GOVERNMENT OF
WESTERN AUSTRALIA

Environmental values and pressures for the Greater Brixton Street Wetlands on the Swan Coastal Plain

Advice in accordance with section 16(j) of the *Environmental Protection Act 1986*

Environmental Protection Authority

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The Greater Brixton Street Wetlands (GBSW) are one of the most important wetlands on the Swan Coastal Plain with outstanding biodiversity attributed to the unique geological, geomorphic and hydrological characteristics. The Environmental Protection Authority (EPA) recognises the environmental significance of the GBSW and has prepared this advice to examine the environmental values, and the existing and potential pressures on those values. The EPA makes recommendations for enhancing the environmental protection of the GBSW and outlines expectations for proposals and planning schemes that have the potential to impact environmental values.

The advice, provided under section 16(j) of the *Environmental Protection Act 1986*, will benefit proponents, decision makers, regulators and the public, and will be considered during the environmental impact assessment of proposals and planning schemes by the EPA.

The EPA has identified that a high level of protection and coordinated management is critical for the GBSW. There are opportunities to expand the Class A nature reserve within the GBSW and its buffers to create a more contiguous reserve system. Improvements to the coordination and management through a shared and expanded partnership involving all relevant groups including, Traditional Owners, would allow for holistic management of the entire GBSW area.

The EPA expects future activities and development to be compatible with the protection of the environmental values of the GBSW and considers these are not readily replaceable or interchangeable with offsets in other areas. Direct and indirect impacts to the environmental values of the GBSW should be avoided to the greatest extent possible and practicable.

Proponents will need to demonstrate best practice environmental management with adaptability in design and approach to protect the environmental values and supporting ecological and hydrological processes of the GBSW. Appropriate and site-specific investigations should be undertaken both in a local and regional context, supported by the best available scientific evidence. This includes the consideration of appropriate buffers, ecological and hydrological connectivity, stormwater management and drainage, impacts on hydrology and water quality, and the potential for direct, indirect and cumulative impacts.

The EPA has found that there are multiple threats to the significant environmental values of the GBSW. There is evidence of impacts to environmental values from existing and historical activities and concern about further incremental and cumulative impacts from potential future development. Continued piecemeal development without enhancing the protection of the GBSW may result in further degradation of the area's unique and significant environmental values.

1 Introduction

The Greater Brixton Street Wetlands (GBSW) are one of the most important and highly diverse wetland areas remaining on the Swan Coastal Plain (SCP). The high conservation values and outstanding botanical significance of the GBSW have long been recognised, including the significance and scarcity of the ecosystem types and botanical diversity represented (EPA 1991, EPA 1992, EPA 2007, Dhakal 2016).

There is a variety of land tenure and interests in the GBSW area, with inconsistent levels of protection and management. Historical development, along with contemporary activities, have resulted in impacts to the significant environmental values. It is also apparent that there is growing pressure on the wetlands from proposed development in the surrounding area.

The Environmental Protection Authority (EPA) has developed this advice under section 16(j) of the *Environmental Protection Act 1986* (EP Act) recognising the significance of these wetlands and the potential risks to environmental values from existing and emerging pressures. The advice considers:

- the environmental values of the GBSW, the existing and potential pressures on those values
- recommendations for enhancing the environmental protection of the GBSW
- expectations for proponents with proposals that have the potential to impact the environmental values.

The advice will be of benefit to proponents, decision makers, regulators and the public, and will be considered during the environmental impact assessment of proposals and planning schemes by the EPA.

1.1 Overview of the Greater Brixton Street Wetlands

The GBSW are located on Whadjuk Noongar Country within the Yule Brook Catchment on the SCP (see Figure 1). The wetlands are located about 20 km south of Perth, covering approximately 215 hectares. They are situated within the local government areas of the cities of Gosnells and Kalamunda. The extent of the GBSW as described in this report is the combined boundaries of *A Directory of Important Wetlands in Australia* (DIWA) (Brixton Street Swamps) and Bush Forever Site 387, as shown in Figure 1.

The GBSW are recognised as one of the most important wetlands remaining on the SCP, characterised by outstanding botanical diversity, with over 650 plant species recorded, including locally restricted species and distinct vegetation communities supporting conservation significant fauna. GBSW's unique biodiversity is attributed to the specialised plant adaptations to the complex soils, chemistry and hydrology of the site.

The wetlands are located at the base of the Darling Scarp and are supported by Crystal Brook and Yule Brook and other surface and sub-surface water inputs. The area supports naturally vegetated wetlands that are rare or no longer exist elsewhere, and it is one of the largest consolidated wetland areas of high conservation value on the SCP. The significance of the GSBW is amplified by the poor state of wetlands across the SCP. The majority of wetlands on the SCP are characterised as largely degraded, with less than 25 per cent of wetlands categorised for conservation (DBCA 2017).

The GBSW area is of international, national, and regional environmental significance and is listed on the *Directory of Important Wetlands in Australia* (Environment Australia 2001) and the Register of the National Estate (DCCEEW 2022; EPA 2015).

Additional recognition for the significance of the GBSW includes:

- a recommendation for enhanced protection in the EPA's conservation reserves report for the Darling System (System Six) (EPA 1983)
- listing of Bush Forever (BF) Sites 387 and 422 (Government of Western Australia 2000)
- numerous conservation category and resource enhancement wetlands as mapped in the Geomorphic Wetlands of the Swan Coastal Plain dataset.

