zone 56

Figure 12-1

0 1.5 3 6
Kilometres

N

Scale 1:300,000 (at A4)

SKM SunWater Making Water Work

NATHAN DAM AND PIPELINES EIS

Sites surveyed for aquatic flora during the baseline surveys

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12.1.2.1. Limitations

- Literature review

No information was available regarding aquatic flora communities prior to the late 1980's, therefore, the estimation of the natural state of the communities could not be based on historical (pre-development) information.

- Baseline surveys

Due to extreme weather conditions, both dry and flood conditions were experienced during the pre-wet season survey with, 11 of the 18 sites being unsuitable for sampling.

Increased water depths in the post-wet season survey may have prevented some submerged species from being noted and recorded.

All genera of macrophytes recorded were mono-specific except *Cyperus* and *Persicaria*. These were identified to species in the pre-wet season survey only. These are treated at genus level in statistical analyses but discussed at species level where relevant.

Site selection for the pipeline study area was limited by access to private property and presence of water. Accordingly, all sites were located on public land (generally road reserve), as close as possible to the pipeline route. Seasonal changes are predicted to be similar to those observed at dam area study sites and to that reported in the literature.

12.1.3. Dam and surrounds

12.1.3.1. Distribution of waterbody types

Pool habitat dominated the study area during both the pre-wet and post-wet seasons (Figure 12-1, Figure 12-3 and Figure 12-4). Tailwater habitat was located at several sites during the post-wet season. At the time of surveys, rapids, riffles, glides and runs were limited to one site on the main channel within the storage area (at the Bundulla Road crossing, site 2).

Tailwaters were limited to the main channel, both within and downstream of the storage area. Baseline survey's included searches for off-stream waterbodies ('wetlands' or constructed dams), however, none were located.

Figure 12-2 Variety of habitats on the Dawson River at the Bundulla Road crossing (rocks apparently placed in the stream as part of an abandoned crossing)

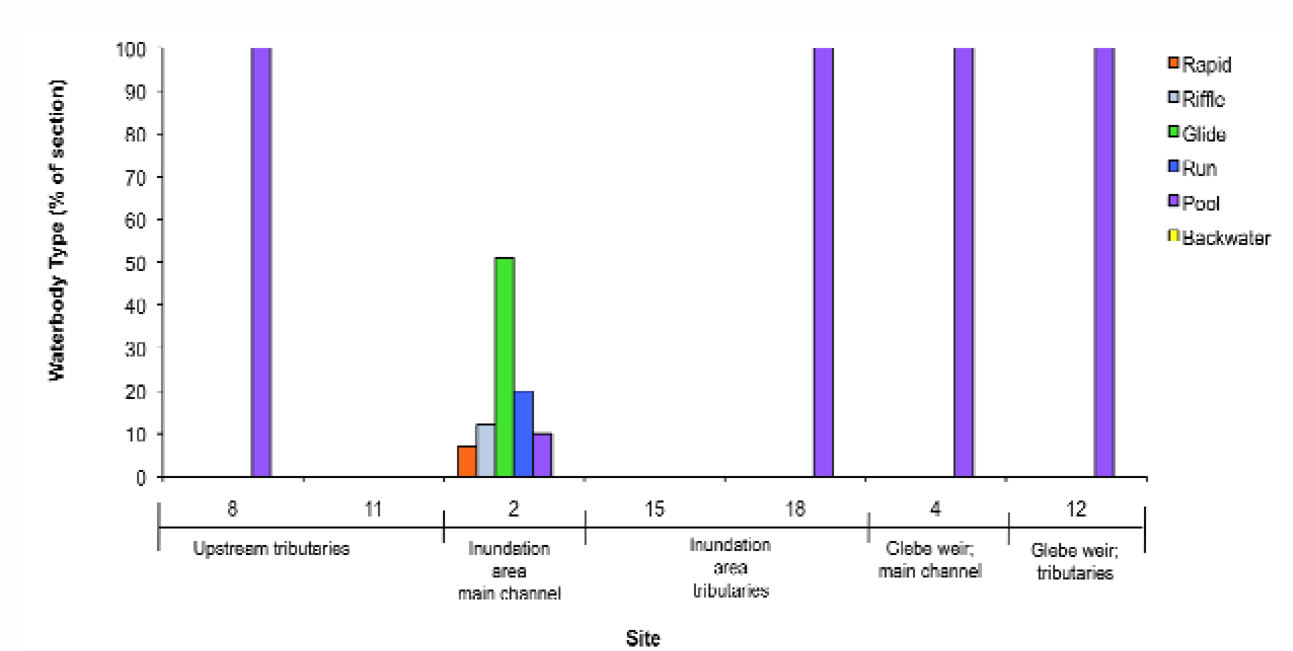

Figure 12-3 Waterbody type (percent) recorded at each site in the dam and surrounds study area in the pre-wet season (frc environmental, 2007)

Note: Sites 11 and 15 were dry; remaining sites were flooded.

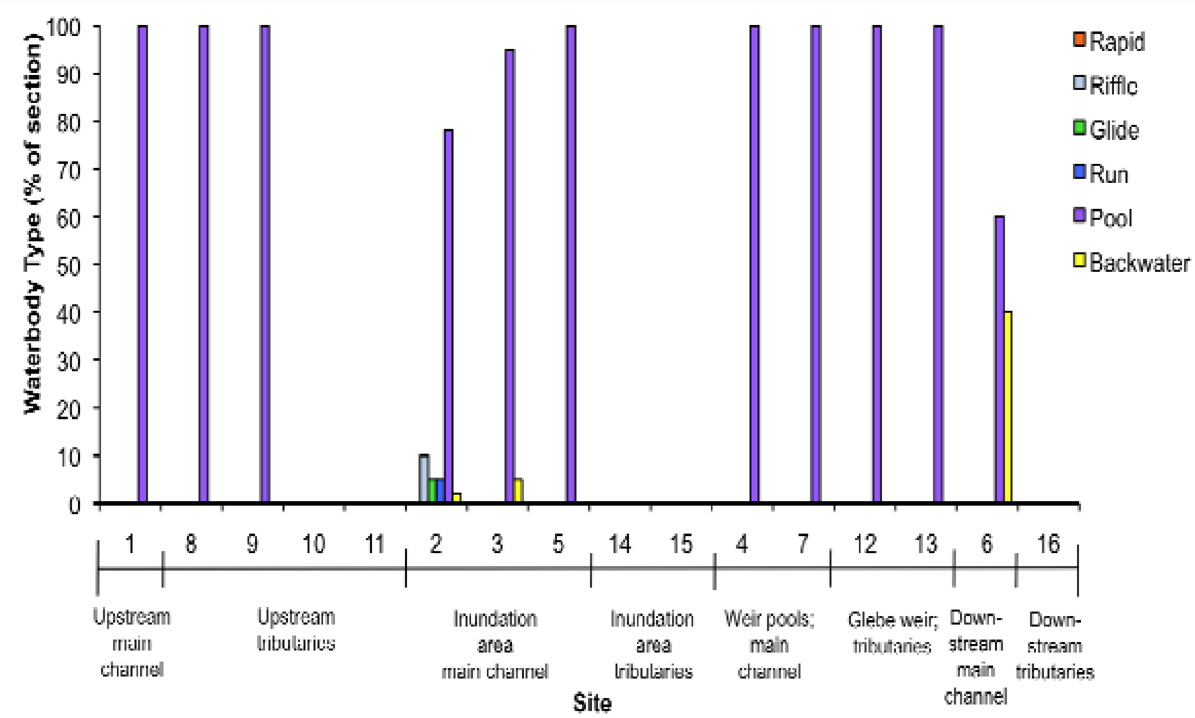

Figure 12-4 Waterbody type (percent) recorded at each site in the dam and surrounds study area in the post-wet season (Ecowise, 2008)

12.1.3.2. Extent and location of freshwater macrophytes

During surveys conducted between 1989 and 1991, 105 aquatic and semi-aquatic macrophyte species were recorded in the Fitzroy Basin (Duivenvoorden 1992). During these surveys, Duivenvoorden generally recorded 2 - 5 species to be present at sites throughout the wider Fitzroy Basin, whilst 2 - 4 species were recorded at sites situated within the Dawson sub-catchment (Duivenvoorden 1992).

On the Dawson River upstream of Taroom, 6 - 9 species were recorded during surveys in June 1994, October 1994 and May 1995 (Duivenvoorden, 1995). Emergent species such as sedges (*Cyperus* spp. and *Juncus polyanthemus*), rushes (*Lomandra* sp.), knotweeds (*Persicaria* spp.), *Bacopa monnieri*, and *Rumex* sp. were most abundant. Floating species (*Marsilea drummondii* and *Ludwigia peploides montevidensis*) were recorded in June 1994 and October 1994, respectively; and the submerged *Potamogeton crispus* was recorded in October 1994 (Duivenvoorden, 1995).

Downstream of the proposed Nathan Dam site, between 8 and 10 macrophyte species were recorded in June 1994, October 1994 and May 1995 (Duivenvoorden, 1995). Emergent species such as *Cyperus* spp., *Juncus* spp. and *Persicaria* spp. were common across the surveys (Duivenvoorden, 1995). Floating *Azolla pinnata* and *Spirodela oligorrhiza* were recorded in May 1995 although no submerged species were found (Duivenvoorden, 1995).

In general, the species richness recorded by Duivenvoorden (1995) was similar to that found during the current Nathan Dam EIS baseline surveys, with the sites being dominated by similar species (Table 12-2). No macrophytes were noted as growing within riffle, run or glide habitats in the study area.