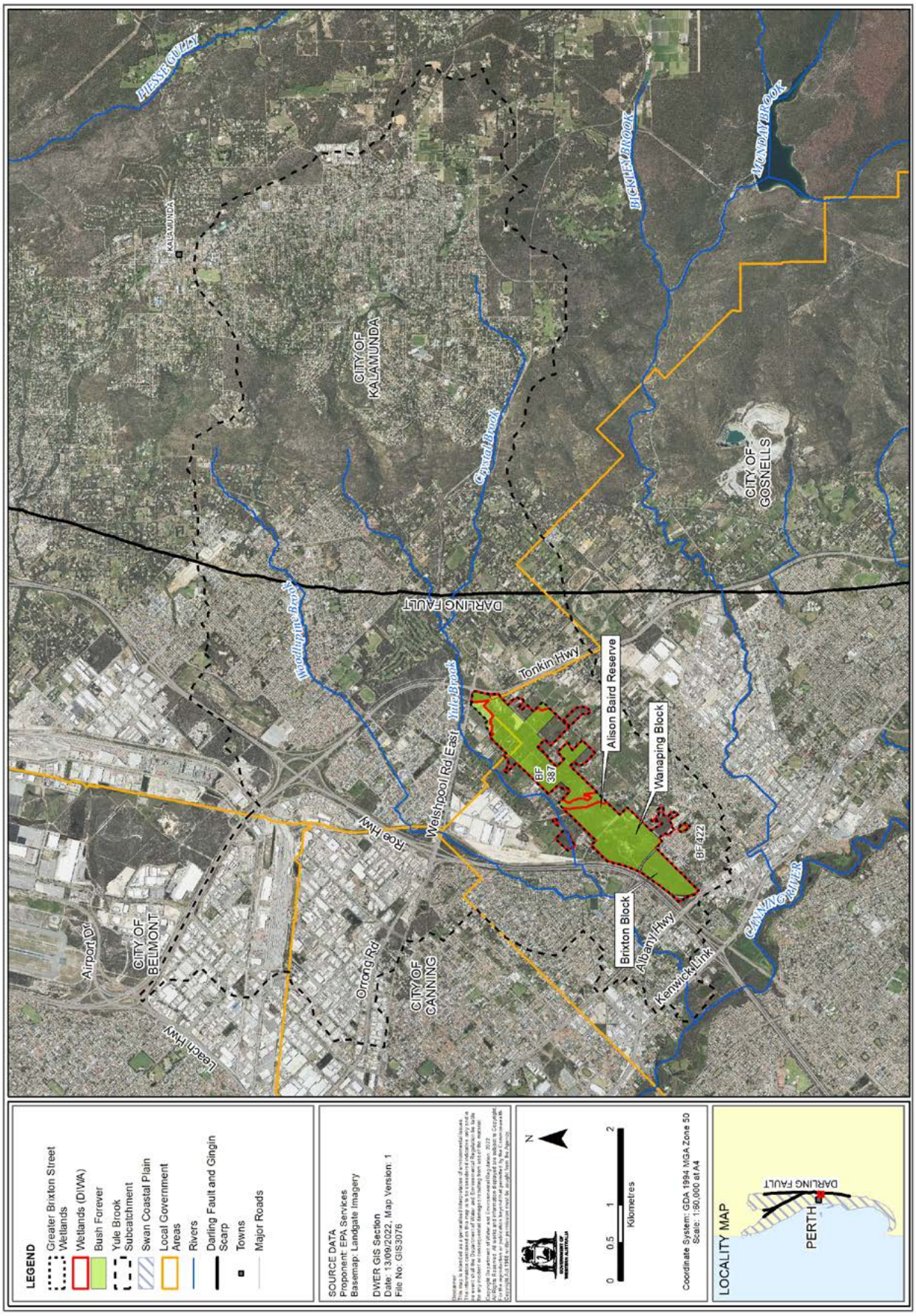

Figure 1: Location of Greater Brixton Street Wetlands within the Yule Brook Catchment and related features

1.2 Approach of the EPA advice

The approach used to develop the EPA advice included:

- evaluation of environmental values and pressures from public databases and information, desktop studies and a review of literature
- describing the environmental values, including any threatened or conservation significant species/ habitats or communities listed under state, national or international frameworks
- consideration of the existing and potential pressures on the GBSW to inform advice and recommendations to improve environmental outcomes for the future of the GBSW area.

1.3 Relevant legislation, land tenure and management

The current land tenure for the GBSW is a mix of government and privately-owned land, with varying levels of legislative responsibilities, protection and management (see Table 1).

Several lots within the GBSW are classified as a Class A nature reserve under the *Land Administration Act 1997* due to their high conservation value. These reserves are collectively known as the Brixton Street Nature Reserve and include the Brixton Block, Wanaping Block and other unnamed lots shown in Figure 2. The land is vested in the Conservation and Parks Commission and managed by the Department of Biodiversity, Conservation and Attractions (DBCA).

The Western Australian Planning Commission (WAPC) has been progressively purchasing some of the private land within the GBSW and rezoning these lots to Parks and Recreation under the Metropolitan Region Scheme for future inclusion in the Brixton Street Nature Reserve.

Several lots remain in private ownership. Some private land is conservation covenanted, with specific land manager responsibilities to maintain the conservation values of the land (e.g. Rehoboth Christian College is on land with native vegetation that must be managed and protected in perpetuity under a Conservation Covenant). Alison Baird Reserve is owned and managed by the University of Western Australia (UWA) as a research and education site, with restricted access. Other private lots are owned by various landowners.

Some parts of the GBSW have been fragmented from the core area, such as BF 422 and other unnamed DIWA areas (see Figure 2). Current parties involved in the management of the GBSW include:

- DBCA (Brixton Street Class A Nature Reserve)
- Department of Planning, Lands and Heritage (DPLH) (BF 387)
- City of Gosnells (BF 422, roads and road verges)
- City of Kalamunda (road and road verges)
- Friends of the Brixton Street Wetlands
- The University of Western Australia (Alison Baird Reserve)
- Department of Education (East Kenwick Primary School)
- Public Transport Authority (railway)
- Rehoboth Christian College
- Main Roads Western Australia (BF 387)
- various private landowners.

Table 1: Legislation and roles of government agencies and organisations

Government agencies	Role in Greater Brixton Street Wetlands	Key legislation
Australian Government	Protection of matters of national environmental significance, including threatened species and ecological communities and migratory species.	*Environment Protection and Biodiversity Conservation Act 1999*
Department of Biodiversity, Conservation and Attractions (DBCA)	Promote biodiversity and conservation through sustainable management of WA species, ecosystems, lands, and attractions.	*Biodiversity Conservation Act 2016* *Conservation and Land Management Act 1984* *Swan and Canning Rivers Management Act 2006* *Botanic Gardens and Parks Authority Act 1998*
Department of Planning, Lands and Heritage (DPLH)	Land use planning, land administration and heritage.	*Planning and Development Act 2005* *Land Administration Act 1997* *Heritage Act 2018* *Aboriginal Heritage Act 1972* *Aboriginal Cultural Heritage Act 2021*
Department of Water and Environmental Regulation (DWER)	Manage and regulate the state's environment and water resources.	*Water Agencies (Powers) Act 1984* *Rights in Water and Irrigation Act 1914* *Environmental Protection Act 1986* *Contaminated Sites Act 2003* *Litter Act 1979* *Waste Avoidance and Resource Recovery Act 2007*
Environmental Protection Authority (EPA)	Conduct environmental impact assessments and provide strategic advice to the Minister for Environment and the public.	*Environmental Protection Act 1986*
City of Gosnells	Local government authorities. Planning decisions and local laws.	*Local Government Act 1995* *Planning and Development Act 2005*
City of Kalamunda		

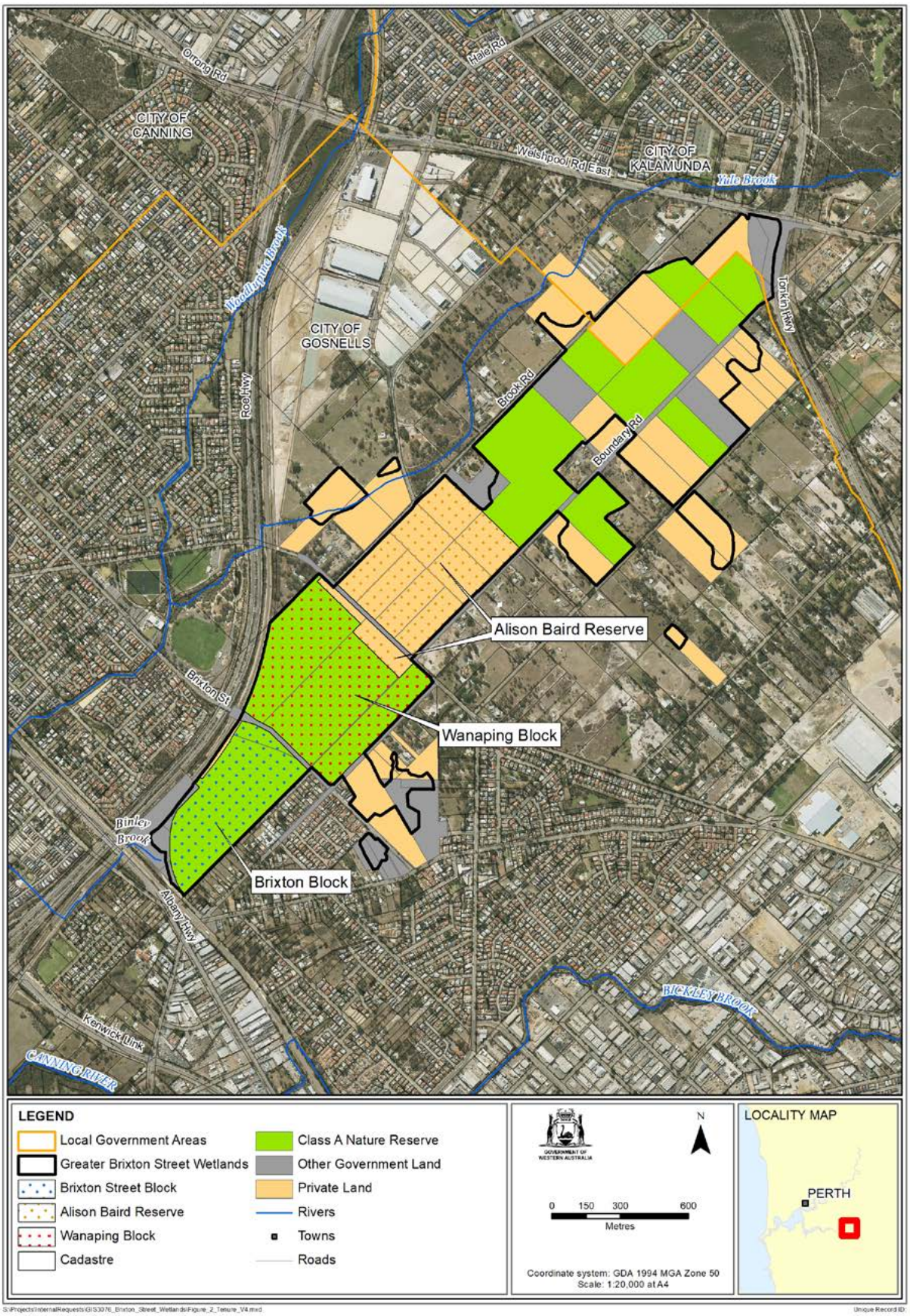

Figure 2: Land tenure of the Greater Brixton Street Wetlands

2 Key values and pressures

Values are outlined for the key environmental factors relevant to the protection and management of the GBSW, in accordance with the EP Act and the EPA's framework of environmental factors and objectives (EPA 2021a). Pressures are discussed in the context of historical activities and existing and potential pressures from proposed activities and development. For the GBSW area, the EPA recognises that the pressure may originate or occur outside of the wetlands or catchment boundary.

2.1 Land

The GBSW are within the SCP Bioregion and SCP 2 Subregion (Thackway & Cresswell 1995). The SCP is characterised by low-lying coastal plains, often swampy with sandhills, and has a warm Mediterranean climate dominated by winter precipitation (Beard 1990). The GBSW area is primarily situated on the heavy soils of the low-lying Pinjarra Plains at the base of the Darling Scarp. The GBSW area has undergone significant modification since European settlement (Keighery & Trudgen 1992), primarily for agriculture and urban development.

Flora and vegetation

The SCP is characterised by both a high plant species diversity at the local scale and a high species turnover between vegetation communities (Lambers *et al.* 2014). The GBSW area exhibits botanical species richness and the diverse vegetation communities of the SCP, driven by both variety of soils and complex hydrology (Lambers *et al.* 2019).

There have been numerous flora and vegetation surveys in the GBSW area and surrounding SCP; however, systematic surveying and a consolidated vegetation analysis remains a knowledge gap for the GBSW area. Consolidated flora surveys within the GBSW area (including BF 387) recorded a species richness of over 650 native taxa from 80 families and characterised 13 vegetation communities (Tauss *et al.* 2019). The GBSW is highly significant for the diversity and conservation of carnivorous plants species with 26 species identified (Cross 2019). It also contains a wide diversity of insect pollinated plants that attract nectar and/or pollen-seeking insect species, which may be important to support the local insect communities (Phillips 2019).

The diverse and conservation significant flora and vegetation within the GBSW area have been recognised at the state and national level as of outstanding conservation value (EPA 1983; Government of Western Australia 2000). DBCA's Threatened and Priority Flora database (2022), covering the GBSW area (with 5 km buffer) recorded 77 conservation significant species (20 threatened species and 57 priority species under the BC Act). Many of the conservation significant species have specific habitat requirements and small areas of occupancy, suggesting that the GBSW is an important species refuge. Three critically endangered species, the Spider net grevillea (*Grevillea thelemanniana)*, the Swamp starflower (*Calytrix breviseta* subsp. *breviseta*) and the Pyramid mulla mulla (*Ptilotus pyramidatus*), have their geographic distributions substantially restricted to the GBSW area. The geographic extent of these conservation significant species ranges from less than 0.01 km^2 (DOTE 2016) to 10 km^2 (DPAW 2015b).

The GBSW area is characterised by highly diverse vegetation communities (Keighery & Trudgen 1992; Marshall 2000; Tauss *et al.* 2019), including Marri (*Corymbia calophylla*) woodlands on the uplands; *Viminaria juncea* tall shrublands of the seasonally inundated flats; *Melaleuca* spp. dominated deeper pools of the clay pans; *Chaetanthus aristatus* dominated dense rushland; and the complex communities of the Pinjarra Plain clays and edge of the Darling Scarp. The dominant vegetation complex mapped for the area, the Guildford Vegetation Complex, has been extensively cleared on the SCP (Heddle *et al.* 1990). It is described as a mixture of open forest to tall open forest of Marri, Wandoo (*Eucalyptus wandoo*) and Jarrah (*E. marginata*), with minor components including Flooded gum (*E. rudis*) and Paperbark (*Melaleuca rhaphiophylla*).

Most of the remnant vegetation of the GBSW is considered of conservation significance under the BC Act (i.e. Threatened or Priority Ecological Communities – TEC and PEC) and the *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act) (i.e. Endangered or Critically Endangered TECs). The EPBC-listed critically endangered ecological community 'Clay Pans of the Swan Coastal Plain', which encompasses multiple BC Act conservation significant ecological communities primarily occurring on the SCP (DPAW 2015a; DSEWPC 2012), typifies the unique botanical diversity and intrinsic ecological and hydrological connectivity of the GBSW area and SCP wetlands.

Terrestrial fauna

The GBSW are part of a regional habitat linkage between the Jarrah Forest and the SCP Bioregions and acts as a transitional zone of fauna species across the foothills and adjacent scarp. The wetlands provide a habitat for waterbirds and frogs during autumn and winter months when they fill with water.

Over 70 species of vertebrate fauna have been recorded or are likely to occur in the GBSW based on local records and observational data. Historical loss, fragmentation and disturbance of habitat (including from fires) have likely reduced the diversity of species present, particularly mammal, reptile and invertebrate species. A 5 km buffer desktop analysis of the DBCA's Threatened and Priority Fauna and Atlas of Living Australia databases (2022) found 319 vertebrate species have the potential to occur, including vagrant bird species and those that occur in habitats along the fringing Darling Scarp. Detailed systematic fauna surveys or consolidated analyses of habitats have not been undertaken in the GBSW area.