Although not all sites were able to be sampled during the pre-wet season survey, richness and coverage was generally higher in the pre-wet than the post-wet season (Figure 12-5 and Figure 12-6). This may be due to the wet season floodwaters drowning macrophytes and/or washing macrophytes downstream. For example, during the pre-wet season survey, there was a high coverage of emergent *Persicaria* spp. on the Dawson River immediately upstream of the Glebe Weir, higher water levels in the weir pool had drowned out these emergent macrophytes prior to the post-wet season survey. It is also possible that decreased visibility (due to higher water levels) during the post-wet season may have reduced the number of taxa recorded. Seasonal and annual variation in macrophyte richness and coverage is typical in the region, reflecting a dynamic environment and prevailing environmental conditions (Duivenvoorden, 1992; Noble *et al.*, 2007).

Table 12-2 Macrophyte species recorded in the dam and surrounds study area during baseline surveys[1]

Species	Common name	Upstream	Water storage		Weir pools		Downstream
		Post-wet	Pre-wet	Post-wet	Pre-wet	Post-wet	Post-wet
SUBMERGED							
None observed							
FLOATING							
Azolla pinnata	Ferny Azolla					✓	
Lemna sp.	Duckweed					✓	
Ludwigia peploides montevidensis	Water Primrose		✓			✓	
EMERGENTS							
Alternanthera denticulata	Lesser Joyweed		✓		✓		
Cyperus difformis	Dirty Dora	✓	✓		✓		
Echinochloa inundata	Awnless Barnyard Grass				✓		
Eclipta prostrata	White Eclipta		✓				
Eleocharis sp.		✓		✓		✓	✓
Juncus prismatocarpus					✓		
Juncus usitatus	Common Rush		✓		✓		
Leptochloa digitata	Umbrella Cane Grass		✓				
Lomandra hystrix	Creek Mat Rush		✓				
Lomandra sp.[2]		✓		✓			✓
Persicaria attenuata	Knotweed	✓		✓		✓	
Persicaria decipiens	Slender Knotweed		✓		✓		
Persicaria orientalis	Knotweed				✓		
Schoenoplectus mucronatus					✓		
Typha domingensis	Cumbungi				✓		

[1] Pre-wet and post-wet season surveys are not strictly comparable as not all sites could be sampled during the pre-wet season survey due to flooding.

[2] It is likely that species of *Lomandra* observed in the post-wet season survey was the same species observed in the pre-wet season survey, i.e. *L. hystrix*.

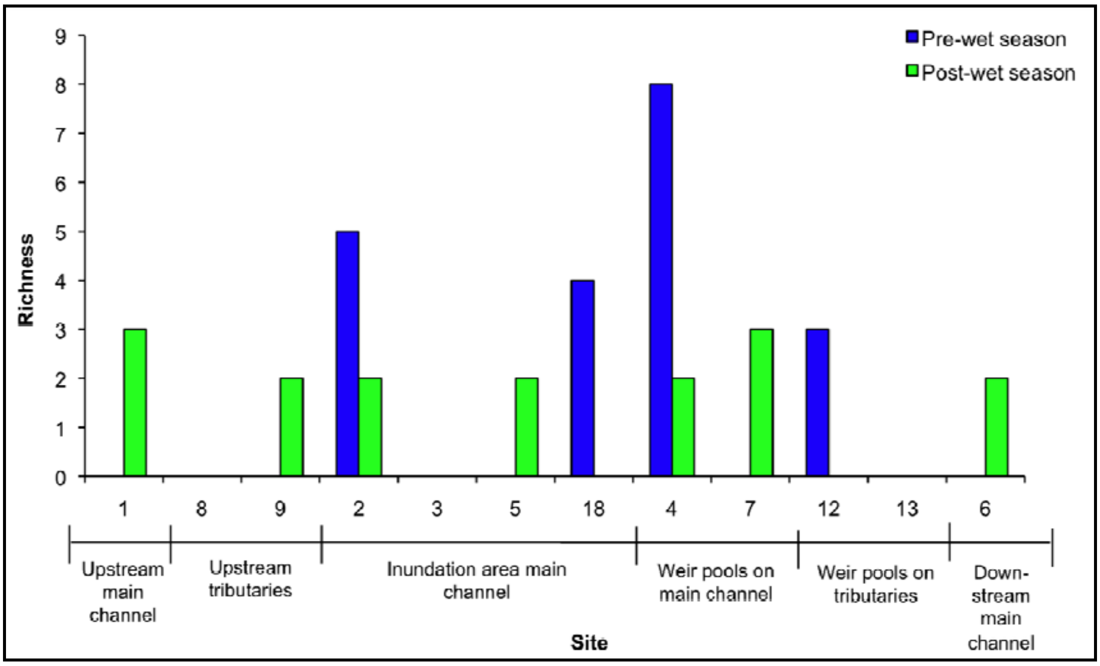

Figure 12-5 Number of aquatic macrophyte species (richness) recorded at each site in the pre-wet and post-wet season surveys (adapted from frc environmental 2007 and Ecowise 2008)

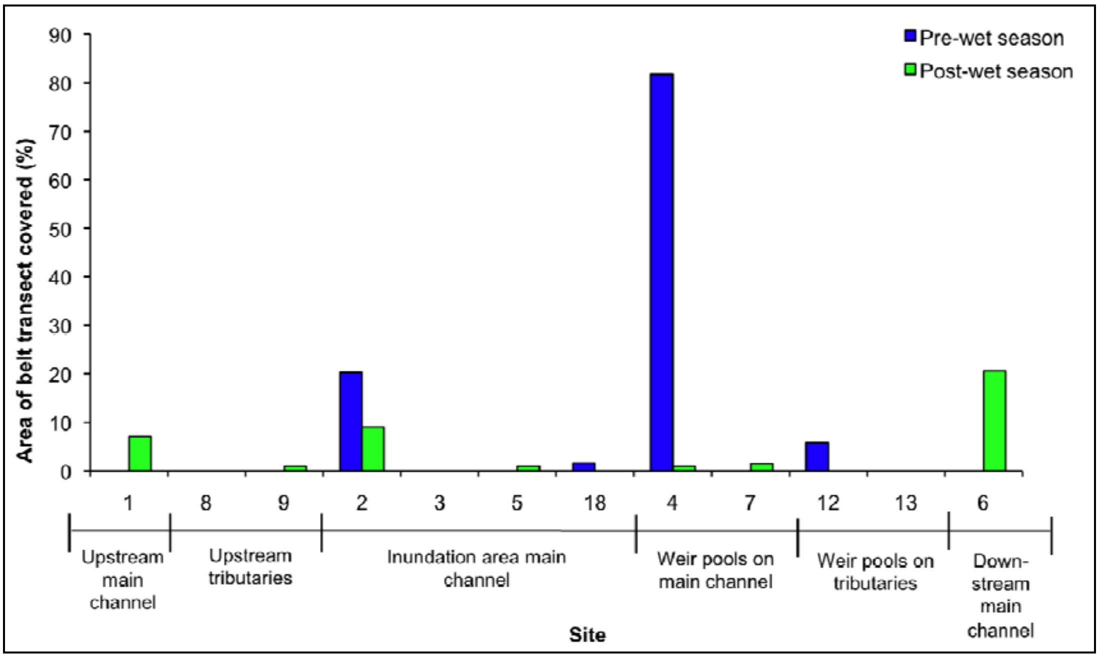

Figure 12-6 Percent coverage of macrophytes recorded at each site in the dam and surrounds study area in pre-wet and post-wet season surveys (adapted from frc environmental 2007 and Ecowise 2008)

The most common genera in the Fitzroy Basin are *Cyperus* (17 species), *Persicaria* (6 species), *Juncus* (6 species), and *Potamogeton* (5 species) (Duivenvoorden, 1992). *Persicaria* (3 species), *Eleocharis Lomandra* and Cyperus were the most common genera in the survey area. *Juncus* (2 species) and *Alternanthera denticulate* (lesser joyweed) were also relatively common in the survey area. These macrophytes are emergent in form and desiccation resistant, and often found on upper riverbanks, away from water (this is typical of macrophyte communities in Central Queensland that need to withstand prolonged dry periods) (Duivenvoorden, 1992; Figure 12-7).

Figure 12-7 Emergent *Persicaria* spp. and sedges (family *Cyperacea* and *Juncaceae*)

The coverage and abundance of floating macrophytes was very low in the study area (Table 12-1). *Lemna sp*. and *Azolla pinnata* were only found in the Gyranda Weir pool (site 7) during the post-wet season survey. Floating *Ludwigia peploides montevidensis* (Figure 12-8) was found in the proposed water storage during the pre-wet season survey.

Figure 12-8 Floating *Azolla pinnata* and *Ludwigia peploides montevidensis*

The lack of submerged species may be a result of high turbidity limiting their growth, especially in the pre-wet season. These species may also have been missed in the surveys due to poor visibility associated with the highly turbid water.

Although a diverse range of macrophyte communities was identified as inhabiting the study area, relative to communities elsewhere in the Fitzroy Basin, they are considered depauperate (Arthington *et al.*, 1992; Duivenvoorden, 1992).

Species of conservation significance

No species of conservation significance are known to inhabit the proposed water storage.

Declared pest plants and weed species

All species of aquatic macrophyte recorded during the Nathan Dam EIS baseline surveys are native.

12.1.3.3. Extent and location of phytoplankton

Phytoplankton species richness and abundance is generally low in the Fitzroy Basin (Negus, 2007). Cyanobacteria (blue-green algae) blooms, however, are noted to occur throughout the Fitzroy Basin - particularly in late winter to summer (Noble *et al.*, 1997). Potentially toxic cyanobacteria species include: *Anabaena circinalis*, *Cylindrospermopsis raciborski*, and *Microcytis aeruginosa f. aeruginosa* (Noble *et al.*, 1997). Conditions favourable to cyanobacterial growth in the region include a range of turbidity levels, high pH, high nutrients, and lower flows towards the end of the year (Noble *et al.*, 1997).

A study of phytoplankton at two sites on the Dawson River concluded that under 'normal' conditions there was potential for highly toxic algal blooms, even when water was flowing and not stratified (Noble *et al.*, 1997). A total of 134 species of phytoplankton were identified from this area, although the species composition was dominated by cyanobacteria when cell-volumes were highest (Noble *et al.*, 1997).

Since November 2001, no cyanobacteria blooms have been recorded in the Glebe, Theodore or Neville Hewitt Weirs, however low levels (< 20, 000 cells/mL) have been occasionally recorded in Moura Weir (based on data provided by SunWater). Outside of the Dawson sub-catchment, monthly monitoring conducted at Fairbairn Dam (the closest large dam to the proposed Nathan Dam site) reveals cyanobacteria blooms to have exceeded 20,000 cells/ml only three times since 2001.

Estuarine and marine

The descriptions below and impact assessment for estuarine and marine flora are brief and commensurate with the associated risks which have been identified as low.

There is significant phytoplankton growth in the upper Fitzroy estuary during the dry season, which is supported by nutrient inputs from the catchment during floods, and sewage discharges (Webster *et al.*, 2006). Phytoplankton growth throughout most of Keppel Bay is nutrient limited (Webster *et al.*, 2005). Intertidal flats in the estuary support extensive mats of microalgae, which is a critically important food source (directly or indirectly) for a variety of commercially and recreationally important species (Connolly *et al.*, 2006, Webster *et al.* 2006).

12.1.3.4. Extent and location of marine macrophytes

The Fitzroy River Delta is one of the five largest mangrove and saltmarsh habitats along the Great Barrier Reef (GBR) coast (Schaffelke *et al.*, 2005). Closed mixed mangrove forests dominate mangrove communities, although closed *Rhizophora* and closed *Avicennia* forests dominate communities close to the water's edge (Bruinsma, 2000). The low coastal plains and dry climate of the Fitzroy delta region also support large areas of unvegetated saltpan.

Fifteen species of seagrass are found within the Great Barrier Reef, with seagrass communities in the Fitzroy region dominated by beds of *Zostera*, *Halodule* and *Halophila* (Schaffelke *et al.*, 2005). Macroalgae communities grow on hard surfaces such as reefs. These communities provide a food source for fauna of conservation significance (Chapter 13).

12.1.3.5. Estimation of natural state

There is insufficient historical data available to reliably describe the natural state of aquatic flora in the waterways that may be impacted by the Project. It is, however, likely that a greater diversity of macrophyte species and growth forms were present in the study area prior to European settlement.

Both water and non-water resource developments have likely caused a reduction in macrophyte diversity. Water resource development, through the construction of weirs, has reduced the diversity of habitat available for aquatic macrophyte. Artificial water bodies however can, under the right conditions, increase abundance of macrophytes. Equally, non-water resource developments, such as land clearing, have resulted in increased sediment, nutrient and pesticide loads, which have also resulted in a reduction in macrophyte diversity (Section 12.1.3.2). In particular, high turbidity is thought to be the reason that no submerged macrophytes were found in the study area.

Estuarine and marine floral communities are altered from their natural state (Section 12.1.3.4), however, they are still regarded as highly valuable, well-functioning ecosystems.

12.1.3.6. Habitat requirements and sensitivity of aquatic flora species

- Freshwater macrophytes

The distribution and species composition of freshwater macrophytes varies with flow conditions and water depth, and varies substantially over time at any given site within the Fitzroy Basin (Duivenvoorden, 1992). Flooding of the river can dramatically reduce both species diversity and abundance (Mackay, 1996, Duivenvoorden, 1992), and is likely to be a factor in the reduction in macrophyte richness and cover observed between the post- and pre-wet-season baseline surveys. In general, macrophyte growth and colonisation is more extensive in habitats with high hydraulic stability and moderate to low water velocities (Mackay, 1996). Physical disturbance can directly destroy or damage macrophytes and introduce large amounts of suspended sediments to the waterway. Growth can also be limited by high turbidity and nutrient levels. High turbidity levels decrease the amount of light available to submerged macrophytes, inhibiting their growth. High nutrient levels favour the growth of phytoplankton and epiphytes, again decreasing the amount of available light reaching submerged macrophytes. Floating macrophytes can be destroyed or damaged when water flow is altered and/or reaches are diverted, and by high suspended sediment loads.

The majority of species recorded within the study area and in the Dawson sub-catchment and the Fitzroy Basin are generally resilient to a wide range of environmental conditions including variable hydraulic conditions (no to low flow in the dry-season followed by flood level flows in the wet-season) elevated turbidity levels and elevated nutrient concentrations.

The life-cycle requirements of macrophytes in relation to habitat and flow regimes are poorly understood (Mackay 1996). However, it is known that most macrophytes do not have subterranean propagules from which to regenerate, and that seeds being washed downstream may be responsible for the replacement of some species by others (Duivenvoorden, 1992). Off-stream wetlands may be particularly important as a source of seeds for downstream waters during floods (Duivenvoorden, 1992). Typical habitat associations of macrophyte species found during the present study (based on field observations and literature review) are presented in Table 12-3.

Table 12-3 Primary and secondary habitat preferences of the species recorded during the present study

Species	Common name	Typical habitat association	Secondary habitat associations
FLOATING			
Azolla pinnata	*Ferny Azolla*	Off-stream wetlands	On-stream pools
Lemna sp.	*Duckweed*	On- and off-stream pools	
Ludwigia peploides montevidensis	*Water Primrose*	Off-stream wetlands	On-stream pools
EMERGENT			
Alternanthera denticulata	*Lesser Joyweed*	*Fringe of watercourses*	*Shallow margins of pools*
Cyperus spp.	*Flatsedge*	*Fringe of watercourses*	*Shallow margins of pools*
Echinochloa inundata	*Awnless Barnyard*	*Fringe of watercourses*	*Shallow margins of pools*
Eclipta prostrata	*White Eclipta*	*Fringe of watercourses*	*Shallow margins of pools*
Eleocharis sp.		*Fringe of watercourses*	*Shallow margins of pools*
Juncus sp.		*Fringe of watercourses*	*Shallow margins of pools*
Leptochloa digitata	*Umbrella Cane Grass*	*Fringe of watercourses*	*Shallow margins of pools*
Lomandra sp.	*Rush*	*Fringe of watercourses*	*Shallow margins of pools*
Persicaria spp.		*Fringe of watercourses*	*Shallow margins of pools*
Schoenoplectus mucronatus			
Typha domingensis	*Cumbungi*	*Fringe of watercourses*	*Shallow margins of pools*

Sources: present study; Arthington *et al.,* 1992; Duivenvoorden, 1992.

□ Phytoplankton and benthic microalgae

Phytoplankton and benthic microalgae distribution and succession are controlled by a variety of environmental factors and intrinsic biological characteristics such as growth rates, and the availability of 'seeding' organisms (such as dinoflagellate cysts) (Jeffrey, 1981). There is usually a much larger range of algal species in dams, lakes and ponds than in moving water, especially when nitrogen and phosphorous concentrations are low. However, if nutrient levels rise, the range of species can decrease, but the number of cells of each species may increase (to form an 'algal bloom').

Cyanobacteria are the main bloom-causing algal groups in freshwaters (ANZECC and ARMCANZ, 2000). Cyanobacterial blooms occur in impoundments and in rivers during periods of low flow, and are common in Queensland water storages. Impoundments that are particularly problematic are typically narrow deep storages with low surface areas, and low exposure to wind. Current information on existing storages on the Dawson River, however, indicates that the risk of a cyanobacterial bloom is low (Section 12.1.3.3).

Phytoplankton and benthic microalgae growth within the Fitzroy Estuary is seasonal. Algae numbers are low during summertime heat and freshwater flows, but large amounts of nutrients and fine sediments are introduced into the system, fuelling high growth during autumn and winter (Webster *et al.*, 2006).

Mangroves and saltmarsh

Mangrove and saltmarsh communities are affected by increases in nutrient levels: slight increases in nutrient concentrations can promote growth and productivity; whereas large increases in nutrients can have negative impacts. Inputs of pesticides and other contaminants, along with changes to inundation frequency and levels can negatively affect mangrove and saltmarsh health (Schaffelke *et al.*, 2005). Mangroves are impacted (often positively) by sedimentation, because the deposition of suspended sediments may cause the formation of new intertidal mud/sand banks which are suitable for mangrove colonisation. For example, *Avicennia marina* (Grey Mangrove) have been found to colonise new banks/islands in the Fitzroy estuary, and this species is generally most prevalent on accreting banks (Bruinsma, 2000).