Conservation significant vertebrate fauna recorded in the GBSW area includes the vulnerable forest red-tailed black cockatoo (*Calyptorhynchus banksii naso*) and endangered Carnaby's black cockatoo (*Calyptorhynchus latirostris*) (EPBC Act; BC Act), and the quenda (*Isoodon fusciventer*) (Priority 4). Notable fauna present include large monitors, microbats, raptorial birds and small bush birds that are now restricted to remnant vegetation on the SCP (Government of WA 2000). Frog species include burrowing species such as the crawling toadlet (*Pseudiphryne guentheri*) and moaning frog (*Heleioporus eyrei*), as well as ground-dwelling species the bleating froglet (*Crinia pseudinsignifera*) and quacking frog (*Crinia georgiana*) that are found around moist areas and damplands.

The terrestrial invertebrate fauna values are not well-understood due to a lack of information and survey. Specimens of two endemic invertebrate species have been collected in the GBSW, including a new species of millipede and unidentified trapdoor spider, both potentially short-range endemics to the area (M. Harvey *pers. comm.* 2022). Two conservation significant native bees have been recorded in the GBSW: *Leioproctus douglasiellus* (Endangered BC Act, Critically Endangered EPBC Act), only known from three locations (DSEWPC 2013), and *Glossurocolletes bilobatus* (Priority 2).

Aquatic fauna

The deeper pools of the claypans host a rich aquatic invertebrate fauna, compared to sites across the south-west, demonstrating that the GBSW have a high conservation value for aquatic invertebrates (A. Pinder *pers. comm.* 2022). Surveys have revealed rare and restricted species including snails (*Glacidorbis*), an undescribed water mite, a rare ostracod and copepod, and the ancient shield shrimp (*Lepidurus apus*) (Brown *et al.* 2016).

Subterranean fauna

No studies or surveys have been undertaken for subterranean fauna in the GBSW, and the limited knowledge of subterranean fauna of the SCP is likely due to an absence of comprehensive studies. The potential for stygofauna to occur in Muchea limestone within the GBSW and adjacent areas is considered a knowledge gap, with any confirmed occurrence potentially of high scientific and conservation significance (Tauss & Weston 2010).

2.2 Water

Inland waters

Groundwater

The GBSW are primarily located on clayey alluvium that has been transported by rivers and streams (Davidson 1995) to form a geomorphological feature known as the Pinjarra Plain (Gozzard 2007). The Pinjarra Plain is part of the SCP, which is bounded to the east by the Darling Fault and Scarp (see Figure 3).

The GBSW are situated in an area of localised groundwater flow between the Swan-Avon and the Canning Rivers (Davidson 1995). Groundwater occurs within the superficial aquifer, a major aquifer in the Perth Region, at shallow depths of 0 to 3 metres below ground level (V & C Semenuik Research Group 2001). Regional groundwater flow in the superficial aquifer is generally from the north-east to the south-west towards the Canning River (see Figure 3).

The superficial aquifer near the GBSW is underlain by the Leederville aquifer, which is made up of varying layers of sandstones and siltstones. Upward discharge of groundwater from the Leederville aquifer to the superficial aquifer is indicated by elevated groundwater salinity in the shallow groundwater (Figure 4, Davidson 1995), as well as previous measurements of groundwater levels (V & C Semenuik Research Group 2001). However, this is based on limited data and further investigation is needed. A spring was also observed in the area, indicating upward groundwater flow (Tauss & Weston 2010).

Evaporation is also a key mechanism for concentrating salts in clayey sediments. Other possible sources of salts in the sediments and groundwater of the GBSW area include deposition by rain and wind, or introduction from runoff and drainage.

As the Leederville aquifer can locally contain higher proportions of calcium than the superficial aquifer (Davidson 1995), discharge from the Leederville aquifer is a possible source of the elevated calcium levels in soils in the GBSW. The local presence of calcium-rich soil and limestone or calcrete rocks is important to the uniqueness of the area. In particular, the Spider net grevillea in the GBSW area is known to rely on the presence of elevated calcium levels in soil pore-water for its growth (Gao *et al.* 2020).

Evidence of increasing salinity in the GBSW was noted from occurrence of salt tolerant species (e.g. *Salicornia* spp.) at the edge of known populations of the critically endangered Swamp starflower (Luu & English 2004).

Geophysical investigations undertaken by the DBCA on the Wanaping block indicate that salinities of sediments and groundwater are variable, with some of the highest salinities occurring in the upper two metres which is generally dry in summer. These salts are likely to have concentrated at a shallow depth due to slow rates of recharge in winter and evaporation due to capillary action when the watertable is close to the surface in summer.

Changes in the water balance of the area could lead to increases in groundwater recharge and raise the natural watertable close enough to the land surface for capillary action to draw up salts and kill vegetation.

When the watertable is high, waterlogging may also be a threat to some vegetation in the GBSW. For example, some species of samphire (e.g. *Tecticornia* spp.) have a low tolerance to prolonged inundation from low salinity surface water (Konnerup *et al.* 2014). DBCA is undertaking further investigations of this on the Wanaping block of the GBSW.

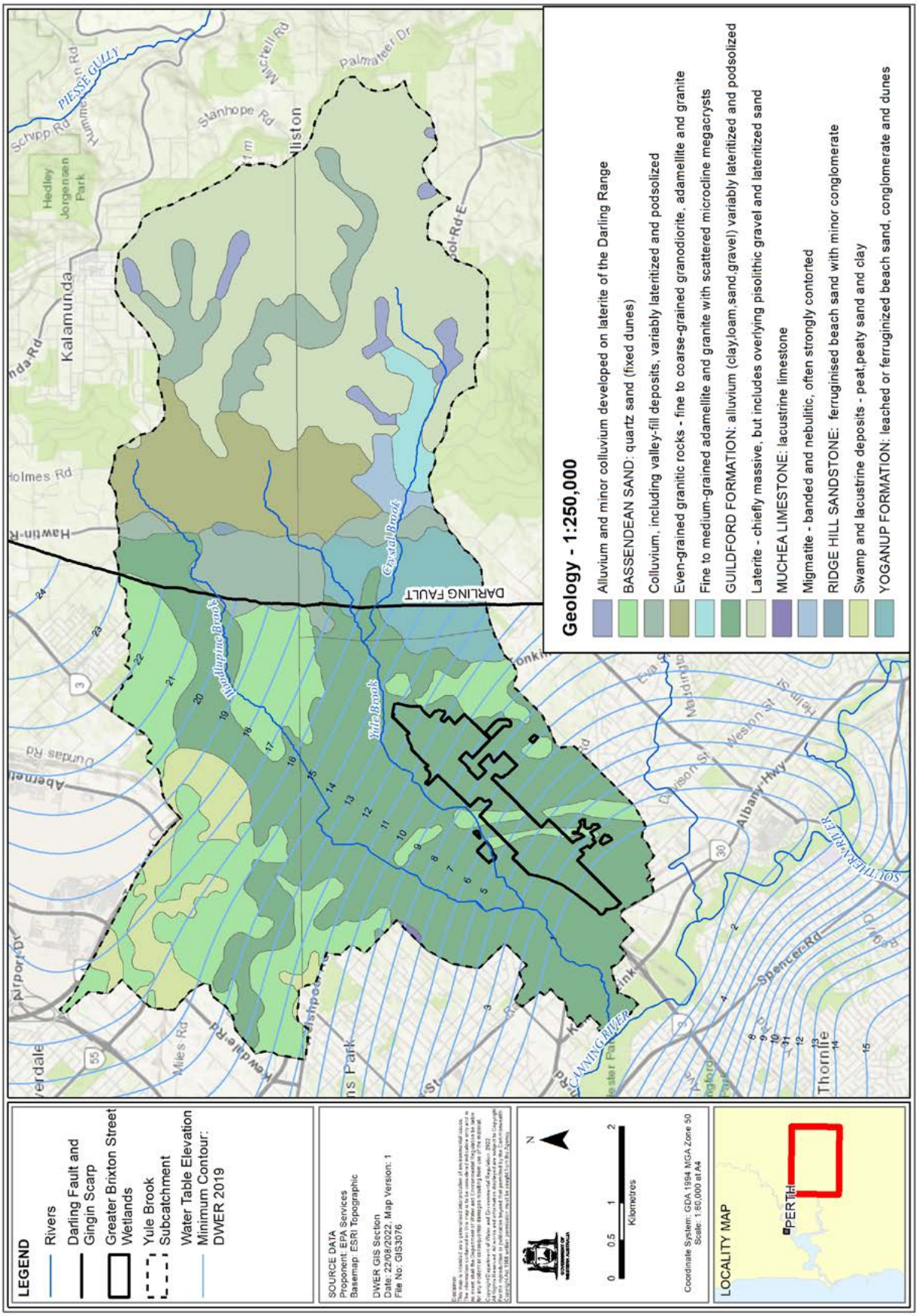

Figure 3: Regional geology and groundwater flow

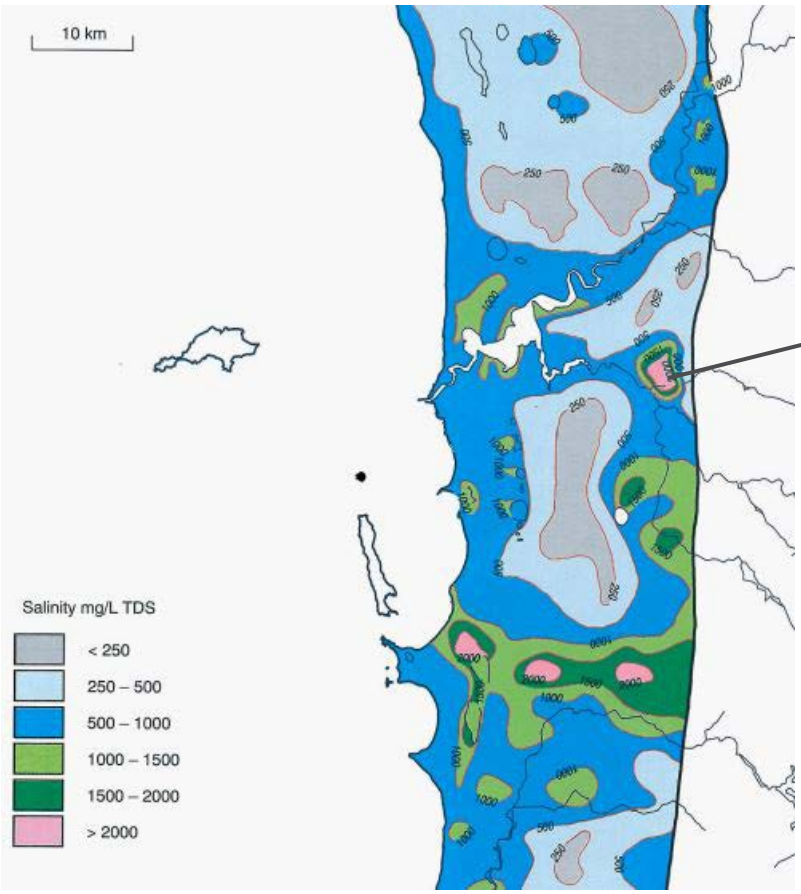

Figure 4: Salinity in the superficial aquifer in the GBSW area (adapted from Davidson 1995)

Surface water

The GBSW occur within the Yule Brook sub-catchment of the greater Canning River catchment. Yule Brook commences to the north-east in the Darling Scarp and flows along the north-west boundary of the GBSW towards the Canning River. Yule Brook and its named tributaries – Crystal Brook, Woodlupine Brook, and Bickley Brook to the south – are proclaimed rivers under the *Rights in Water and Irrigation Act 1914*.

Other minor seasonal tributaries include Binley Brook in the south-west (Bourke 2017) and small tributaries of Yule Brook and Crystal Brook (see Figure 1), which support small ephemeral claypan pools in Alison Baird Reserve (Tauss *et al.* 2019).

Wetlands of the SCP are classified according to their landform and water regime (Hill *et al.* 1996). The GBSW is a complex suite of seasonally inundated or seasonally waterlogged areas classified as palusplains, floodplains, sumplands and channels (V & C Semenuik Research Group 2001).

Small scale changes in stratigraphy and microtopography are key determinants of the wetland water regime, which in turn is an important driver of the biodiversity across the GBSW and surrounds. Enhanced vegetation growth along the north-eastern extent of the Wanaping Block is suggested to be attributed to seepage from north-south trending dunes (Bourke 2017; Tauss *et al.* 2019).

Connection between wetlands and groundwater

Connection between the wetlands and groundwater is considered likely across much of the GBSW and wider area, based on surface and groundwater levels and the shallow depth to groundwater (V & C Semenuik Research Group 2001; DCCEEW 2022). Recent investigations by the DBCA on the Wanaping and Brixton blocks also identify connection between the wetlands and underlying aquifers, including through slow leakage from clay-based wetland areas.

The wider connectivity of the GBSW with its surrounds is uncertain due to the limited coverage and timeframes of hydrological investigations (Bourke 2017), and further investigation is needed. However, the wetland connectivity with groundwater suggests that parts of the site may act as throughflow wetlands when water levels are high, where groundwater flows into the wetland within a distinct 'capture zone' and is discharged back into the aquifer downgradient (see Figure 5).

A recent review of hydrological studies identified that the hydrology of the GBSW is still poorly understood due to significant gaps in the spatial and temporal collection of data, and incomplete reporting (Bourke 2017). The importance of a detailed and coordinated hydrogeological investigation to characterise local stratigraphy and groundwater interactions across the wider region has been identified as a key knowledge gap (V & C Semeniuk Research Group 2001; Cardno 2005; Tauss & Weston 2010; Endemic 2012; Bourke 2017).