A reduction in flows to estuaries has been shown to increase salinity levels in the upper estuary (Attrill *et al.,* 1996). Increased salinity levels have been implicated as the causal agent of dieback of *Avicennia marina* mangrove communities, including in far north Queensland (Conacher *et al.,* 1996); the arid Pilbara coast of Western Australia (Gordon 1987); and commonly in West African mangrove ecosystems (Marius and Lucas 1991). High salinity levels are associated with reduced leaf photosynthesis (Sobrado 1999; Li et al 2008), reduced leaf ion concentrations and hydraulic conductivity (Lovelock et al 2007), reduced mangrove growth (Cintron *et al.,* 1978; Ball 1988; Kahn and Aziz 2001; Naidoo 2006; Li *et al.,* 2008; Yan *et al.,* 2007), and mangrove death (Perdomo *et al.,* 1998).

Seagrass and macroalgae

Declining water quality has been shown to negatively affect Great Barrier Reef (GBR) macrophytes, and pollutants such as herbicides, metals and petrochemicals affect seagrass health (Schaffelke *et al.*, 2005). High turbidity reduces the growth of seagrass due to shading and reductions in photosynthesis (Brizga *et al.*, 2003). The effects of increased nutrient availability are less understood and are more situation-dependent. Whilst moderate nutrient enrichment may stimulate seagrass growth, nutrient enrichment may also stimulate the growth of epiphytic algae, decreasing the productivity of seagrass.

High nutrient availability, in conjunction with high substrate availability and reduced grazing pressure, has lead to altered benthic reef communities, with high macroalgal cover in some nearshore reefs (Schaffelke *et al.*, 2005).

12.1.3.7. *Existing impacts*

Impoundments

The reduction in habitat diversity, increased permanence of water, and altered flow regime caused through the construction of impoundments is likely to alter inhabiting macrophyte communities from the natural state. Nevertheless, the conditions resulting from the construction of impoundments generally support diverse macrophyte communities. Weir and dam impoundments throughout the Fitzroy Basin have historically had a relatively high diversity of macrophytes (e.g. 16 species in the Theresa Creek Dam, 18 in the Fitzroy Barrage impoundment), including a relatively high number of floating and submerged species (Duivenvoorden, 1992).

Flow regulation

The Dawson Valley Water Supply Scheme (DVWSS) extends along the Dawson River from Glebe Weir to downstream of Boolburra (a distance of 338 km). The scheme relies on six water storages: Glebe Weir; Gyranda Weir; Orange Creek Weir, Theodore Weir; Moura Weir and Neville-Hewitt Weir. Consequently, flow is regulated throughout much of the Dawson River. Fluctuating water levels within and downstream of existing impoundments affect macrophyte distribution and growth. For example, the richness and cover of emergent macrophytes in the Glebe Weir impoundment was high around the margins and on sediment islands of the weir pool during the pre-wet season surveys (when water levels were low (prior to flooding)), but low during the post-wet season survey (when water levels were higher), as much of the habitat previously occupied by these emergent species had been inundated.

Non-water resource developments

There are a large number of road crossings of waterways within the Fitzroy Basin, ranging from multi-span bridges, through pipe and box culverts, to concrete or gravel fords. Macrophyte communities would likely have been impacted during the construction, and continued use, of these crossings.

Grazing and cropping are the dominant land-use adjacent to waterways within the study area. Activities such as riparian clearing and cattle access to waterways, can potentially impact turbidity, sedimentation and nutrient levels in waterways; which, in turn, can potentially impact the presence and diversity of macrophyte communities.

The generally low macrophyte richness and abundance in the Fitzroy Basin has been attributed to climatic conditions, high turbidity and grazing pressures (Negus, 2007). The paucity in species diversity in farm dams noted throughout the Fitzroy Basin is likely due to a combination of permanence, grazing pressure, the lack of connectivity and the small relative size of these water bodies.

Impacts to estuarine and marine habitats

Between 1946 and 2002 approximately 840 ha of mangroves and saltmarsh were reclaimed in the Fitzroy estuary for salt farms and agriculture, although there has also been expansion of mangrove areas at the mouth of the Fitzroy River more recently (GBRMPA, 2007). This expansion coincides with increased sediment loads in runoff caused by vegetation clearing, reduced river flows and flushing caused by the construction of the Fitzroy Barrage (Schaffelke *et al.*, 2005).

Nutrients and sediment washed downstream from the catchment, and nutrients discharged from sewerage treatment plants, are likely to influence phytoplankton, mangrove and seagrass growth; this impact may be positive or negative, depending on a range of factors although no obvious negative impacts of high nutrients on these systems have been reported. Coastal seagrass meadows are disturbed by increased turbidity after extreme flood events. They generally recover and there is no evidence of an overall trend of decline or expansion of seagrass meadows in the Great Barrier Reef (Schaffelke *et al.*, 2005).

12.1.4. Pipeline

Information regarding the relative position and site characteristics of sites sampled throughout the pipeline study area is presented in Appendix 12-D.

12.1.4.1. Distribution of waterbody types

Habitat surveys (including information regarding waterbody characteristics) were completed at 11 sites throughout the pipeline study area during a one off survey completed in January 2009. Similar to watercourses in the dam and surrounds study area in the pre-wet season (prior to flooding), smaller watercourses (Juandah, L Tree, Jingi Jingi and Jimbour Creeks) contained only shallow pools, while larger watercourses (Dogwood, Columboola, Rocky, Cooranga and Myall Creeks, and the Condamine River) had perennial pools at least 1 m deep. It is likely that during periods of flow, there are run, riffle and tailwater habitats in some of these waterways, similar to those observed in the Dawson River in the dam and surrounds study area. Two Mile Creek was dry at the time of survey.

12.1.4.2. Extent and location of macrophytes

Aquatic flora surveys were completed at six locations throughout the pipeline study area. Twelve genera of macrophytes were recorded in the pipeline study area, including two species of *Alternanthera*, two species of *Cyperus* and two species of *Persicaria* (Table 12-4).

Macrophyte richness was highest at the Condamine River (site P8) and lowest at Columboola Creek (site P6) (Figure 12-9).

Macrophytes were generally sparse with less than 8% coverage at all sites surveyed (Figure 12-10). The highest macrophyte coverage was observed at Rocky Creek (site P7), while the lowest coverage was observed at Jundah Creek (site P1).

Similar to watercourses in the dam and surrounds study area, emergent genera such as *Cyperus*, *Juncus* and *Persicaria* were the most common. *Ludwigia* was the most common floating macrophyte, growing at three sites.

Table 12-4 Macrophyte genera recorded at sites within the pipeline survey area

Latin Name	Site					
	Fitzroy Basin	Condamine River sub-catchment				
	P1	P6	P7	P8	P9	P11
	Jundah Ck	*Columboola Ck*	*Rocky Ck*	*Condamine Rv*	*Cooranga Ck*	*Myall Ck*
FLOATING						
Azolla				✓		
Ludwiga			✓	✓		✓
unknown waterlily						✓
EMERGENTS						
Alternanthera	✓	✓		✓	✓	✓
Cyperus	✓	✓		✓	✓	✓
Juncus	✓	✓	✓		✓	✓
Lomandra			✓	√		✓
Marsilea				✓		
Paspalum	✓			✓		
Persicaria	✓			✓	✓	
Phragmites			✓			
Typha						✓
Urochloa				✓	✓	

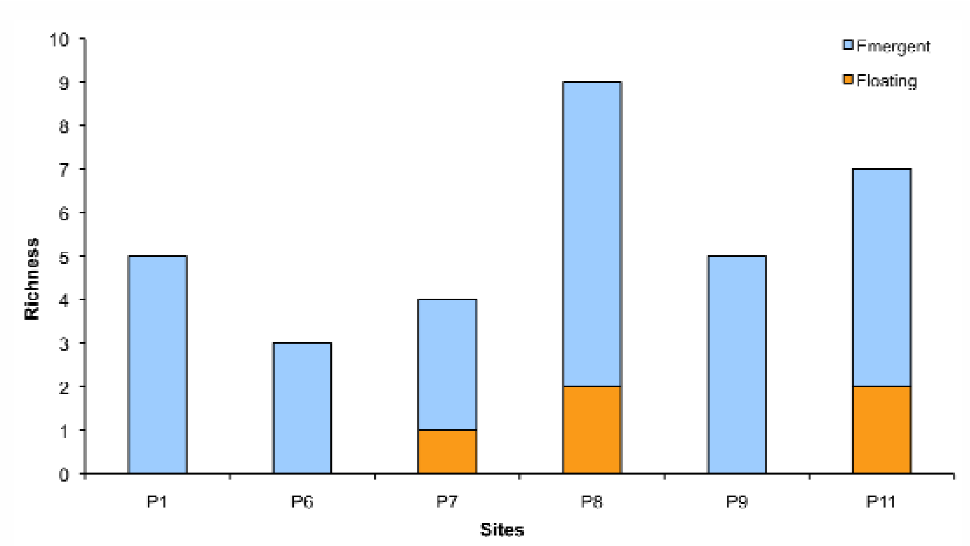

Figure 12-9 Richness of each macrophyte growth form at each site surveyed within the pipeline survey area

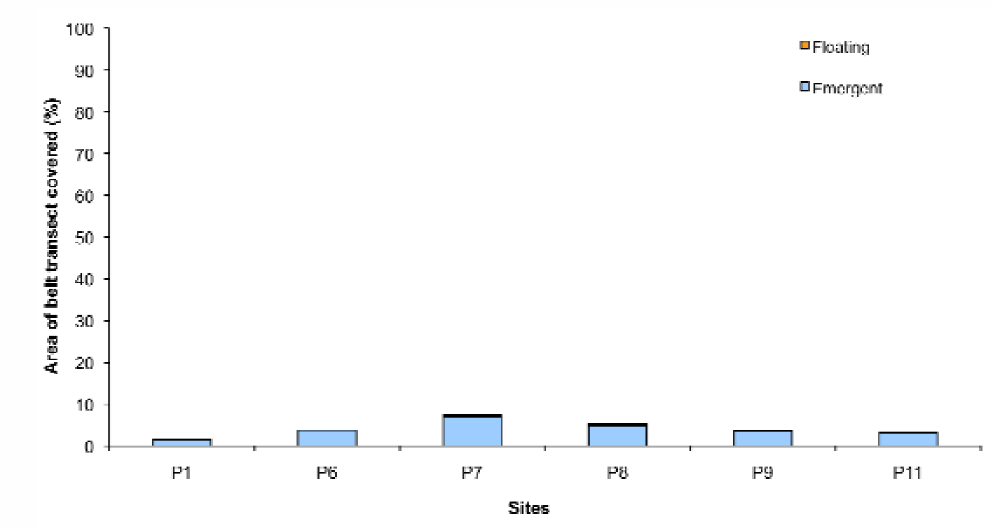

Figure 12-10 Percent coverage of each macrophyte growth form at each site surveyed within the pipeline survey area

12.1.4.3. Species of conservation significance

As outlined in Section 12.1, *Myriophyllum artesium* (classified as 'endangered' in Queensland under the NC Act and Nationally under the EPBC Act) has been recorded in Sandy Creek a tributary of Cockatoo Creek approximately 20 km upstream (east) of the water storage. *Eleocharis blakeana* (classified as 'near threatened' under the NC Act) was identified in the database search results for the study area. Neither species was observed in either the dam and surrounds or pipeline study area, during pre- and post-wet season baseline surveys.

12.1.4.4. Declared pest plants and weed species

Two species of exotic macrophytes were observed within the pipeline survey sites (Table 12-5). Exotic terrestrial non-macrophyte species are discussed in Chapter 10.

Table 12-5 Exotic plant species recorded within the pipeline study area

Latin name	Common name	Site		
		P6	P8	P9
Exotic Species				
Alternanthera philoxeroides	Alligator weed	√		
Urochloa	Para grass		√	√

12.1.4.5. Estimation of natural state

There is insufficient historical data to reliably describe the natural state of aquatic flora communities inhabiting waterways that may be impacted by construction and operation of the pipeline. However, similar to the dam and surrounds study area, land development has likely resulted in a reduction in macrophyte diversity. Aquatic weeds have colonised the pipeline study area, and weeds and agricultural land use have also impacted the riparian zone and surrounds.

12.1.5. Associated infrastructure

Details of associated infrastructure to be included in the Project are provided in Chapter 2 and Chapter 7. The majority of associated infrastructure will be located in proximity to small intermittent streams within the immediate catchment area of the dam. The existing environment relevant to aquatic floral communities within these waterways is expected to be similar to those described at tributary sites within the dam and surrounds catchment area (Section 12.1.3).

12.2. Potential impacts and mitigation measures

This section addresses Section 3.3.4.2 of the ToR, describing the potential impacts and mitigation measures for the Project, with respect to aquatic flora.

12.2.1. Dam and surrounds

Construction and operation of the dam has the potential to impact aquatic flora through:

- direct loss of habitat within the water storage;
- alteration of flows and water levels in the downstream receiving environment;
- changes to water quality and sedimentation above and below the dam;
- creation of a physical barrier to dispersal and reproduction; and
- creation of suitable habitats for noxious and/or introduced species.

12.2.1.1. Construction

□ Aquatic flora to be lost within the water storage

The macrophyte communities within the water storage include emergent, submerged and floating species, with community composition varying over time. Macrophytes in the water storage are typically found in pool habitats. Aquatic flora may be lost from the water storage due to:

- direct physical disturbance during construction;
- inundation of macrophytes by deep water during the filling phase;
- sedimentation and turbidity caused by construction activities;
- changes in water quality in the water storage during the filling phase, and
- introduction of weeds and contaminant spills during construction.

Earthworks and construction activities around the dam wall and diversion channel entrance points may result in the direct disturbance and loss of aquatic flora through excavation or burial. Aquatic flora in the water storage is also unlikely to survive, primarily because of inundation.

There is the potential for soil erosion following earthworks and construction activities. This could result in elevated turbidity and sedimentation in adjacent waterways. Without management, sedimentation impacts could be widespread downstream of construction areas, due to the mobile nature of the bed and within-channel features within the Dawson River catchment (Section 14.4). To minimise this risk, current best practice erosion and sediment control measures will be provided in the Construction Environmental Management Plan (EMP; Chapter 29).

During filling, water quality in the dam is likely to be affected by rotting inundated vegetation and high turbidity. This will inhibit the colonisation and growth of macrophytes until conditions have stabilised. Detrimental impacts are likely to be lessened by:

- physical removal of vegetation from within the footprint before filling (Chapter 10); and
- identifying and prioritising areas of erosion in the flood buffer zone surrounding Full Supply Level (FSL), and rehabilitating these areas by replanting and restoring vegetation.

Vehicles and equipment associated with construction could introduce aquatic weed species to the construction area. However, the risk of an introduction of aquatic weed species is considered to be minimal, as the vehicles have limited opportunity to pick up propagules and weed washdown facilities will be used on construction machinery. Wash water will be isolated from waterways.

Hydrocarbons (fuels and lubricants) and cement slurry spilled or leaked into the water storage has the potential to kill macrophytes in the water storage and below the dam wall. Cement slurries are highly caustic and can raise pH above tolerable limits for aquatic plants. Although unlikely, a large-scale hydrocarbon spill would result in the formation of a toxic surface slick with the potential to cause death, poor health and / or reduced reproductive success in aquatic floral (and faunal) communities for a period of months to years.

Risks associated with the spillage of fuels and other contaminants can be substantially reduced, if not eliminated, by conformance with legislation, guidelines and procedures specified in the Description of Project (Chapter 2) and the EMP (Chapter 29).

Conservation importance of the aquatic flora communities to be lost

The aquatic flora to be lost during construction of the dam is comprised of common species with widespread distributions, with none of the species recorded in the study area being endemic to the Dawson sub-catchment or even the wider Fitzroy Basin. Additionally, no species recorded are listed as threatened.

12.2.1.2. Operational

Flora community expected to develop within the water storage

The water storage will provide habitat suitable for a range of macrophyte species. It also represents a significant expansion in the total area of potential habitat. Community composition will be influenced by: the existing macrophyte community of the water storage and upstream areas; water depth, the slope of the edges of the dam and turbidity. Areas of the dam that have a gradually sloping edge will provide better habitat for emergent macrophytes. Generally, all edges of the water storage are expected to provide suitable habitat for establishment of diverse macrophyte communities. Where water depths are sufficiently shallow, open water areas such as around islands, may also be colonised by emergent and attached floating macrophytes. Free-floating macrophytes are likely to colonise the water storage, with their distribution dependent on wind action and water movement.

The species of macrophyte already present within the catchment are likely to colonise the water storage, as each of the species were recorded in pool habitat (particularly that present at Glebe and Gyranda Weirs, in which 77% of species observed during the baseline survey's were recorded) and are considered to be generally tolerant to a range of environmental conditions. The relative abundance of each species in the community may, however, change due to the altered environmental conditions. For example, floating species may be relatively more abundant in the water storage than they are currently, as the dam will moderate flushing effects relative to those that typically wash floating macrophytes downstream in riverine environments.

Effects of variations in water level of the impoundment

Water level fluctuations may restrict the types of macrophytes that colonise the edge of the water storage; and may also encourage the spread of those macrophytes able to survive in deeper water, but that require shallow water to become established. Free-floating unattached forms (such as duckweed and *Azolla sp*.) may become desiccated around the shallow margins of the impoundment if water levels decline rapidly, although it would be expected that some plants would move with the water body. Emergent, fast-growing forms such as rushes, sedges and *Persicaria sp*. may be able to survive draw-down events where there is sufficient rainfall, but are unlikely to survive prolonged inundation after filling events. As in Glebe Weir, *Persicaria* would be expected to rapidly colonise newly exposed wet substrate as dam water levels receded. Submerged and slow-growing emergent forms are less resilient against fluctuating water levels.

Significant inflow of water to the dam may also lead to increased turbidity, which would act synergistically with the impacts of rapid inundation to negatively affect macrophytes in the short-term (though communities would be expected to recover to a similar condition once conditions stabilise).

The FSL of the dam is 183.5 m AHD and the minimum operating level (MOL) is 170.0 m AHD. The dam level is expected to fluctuate between FSL and MOL approximately 94 % of the time. During operation, the water level of the inundation and buffer will fluctuate less rapidly than natural streams. During normal conditions, inflows to the dam generally occur as large flow pulses, with long periods of zero flow between events. There are no apparent baseflow trends or long periods of sustained flow (Figure 12-11). While submerged and emergent macrophytes may die-off during the inflow periods due to rapid inundation, stable communities are expected to recolonise suitable habitat between inflow events (due to the presence of plant fragments and seed banks).

During normal periods (Figure 12-11), water levels:

- can rapidly increase by between 1 and 2 m during inflow events – generally occurring during the wet season; and,
- remain high and unstable for several months after filling due to smaller inflow events;

During wet periods (Figure 12-12), water levels:

- can rapidly increase by between 1 and 2 m during inflow events – with flows occurring during the wet-season as well as significant unseasonal (dry –season) inflows;
- remain high and unstable for several months after filling due to smaller inflow events; and,
- gradually decrease by approximately 1 m over a period of approximately 12 months.