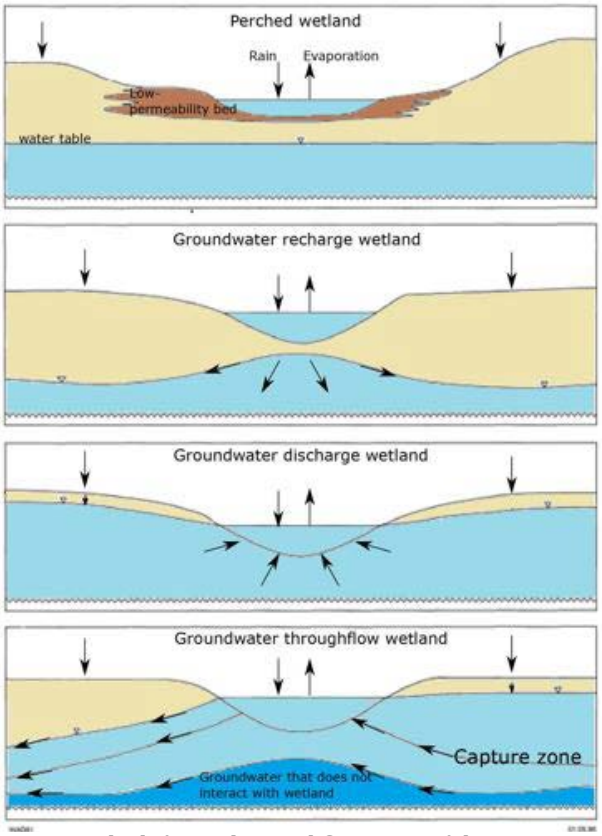

Figure 5: Groundwater-wetland interaction on the Swan Coastal Plain (adapted from Davidson 1995)

Groundwater dependency of flora and vegetation

The maintenance of the hydrology of the GBSW is important to protect the unique flora and vegetation communities. Small variations in water levels and wetting and drying cycles may adversely impact the groundwater-dependant ecosystems.

Previous flora and vegetation surveys of the GBSW identified a number of species that rely on groundwater for all or part of their water requirements (Marshall 2000; Tauss & Weston 2010).

All ecosystems across the GBSW area (including upland *Banksia* and *Corymbia* woodlands) were considered groundwater-dependent by Tauss *et al.* (2019). This is supported by hydrological surveys that identify shallow depth to groundwater and potential for surface and groundwater interaction across parts of the site (Bourke 2017).

The clay pan ecological community is entirely dependent on the hydrological functioning of the GBSW. Changes to these processes may result in their decline and be significant enough that they are unlikely to remain part of the ecological community (TSSC 2012).

The Muchea Limestone TEC within the GBSW is located in a shallow groundwater area where there is likely to be some surface water and groundwater interaction during winter months.

Dense rushland (e.g. dominated by *Chaetanthus aristatus*) receives freshwater seepage from dunes in the Wanaping Block and Alison Baird Reserve (Tauss *et al.* 2019).

Stable isotope studies have suggested that Spider net grevillea directly accesses shallow groundwater (Gao *et al.* 2020), with roots accessing groundwater at depths of 1.5 m to 4.3 m in winter and becoming stressed if water is not available, which sometimes occurs in summer (Western Australian Naturalists Club 2022). Research is currently being completed to understand the response of the unique flora to environmental conditions within the Wanaping Block and Alison Baird Reserve (Lambers *et al.* 2019).

2.3 People

Social surroundings

Social values

The GBSW are noted to be highly regarded on an international level for their scientific and educational values (DCCEEW 2022). There is strong engagement from researchers, citizen scientists and community groups that collectively aim to enhance knowledge, including sampling invertebrates and flora surveys (Lambers et al 2019). These groups are active in the protection and management of the GBSW area and consider the wetlands a high priority for conservation, restoration and protection. Urban environmental volunteering has been ongoing in the region for over 35 years (Dhakal 2016), including monthly hydrological monitoring (Luu & English 2004), as well as field assistance by community volunteers (WAH 1998).

Aboriginal cultural heritage

The GBSW and the *Mandoorn* (Yule Brook) region are *Beeloo Boodjar (*Country). The Whadjuk Noongar people are the Traditional Owners of the land. *Mandoorn* (Mythological site ID 36929) flows from the edge of the Kartamoarnda (Darling Scarp) at *Jerban* (Lesmurdie Falls) to the *Dyarlgarro* (Canning River). Crystal Brook, a tributary of the Yule Brook catchment, runs along the *Bulya Muminkuppie* dreaming track (Tauss *et al.* 2019). Since the *Nyitting* (dreamtime) the Traditional Custodians have celebrated the ancient meaning of this *Boodja* for over 50,000 years (Tauss *et al.* 2019). The long history and connection with places like *Mandoorn*, means the landforms and biota within the catchment have evolved side by side with the Aboriginal people living here, making this ancient cultural heritage globally significant (Tauss *et al.* 2019).

Two patches of threatened ecological communities, comprising of Marri-Grasstree (*Corymbia calophylla – Kingia australis* woodlands on heavy soils, Swan Coastal Plain) woodlands, lie within the Brixton Street Nature Reserve. These woodlands hold important socio-cultural significance for Aboriginal people (Dhakal 2016). It is suggested that the reserve's wetlands were likely associated with Aboriginal occupancy or use (Dhakal 2016), based on proximity to known tracks used by Noongar people travelling between Perth and Albany (SWALSC 2016). The *moodjar* (Western Australian Christmas Tree, *Nuytsia floribunda*) can be found within the GBSW. This tree is sacred to Aboriginal people, and breaking their branches is forbidden (Forster 2021). Some species of flora provided important sources of food, for example, the tubers of *Haemodorum* spp. and *Tribonanthes* spp. (Tauss *et al.* 2019). Furthermore, the *djop born* shrub (*Trymalium odoratissimum*) is a traditional Noongar medicine and soap (Hansen & Horsefall 2017) and is associated with Muchea Limestone (Tauss *et al.* 2019).

Directly north-east of the GBSW is Hartfield Park, the former Maamba Aboriginal Reserve (Site ID 3773). This park includes indigenous values, historical links, and scarred trees (Archae-aus Pty Ltd 2019). The park is also linked to significant indigenous figures from the 19th century Balbuk and Joobaitch, and anthropologist and Aboriginal welfare worker, Daisy Bates (The Beeliar Group 2018).

2.4 Existing and potential pressures

There is the potential for land use change, development and a range of other activities to impact on environmental values. This can include historic, existing and potential future pressures. The broad characteristics of these pressures are discussed in the following sections.

Existing and historical pressures

Historical clearing and land modifications have significantly reduced the quality and extent of native vegetation and habitat, and their ecological function and connectivity both within the GBSW and at a wider regional scale. Historical clearing of native vegetation and the building of infrastructure has also resulted in changes to hydrology and reduced ecological and hydrological linkages in some areas of the GBSW.

Existing development and infrastructure have fragmented the GBSW and changed its ecological and hydrological functions. Drains and infrastructure that intersect the watertable may alter shallow groundwater flow locally. For example, Brixton Street bridge contributes to flooding and salinisation upstream in the Wanaping Block and has reduced water flows to the downstream Brixton Street wetland near Alton Street (Bourke 2017; Beeliar Group 2018). Bickley Road divides the Alison Baird Reserve and Wanaping block, and associated drainage disrupts natural surface and groundwater flows between the two areas (Bourke, 2017; The Beeliar Group 2018). Roadside drains along Boundary and Brook roads intersect the shallow groundwater and have altered the surface water hydrology of the GBSW (V & C Semeniuk Research Group 2001).