During these wet periods, the unstable or rapidly changing environments are likely to promote the growth of opportunistic species, and may prevent stable macrophyte communities from establishing.

During drought periods (Figure 12-13), water levels:

- water levels can decrease by approximately 8 m over 3 years – as little to no inflows occur; and,
- during the refilling phase, water can increase by as much as 7 m over 6 months (Figure 12-13).

During these drought periods, the steady reduction in water level is predicted to promote the growth of emergent macrophytes as the water body becomes shallower and warmer, and habitat suitable for colonisation becomes available. Also, macrophytes which established at higher water levels will desiccate as the water level drops. During small inflow events, high water in the water storage may cause emergent macrophytes (that colonised during periods of low water level) to die-off. This may produce large amounts of decomposing vegetative matter, releasing nutrients and reducing dissolved oxygen concentrations. These conditions, if severe enough, can cause fish kills and blue-green algal blooms. An increased coverage of floating unattached macrophytes may be expected to occur following a significant drought as a result of the increased water surface area, although (due to their mobile nature) they are also susceptible to high flows. Additionally, free-floating unattached macrophytes are also commonly observed to overtake small, drying waterbodies.

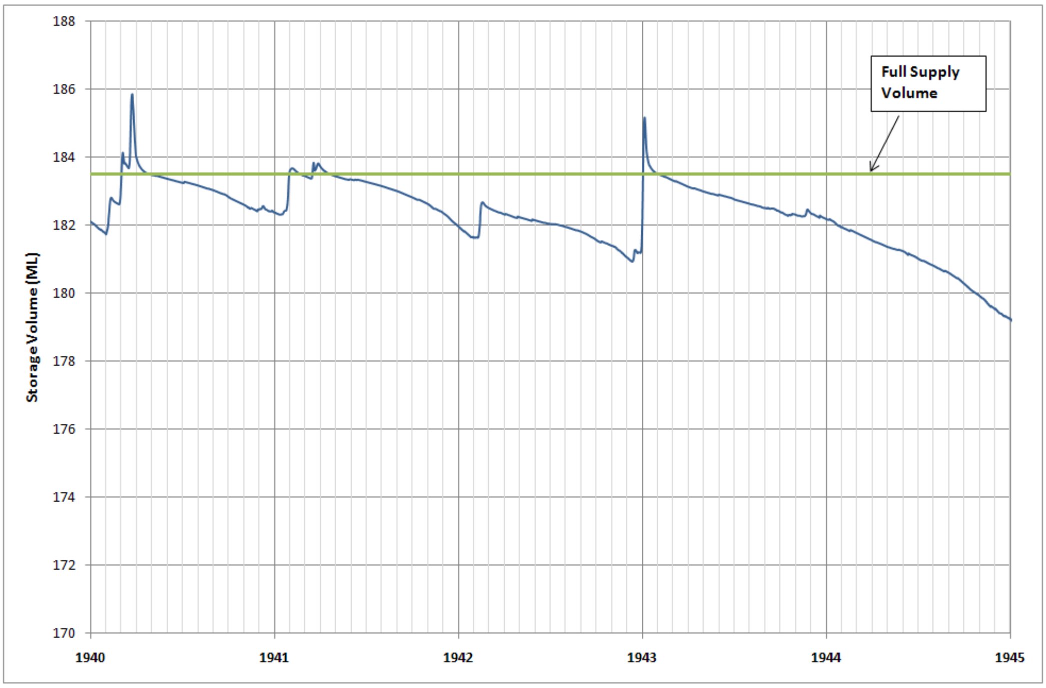

Figure 12-11 Storage level trace plot based on modelled flow data from 1940-45 (normal conditions)

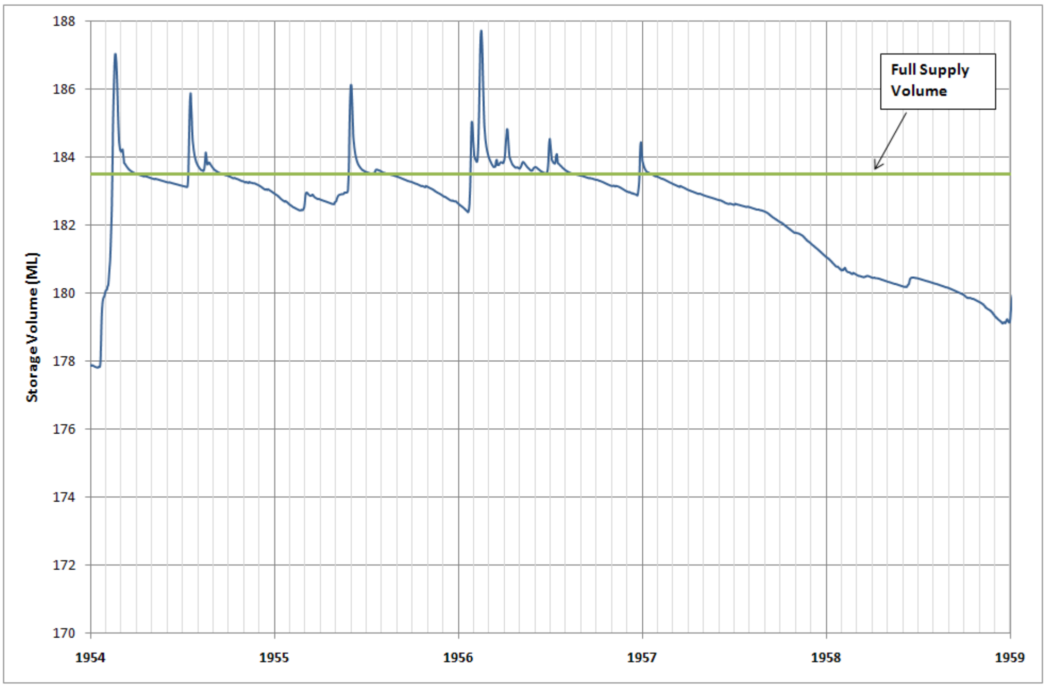

Figure 12-12 Storage level trace plot based on modelled flow data from 1954-59 (wet conditions)

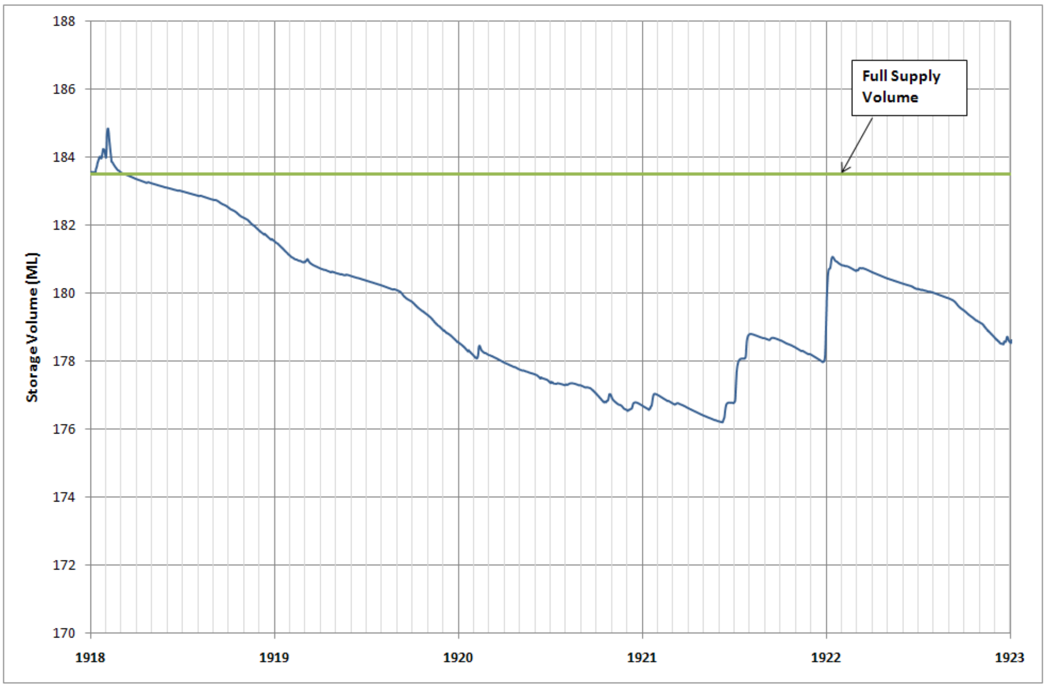

Figure 12-13 Storage Level Trace Plot based on modelled flow data from 1918-23 (dry conditions)

- Potential for blue-green algae outbreaks

Blue-green algal blooms are stimulated by a number of conditions that may arise in the water storage or in downstream waterways as a result of the Project. Blue-green algae grow best in still surface conditions where nutrients are readily available. Blooms tend to form in waterways with high nutrient concentrations, high pH, and are thermally stratified; they can form in waters with varying turbidity levels.

One of the biggest factors contributing to blue-green algal bloom formation is thermal stratification. Thermal stratification creates a density gradient that prevents oxygen created in surface waters from reaching deeper waters. Anoxia and microbial production in deep waters then release nutrients that can stimulate algal blooms. Warm, still surface waters also promote faster growth because they allow the positively buoyant, thermophilic (warm-loving) blue-green algae cells to stay close to well-lit surface waters. Well-mixed waters do not suffer anoxic conditions, are less eutrophied, and have other species of algae (non-harmful) in suspension to compete with the blue-green algae for nutrients and light and mitigate blooms. There is moderate potential for stratification and over-turn events in the dam, particularly during periods of drought, however they are not expected to be a feature of the storage (Chapter 16).