Changes to existing watercourses include the diversion of Crystal Brook into Yule Brook north of Welshpool Road, which has deprived the GBSW of a source of high-quality surface water (Tauss *et al.* 2019). The lower reach of Crystal Brook has been excavated within Alison Baird Reserve to serve as a drain for nutrient rich runoff from roads and rural lands to the south of Boundary Road, through the GBSW to Yule Brook (Tauss *et al.* 2019). Excavation and realignment of Yule Brook for use as a main drain, has resulted in clearing of much of the riparian vegetation. Water quality monitoring of Yule Brook indicates a long-term increasing trend in total phosphorus and a short-term increasing trend in total nitrogen (DWER 2019). Use of land as a drainage reserve has resulted in Yule Brook becoming highly degraded between GBSW and the Canning River.

There are currently minimal or no buffers to mitigate against the existing pressures on the GBSW, with the wetlands primarily bordered by roads with open roadside drains. Lack of adequate buffers has contributed to a number of environmental impacts, including weed invasion, edge effects, contaminant and nutrient runoff, disturbances to fauna and diminished capacity for fauna to forage and breed (Davies & Lane 1995a,b).

Illegal activities such as littering, rubbish dumping and dumping of garden waste have occurred within the GBSW area (EPA 1992). Unauthorised vehicle access has contributed to degradation of the land surface and impacted existing vegetation and hydrology.

Several sites in the GBSW area have been reported and classified under the *Contaminated Sites Act 2003.* WAPC is remediating and revegetating one of the sites classified as contaminated – restricted use due to the presence of asbestos within soils.

Pressures from future activities and development

Some activities and development may cause direct, indirect, or cumulative impacts to the environmental values of the GBSW. The flora, vegetation and fauna are particularly vulnerable to pressures stemming from land clearing, fragmentation of habitat, edge effects, weed invasion and disease. Removal of riparian, water-dependent and terrestrial vegetation may affect waterway foreshore functions. Significant flora and vegetation may also be lost or degraded, resulting in loss of habitat, connectivity, ecological function and genetic diversity.

Activities such as urban development and infrastructure may lead to changes in the water balances and hydrological regimes of wetlands and watercourses. In the Perth region, land use changes and associated clearing of vegetation have resulted in localised rises in groundwater levels and drainage flow rates due to the increased recharge post-development (Appleyard, 1995; Davies *et al.* 2014; Silberstein *et al.* 2009). Changes to levels of groundwater abstraction resulting from modifications to land use and other activities has the potential to further alter the local water balance.

Surface and groundwater quality changes also have the potential to harm sensitive plant communities and aquatic fauna. Dewatering or direct disturbance of acid sulfate soils during construction may result in oxidation and acidification of soils and groundwater and directly impact flora, vegetation and aquatic fauna.

The discharge of nutrients and sulfate in untreated runoff from urban areas may cause adverse changes in the biogeochemistry of wetland sediments through eutrophication, algal overgrowth, or from acidification when sulfate is converted to sulfide.

Such impacts can result in the decline and loss of valuable individual species, or more widespread and significant events in the case of significant changes to hydrology, water quality and fire.

Future activities and development may also impact the natural and heritage values of the GBSW. Fragmentation of natural areas may result in loss of connection and accessibility to land. The proximity of industry and development may also result in declining visual amenity. Places of Aboriginal cultural significance may be disturbed or destroyed, particularly if engagement with Traditional Owners is not undertaken adequately.

Climate change

Climate change is a key pressure impacting the state of Australia's environment and is increasing the impacts of other pressures on the environment (Cresswell *et al.* 2021). Climate change has been identified as a clear driver for potential cumulative effects across environmental values (He & Silliman 2019).

The CSIRO estimates that for the south-west of Western Australia runoff will reduce by 20 to 30 per cent under the median future climate and reduce by 40 to 50 per cent under the dry extreme future climate, which would affect surface water dependent ecosystems (EPA 2015, CSIRO 2009). These are significant reductions with large implications for water supply security and water-dependent ecosystems.

Average annual rainfall in the region has declined significantly since the 1970s and global climate models suggest this trend will continue. This trend, combined with increases in summer temperatures, is likely to lead to reduced recharge of aquifers, resulting in more intense drying of the GBSW during summer. This contributes to an increased risk of acidification and heavy metal contamination from oxidation of acid sulfate soils.

While aquifer recharge as a result of rainfall and surface flows is likely to continue to decline, urban development may result in an increase in recharge to the wetlands from groundwater. Modifications to land surfaces through the removal of vegetation, construction of roads, and development of drainage infrastructure is likely to affect the dynamics of aquifer recharge. The spatial concentration of recharge points in modified urban systems may also affect groundwater processes in the GBSW.

There is also the potential for any increase in recharge to result in a higher salt loading when combined with lower surface flows and direct rainfall. The higher evaporation from hotter summers has the potential to change the hydrochemistry of the groundwater and soils in the wetlands, which is likely to change the biodiversity of GBSW.

Wetlands play a significant role in capturing and storing carbon and are estimated to store more than one-third of the world's terrestrial carbon (DOEE 2019). If wetlands are drained, burned or cleared, they become a carbon source, releasing into the atmosphere centuries of stored carbon, equating to about 10 per cent of global annual fossil fuel emissions (DOEE 2019).

3 Advice and recommendations

3.1 Findings

The GBSW are recognised as one of the most important wetlands remaining on the Swan Coastal Plain with outstanding biodiversity attributed to the unique geological, geomorphic and hydrological characteristics of the site.

The GBSW are under pressure from existing and historical activities, proposed development and climate change. The area has undergone changes in its biodiversity and ecological function as a result of these pressures. Environmental values already under pressure have reduced capacity for persistence and resilience when considering future pressures, including climate change. Some activities and development may not be compatible with the protection of environmental values of the GBSW.

The complex land tenure of the GBSW area creates a key challenge for the management and protection of its unique environmental values. The EPA has identified that a high level of protection and coordinated management is critical for the GBSW, particularly considering potential cumulative impacts of existing pressures and future development.

The EPA expects future activities and development to be compatible with the protection of the environmental values of the GBSW.

The EPA provides advice on:

- protecting and enhancing the environmental values of the GBSW
- expectations for proposals and planning schemes that have the potential to impact the GBSW.

3.2 Protecting the environmental values of the Greater Brixton Street Wetlands

The EPA recommends a high level of protection for the GBSW and recognises that there are numerous mechanisms to support and enhance the protection of the environmental values.

1. Enhancing the level of protection

Given the globally significant environmental values associated with the GBSW, the EPA recommends that the level of protection within the area is enhanced. An enhanced level of protection would create a more contiguous reserve system that offers the basis for integrated protection and management.

The EPA is of the view that in addition to the existing lots classified as Class A nature reserve (i.e. Brixton Block, Wanaping Block and a number of unnamed lots as shown in Figure 1), there is an opportunity to increase the level of protection of other parts of the GBSW to a Class A classification.

There are a number of other lots within the GBSW that are currently owned by the State or local government (as shown in Figure 2) that have varying levels of protection and management. The EPA strongly supports increasing the level of protection for these lots to Class A classification as a priority (shown in Figure 1).

The EPA also supports the continued purchasing of privately owned land by the WAPC within the GBSW and its buffers, in accordance with implementation of State Government's Bush Forever Policy (Government of Western Australia 2000).