Blue-green algal blooms are not a current feature in other storages of the Fitzroy Basin (Chapter 16) and the risk of blue-green algal blooms in Nathan Dam is considered to be low to be medium. The surface area of the dam pondage is large, and the dam will act to trap nutrients bound in sediment from upstream or from rotting vegetation matter, which could accumulate over time (though this accumulation is not expected to be substantial given the short residence times in the dam) (Chapter 16). SunWater will implement an appropriate monitoring program for cyanobacteria similar to other storages in Central Queensland, and signage will be provided at each recreation facility indicating the current hazard level associated with monitoring results.

Blooms in rivers are often stimulated by periods of reduced flow, particularly after pulses of nutrients have been introduced. Flow releases from the dam are expected to maintain low flows in accordance with their natural distribution, and as such the likelihood and severity of blue green algae blooms is not expected to increase downstream of the dam compared with the existing situation.

Changes to flow regime and associated factors downstream

Immediately downstream of the dam there is likely to be clear-water scouring when large volumes and high velocities of relatively sediment-free water are spilled or released. Scouring and erosion may reduce the cover of macrophytes close to the dam wall; however, the resulting sediment deposition is unlikely to affect macrophytes further downstream, as there is likely to be an overall reduction in sediment deposition in these reaches, due to the trapping of sediments behind the dam wall.

Baseflows provided in the operating strategy will provide a stable habitat for macrophyte colonisation downstream of the dam, which may result in the development of a stable and abundant community during the dry season. A reduction in moderate flow to reaches downstream of the dam may result in a decrease in available habitat compared with the current situation (due to lower water levels) and decreased flushing, but will likely result in a more stable habitat for macrophyte communities for most of the year. However, there will be minimal impact to high flow events and larger flushing events that result in the seasonal loss of some macrophytes (e.g. by sweeping them downstream for example) will still occur (Chapter 14). Sudden changes in discharge rates should be avoided, to minimise the occurrence of rapid changes in water depth below the dam as far as practical.

The Critical Water Supply Strategy will result in prioritisation of high priority allocations when the volume in storage falls below a specified level (Chapter 14). At these times the natural impacts of drought downstream may be reduced due to the provision of water downstream for high priority users, and thus the presence of low levels of water in the system at times when there would usually be little to none. The result of the increased water in the systems during times of drought is an increase in the amount of habitat for all macrophytes.

There will be no discernable impacts to flow in the Fitzroy River or downstream, and the dam is not expected to impact on water quality, the location of the salt wedge or sediment input to the Fitzroy Estuary (Chapter 14 and Chapter 16); therefore no significant impacts on estuarine and marine flora, including in the GBRWHA and the Shoalwater and Corio Bays Area Ramsar site, are expected.

Impacts of barriers to aquatic flora reproduction

The dispersal of macrophyte seeds and propagules is likely to occur predominantly during periods of significant flow resulting in over-topping of the dam and / or releases downstream. The seeds of many emergent macrophytes can be dispersed by wind as well as water and animal vectors. The dam is therefore unlikely to be a significant reproductive barrier to macrophytes.

Potential for introduction of exotic, non-indigenous and noxious plants

Large open water habitat, such as the water storage, is favourable habitat for exotic floating waterweeds such as *Salvinia molesta* and *Eichhornia crassipes* (Water Hyacinth). Water hyacinth disperses using water-borne seeds, and *S. molesta* can only disperse through vegetative fragmentation. Although these species were not recorded within the

Project area, they are present within the lower reaches of the Fitzroy Basin, and could be introduced to the water storage. The risk of an accidental introduction from further upstream is considered small, as no record of these species in the Dawson sub-catchment has been found. It is unlikely that the macrophyte community will be dominated by exotic species as no species of exotic macrophyte have been recorded within the dam and surrounds study area. However, the presence of other introduced macrophytes at other locations within the footprint cannot be excluded, and seeds may be introduced from elsewhere by extreme weather events or by attachment to waterfowl, boats or fishing gear. The risk of colonisation of the dam by exotic species can be reduced by:

- regular monitoring for exotic weed species; and,
- implementing appropriate physical, mechanical or chemical control if aquatic weed species are detected.

Additionally, SunWater will liaise with DERM regarding the provision of weed and pest transfer signage at each recreational facility.

12.2.2. Pipeline

12.2.2.1. Construction

Construction of the pipeline has the potential to impact aquatic flora through:

- the direct loss of a very small proportion of aquatic flora at waterway crossings;
- changes to water quality, erosion and sedimentation and flow regimes surrounding pipeline crossings;
- fuel and oil spills; and
- the translocation of noxious and/or introduced species..

The overall potential impact of placement of the pipeline on aquatic floral communities is considered low, as crossings constitute a relatively small total area of any one watercourse, existing macrophyte cover is scarce, and much of the habitat consists of dry areas with occasional intermittent or perennial pools.

The potential for clearing to result in erosion is affected by the soil characteristics, the slope of the terrain and the state of flow in the watercourse. At locations where the pipeline and access track are the only infrastructure crossings, macrophyte communities are likely to be impacted by disturbance to the bed and banks, where waterways are relatively intact and otherwise un-impacted (e.g. where cattle have not damaged banks).

Where the pipeline is located above ground, it will cross the very small and ephemeral creeks that occur in those areas at a level above that of the banks so it will not affect flow regimes. Where the pipeline is buried it will have no effect on the flow regime.

After pipeline crossings have been constructed, the newly formed bed and banks could erode given the high flows that occur in the region during some wet seasons. However, as best-practice environmental controls will be used at all waterway crossings of the pipeline, it is likely that any bed and bank instability would be localised to crossing points, and that impacts on aquatic flora from the placement of the pipeline would be minimal. The design of the Project, the proposed construction standards and the environmental management controls have already taken into account many of the potential impacts.

Mitigation measures include:

- the pipeline is mainly buried;
- construction times at crossings will be minimised;
- crossings located in areas that result in minimal disturbance to wooded areas;
- existing road or other infrastructure corridors will largely be followed;
- construction will be undertaken during the dry season (minimising the likelihood of rainfall and runoff carrying sediment and other pollutants into the creeks);
- stormwater, erosion and sediment control measures will be implemented;
- sensitive or problem soil / geotechnical areas will be avoided;
- pipeline corridors and the banks of watercourse crossings will be re-contoured, revegetated, stabilised where need be and otherwise rehabilitated;
- schedulers will remain vigilant about flood and severe weather warnings on a daily and longer-term basis; and
- water quality monitoring will be undertaken where necessary to inform adaptive management.

Where the watercourse contains water, to minimise impacts to aquatic flora, the isolation should be designed such that:

- measures are taken to prevent erosion surrounding the outlet of a bypass/dewatering pump or flume. This can be done by dissipating the energy of the released water using devices that include, but are not limited to, tarps, flip buckets, plates, and appropriately sized granular materials (AE, 2001);
- if flowing water is present, downstream flow is maintained by maintaining an open channel or using pumps with a substantial discharge capacity that exceeds expected flows;
- sediment-laden water is pumped into sumps; and,
- operation of the clean-water pump to sustain partial flow below the downstream dams is continued until the downstream dam is removed.

Vehicles involved in the construction and maintenance of the pipeline could impact waterways by spilling fuel and oil into waterways. Risks associated with the spillage of fuels and other contaminants can be substantially reduced, if not eliminated, by conformance with legislation, guidelines and procedures specified in the EMP (Chapter 29).

The risk of an introduction of aquatic weed species is considered to be minimal, as construction will be during the dry season, weed washdown facilities will be used on construction machinery and few aquatic weeds exist in the local environment. Wash water should be isolated from waterways.

Impacts of construction of the pipeline and associated access tracks to aquatic flora will be short-term and minimal where the bed and banks are rehabilitated immediately after construction. Rehabilitation is expected to include methods such as compaction, armouring if required, ensuring sufficient drainage and replanting with grasses (trees cannot be planted on the access tracks or over the pipeline). It is anticipated aquatic flora will recover in suitable habitat quickly after construction activities have ceased.

12.2.2.2. Operation

Operation of the pipeline could result in aquatic flora being entrained into the pipeline. This can be minimised through a design that minimises suction, and that incorporates screens to restrict plants entering the pipeline.

Operation of the pipeline has the potential to translocate aquatic flora. That is, plants, fragments or seeds may be drawn into the pipeline and transferred along its length to the receiving environment. However, the likelihood of successful transfer of noxious aquatic flora is considered to be negligible, as no exotic species were recorded in the Project area, and the dam is expected to be colonised by native species that are typical of the Dawson and Condamine catchments. Further, most of the water will enter coal mine washing processes, be used as cooling water in power stations or be treated to urban supply standards so any plants transferred to end users are unlikely to survive or reach the natural environment.

During operation, sections of the pipeline may require scouring by release of water from dedicated “scour valves”. The water will contain sediment and may contain some biofilm (Chapter 2). However, the volume of water released will be relatively small and the biofilm will not survive at the discharge locations because it normally grows in dark wet locations (Chapter 2) and as such the impacts are expected to be localised and minimal. The impacts will be further reduced where the water released is directed away from watercourses. Any weeds which germinate at discharge points will be controlled in accordance with the weed management strategy outlined in the EMP.

12.2.3. Associated infrastructure

Construction of the associated infrastructure has the potential to impact surrounding aquatic flora through:

- the direct loss of a small proportion of aquatic flora at waterway crossings;
- changes to water quality, erosion and sedimentation surrounding road crossings;
- the translocation of noxious and/or introduced species; and
- fuel and oil spills.

These impacts are discussed in detail in Sections 12.2.1 and 12.2.2. Mitigation measures for associated infrastructure are consistent with those presented for the dam and pipeline in Sections 12.2.1 and 12.2.2.

12.3. Impact assessment and residual risks

The methodology used for risk assessment and management is discussed in Section 1.8.

This section assesses the risks relevant to aquatic flora and summarises the mitigation measures proposed to minimise those risks. Where significant residual risks remain after mitigation, offsets are described where practicable.

Risks associated with construction and operation phases of the Project are presented in Table 12-6 to Table 12-8 respectively. The definition of consequence and likelihood is presented in Chapter 26. The risk assessment is of the Project as described in Chapter 2, in which SunWater has already incorporated a range of risk reduction and mitigation measures.

Based on this assessment, the following conclusions can be made:

- While there will be a short-term loss of aquatic flora and habitat within the proposed inundation and buffer due to inundation, overall, this loss is expected to be offset upon completion of the dam through the creation of new larger areas of habitat;
- mitigation measures to minimise this loss will reduce the risk to Medium (as low as reasonably practicable);
- feasible mitigation actions are described in Sections 12.2.1, 12.2.2 and 12.2.3, and these will be reflected in the EMP and/or the Proponent Commitments; and
- based on this risk assessment, the impacts relevant to aquatic flora can be effectively managed and the residual risks are acceptable.

Table 12-6 Risk assessment – dam and surrounds - construction

Hazards	Factors	Impacts	Project Description Controls & Standard Industry Practice	Risk with controls			Additional Mitigation Measures	Mitigation effectiveness	Residual risk		
				C	L	Current risk			C	L	Mitigated risk
Reduction in diversity and abundance of aquatic flora communities and aquatic flora habitat within the water storage	Inundation of the inundation and buffer	Impacts on the localised species inhabiting the water storage. Large areas of aquatic flora habitat remain within the Project area and the species are well represented within catchment. Upon completion of the Project, large areas (at least as large as those lost) of aquatic flora habitat will be created.		Minor	Absolute	Medium			Minor	Absolute	Medium

Table 12-7 Risk assessment – dam and surrounds - operation

Hazards	Factors	Impacts	Project Description Controls & Standard Industry Practice	Risk with controls			Additional Mitigation Measures	Mitigation effectiveness	Residual risk		
				C	L	Current risk			C	L	Mitigated risk
Change in aquatic flora community composition in the water storage.	Fluctuating water levels cause change in available habitat	Reduced diversity of aquatic flora communities. The species present in the study area are generally resilient and are likely to colonise the water storage, with a slight shift in community composition.		Minor	Possible	Medium			Minor	Possible	Medium
Blue-green algae bloom in the water storage.	Higher risk in dry season.	Temporary reduction in environmental values (primarily impacting upon consumptive and aesthetic values).	Vegetation will be removed from the water storage to minimise the input of nutrients to the dam. Regular monitoring will alert of potential outbreak Signage will be posted alerting recreational users of potential hazard	Minor	Possible	Medium			Minor	Possible	Medium
Blue-green algae bloom downstream of the water storage.	Higher risk during dry season.	Temporary reduction in environmental values.	SunWater is to implement a routine water quality monitoring program to monitor blue-green algae levels. The use of a multi-level offtake will ensure that only water of appropriate quality will be released downstream. No water will be released downstream in the event of an algal bloom classified as a high risk hazard.	Minor	Unlikely	Low			Minor	Unlikely	Low

Hazards	Factors	Impacts	Project Description Controls & Standard Industry Practice	Risk with controls			Additional Mitigation Measures	Mitigation effectiveness	Residual risk		
				C	L	Current risk			C	L	Mitigated risk
Impacts to aquatic flora listed as threatened.	None of the aquatic flora recorded or likely to occur in the study area is listed as threatened.			Insignificant	Rare	Low			Insignifica nt	Rare	Low
Potential introduction of exotic aquatic flora.	The water storage will provide suitable habitat for exotic species. No exotic species have been recorded within the dam and surrounds project area Seeds may be introduced into the catchment by extreme weather events or by attachment to water-fowl, boats or fishing gear.	Potential localised loss of native species diversity due to competition from exotic species.	Wash down of construction equipment in the dry season. Educational signage will be posted at boat ramps and other recreational areas to aid in the prevention of accidental transfer	Moderate	Unlikely	Medium			Moderate	Unlikely	Medium

Table 12-8 Risk Assessment – Pipeline

Hazards	Factors	Impacts	Project Description Controls & Standard Industry Practice	Risk with Controls			Additional Mitigation Measures	Mitigation Effectiveness	Residual Risk		
				C	L	Current Risk			C	L	Mitigated Risk
Colonisation of exotic aquatic flora.	Two exotic macrophytes were recorded within the pipeline study route.	Potential localised loss of native species diversity due to competition from exotic species.	Wash down of construction equipment.	Minor	Rare	Low			Minor	Rare	Low

12.4. Cumulative impacts

There will be a loss of the existing aquatic flora and habitat within the storage area due to inundation. Overall, however, water storages create a greater surface area for potential colonisation by aquatic flora. Geomorphic diversity within the Dawson River will change as further riverine habitat is replaced by water storage habitat. In the case of Nathan Dam, a significant proportion (40%) of the river within the inundation and buffer is already pool habitat as a result of Glebe Weir. Further, very little riffle, run or glide habitat was encountered in field surveys and no macrophytes were noted as growing in these habitats, therefore potential cumulative impacts are considered minimal.

There are no other known water related projects which would impact on aquatic flora within the Dawson River. Other construction related projects could impact on water quality but those presently known are either on very small tributaries or are in the Condamine catchment. The WRP environmental flow objectives are met under the Cumulative Impacts scenario in most cases, and where they are not met initially, operational strategies will be revised to ensure that they are met (at least in the case of mandatory flow objectives). Adverse impacts on water quality and flows in the Fitzroy River and Estuary are not expected (Chapter 16). Therefore, no significant impacts to the aquatic flora of the Fitzroy River and Estuary, or Keppel Bay, are expected due to the cumulative impacts of proposed water infrastructure.

In summary, due to the highly regulated nature of the Dawson River (including the existing Glebe Weir) and the lack of relevant other local projects, the cumulative impact upon the Dawson sub-catchment and the wider Fitzroy Basin, associated specifically with Nathan Dam is considered to be low.

12.5. Summary

This section has assessed the potential impact of the Project on aquatic flora within the Dawson River Catchment and greater Fitzroy Basin. This assessment showed that:

- the aquatic flora communities inhabiting the dam and surrounds study area are typical of that found throughout the wider Fitzroy Basin and comprised primarily of common and widespread taxa, with no taxa unique to the Dawson sub-catchment or the wider Fitzroy Basin recorded.
- macrophyte richness and coverage was highest at the existing Glebe Weir.
- aquatic flora will be lost within the water storage during construction and filling. Once conditions stabilise, the dam is expected to support diverse communities of aquatic flora similar in diversity and composition to those observed prior to construction.
- baseflows provided in the operations strategy will provide a stable habitat for macrophyte colonisation downstream of the dam, which may result in the development of a stable and abundant community during the dry season. A reduction in moderate flow to reaches downstream of the dam may result in a decrease in available habitat compared with the current situation (due to lower water levels), but will likely result in a more stable habitat for macrophyte communities for most of the year as a result of decreased flushing. There will, however, be minimal impact to high flow events or larger flushing events that result in the seasonal loss of some macrophytes.
- *Myriophyllum artesium* is known to inhabit a mound spring on Sandy Creek (a small tributary of Cockatoo Creek) approximately 20 km upstream (east) of the water storage and 12 km from the pipeline corridor, and is nationally

listed as 'endangered' under the EPBC Act and in Queensland under the NC Act. This species is not located within the dam and Surrounds or pipeline study areas and therefore the Project will not impact on this species.

- two exotic macrophyte species (*Alternantherea philoxeroides* (Alligator Weed) *and Urochola* (Paragrass)) were recorded within the pipeline study area, however, the risks of transfer, or introduction of new exotic species, are considered to be low.
- although blue-green algae outbreaks may occur within the reservoir, such events are not a feature of other storages in the Fitzroy Basin and the risk of occurrence within the dam is considered to be medium (as low as is reasonably practical). SunWater will implement an appropriate monitoring program for cyanobacteria similar to other storages in Central Queensland.
- construction of the pipeline has the potential to result in a very small and temporary loss of aquatic flora, either due to direct disturbance, or impacts to water quality. However, the native communities are expected to recover after construction.
- these impacts will be effectively managed and mitigated through EMP's for erosion and sediment control, dam operations, and rehabilitation of both temporary and permanent creek crossings; and implementation of best-practice fuel-handling and storage in accordance with Australian Standard AS 1940 (2004).
- aquatic flora in the Fitzroy Basin is currently impacted by existing impoundments, flow regulation, and non-water resource developments.
- where proposed water infrastructure in the Fitzroy Basin (i.e. Connors River Dam, Nathan Dam and Lower Fitzroy Weirs) is operated to meet the conditions of the WRP and ROP, the cumulative impacts of this water infrastructure to aquatic flora are expected to be minimal and acceptable.
- as no flow, water quality or sediment regime changes are predicted in the estuary or near-shore environments, no impacts are predicted on flora in those locations (including in the GBR and the Shoalwater and Corio Bays Area Ramsar sites).
- based on this risk assessment, the impacts relevant to aquatic fauna can be effectively managed and the residual risks are acceptable.