In addition, the EPA is of the view that there are further opportunities to expand the reserve system and further enhance protection through the acquisition of private land within the GBSW and its buffers. A number of mechanisms may be available to acquire land, including offsets for impacts to similar environmental values as those found at GBSW.

Alison Baird Reserve is owned and managed by UWA as a research and education site. However, the EPA notes the recommendation made in its report on conservation reserves for Western Australia (EPA 1983) that, should UWA wish to dispose of what is now known as Alison Baird Reserve, this too should be considered for Class A nature reserve status.

2. Coordinated management

In addition to enhancing the level of protection for the GBSW, the EPA recommends a coordinated approach to improve long-term management and environmental outcomes. There are a number of models that have been used for relatively small but high value environmental contexts that bring together state government agencies and local government, as well as community and industry stakeholders, to ensure coordinated management and shared responsibility.

DBCA manages several lots within the GBSW with Class A nature reserve status (Brixton Street Nature Reserve, shown in Figure 2) and partner with some key stakeholders, such as the Friends of Brixton Street Wetlands community group. A number of other agencies and stakeholders are also involved in the management of the GBSW or have an interest in their protection, as outlined in section 1.3 of this report.

The EPA considers that the provision of this advice presents an important opportunity to improve the coordination and management through a shared and expanded partnership involving all relevant groups including Traditional Owners, to allow holistic management of the entire GBSW area. Given the EPA's view that the levels of protection within the GBSW should be enhanced and a contiguous reserve system established, DBCA would be well-placed to take a stewardship role for this body. Adequate resourcing is essential to enable effective stewardship and management for improving environmental outcomes for the GBSW.

The EPA considers that there is an important role for such a body to play in the protection of biodiversity and cultural values of the GBSW, including in addressing knowledge gaps.

The EPA highlights the following knowledge gaps and areas for improvement:

- integration of Aboriginal cultural knowledge into the coordination and management of the GBSW
- understanding of the hydrology and hydrogeology of the GBSW, particularly:
    - the interaction between wetland areas, the superficial aquifer and the Leederville acquifer
    - the groundwater inflow or capture zone of the wetlands and vulnerability to groundwater contamination and potential impacts from landuse, activities and climate change Turner and Townley (2006) outline the types of groundwater investigations that could be undertaken
    - groundwater quality of the shallow and deeper aquifers to understand chemical compositions in this area and the risks of salinisation and acidification
- understanding of environmental requirements, especially the flora and vegetation
    - particularly in the context of potential intensification of development in the catchment and climate change and the need to maintain the hydrological regime and water levels
- systematic surveys and analyses to support the understanding and protection of flora, vegetation, and fauna habitats.

3. Restoring and enhancing environmental values and connectivity

The EPA is of the view that improvements to ecological linkages should be a priority to help maintain hydrological and ecological processes and reduce impacts of habitat loss and fragmentation in the GBSW (EPA 2021b).

The EPA supports further science-led evaluation of ecological linkages to enhance the hydrological and ecological connectivity of the GBSW within the broader SCP. Improvements to connectivity could be delivered through mechanisms such as the development or expansion of regional parks, advanced offsets, areas of public open space with a conservation objective, or ecological restoration on private lands.

The ecological, water quality and quantity benefits of vegetated buffers around wetlands have been well documented since the early 1990s (Davies & Lane 1995a,b; 1996; WAPC 2005; The Beeliar Group 2018). The EPA is of the view that buffers are an important mechanism for protecting the environmental values of the GBSW by minimising the risks of impacts from nearby land uses and development. It is important that buffer widths are appropriate to support the ongoing ecological and hydrological integrity of the wetlands and ensure that the potential for changes to soil and water chemistry from proposed activities or development are minimised. Buffers may incorporate surface and groundwater catchment areas, and vegetation and fauna habitat. They should be based on site-specific studies and the best available scientific evidence.

The EPA supports opportunities for the restoration and rehabilitation of native vegetation within the GBSW. Opportunities to rehabilitate existing impacts from roads and drainage and convert stormwater drains into living streams are also supported.

3.3 Expectations for proposals and planning schemes that have the potential to impact the Greater Brixton Street Wetlands

The EPA expects future activities and development to be compatible with protecting the environmental values of the GBSW. The EPA will apply careful scrutiny to proposals and planning schemes that may be incompatible with the protection of these values. The EPA emphasises the role of the mitigation hierarchy where proponents should first avoid impacts to the environmental values of the GBSW by considering alternative sites or design. Where avoidance is not possible, impacts should be minimised including through development of appropriate management and contingency measures.

The EPA provides the following expectations for proponents.

1. Traditional Owner engagement

Proponents will need to demonstrate explicit regard for Aboriginal knowledge, connection to country and protection of Aboriginal cultural and environmental values. Proponents should demonstrate that Traditional Owners have been consulted, that cultural and environmental values are identified, and potential impacts will be avoided where possible, or minimised.

2. Protection of ecological and hydrological values

The EPA considers that the unique environmental values within the GBSW are not readily replaceable or interchangeable with offsets in other areas. Direct and indirect impacts to the environmental values of the GBSW should be avoided to the greatest extent possible and practicable.

Proponents will need to demonstrate best practice environmental management with adaptability in design and approach to protect the environmental values and supporting ecological and hydrological processes of the GBSW. This includes the consideration of the ecological and hydrological connectivity of the GBSW with the broader catchment areas of the SCP.

As outlined in section 3.2 of this advice, where proponents require offsets for impacts to similar environmental values as those found at GBSW, purchase of private land within the GBSW and its buffers for conservation purposes could be considered. This may include rehabilitation and restoration, and/or undertaking appropriate research or scientific investigations.

Hydrological and hydrogeological investigations

Proponents will need to demonstrate that proposed developments, related activities, and any water abstraction will not adversely impact the environmental values of the GBSW directly or indirectly.

Appropriate and site-specific hydrological and hydrogeological investigations should be undertaken, supported by relevant and accepted scientific evidence, to inform the environmental impact assessment of any proposed development.

Site specific studies must consider the regional hydrogeological and hydrological context. Proponents must address potential impacts on the local water balance, hydrological regime, and water-dependent environmental values, as well as potential changes in surface and groundwater flow and quality, in a local and regional context. This includes consideration of any levelling of land, use of fill or drainage to create a developable area. Of particular importance is to demonstrate that changes to hydrological regimes will not adversely affect the flora and vegetation of the GBSW.

The potential for direct, indirect and cumulative impacts to the GBSW must be considered, including in connected aquifers and ecosystems.

Stormwater management and drainage

Best practice stormwater and drainage management must be applied to ensure that changes to the hydrology of the GBSW are minimised. This should include appropriate water sensitive design approaches and treatment of stormwater runoff. Proponents should provide the indicative design and placement of any stormwater infrastructure in the context of the GBSW.

Proponents will need to demonstrate that any potential changes to the water balance, hydrological regime, or water quality will not adversely impact the environmental values of the GBSW.

Buffers

Providing a buffer for wetlands is a key mechanism for minimising the risks of impacts from activities of nearby land uses and development. Wetland buffers may incorporate surface and groundwater catchment areas (Davies & Lane 1995a,b).

Proponents of proposed activities and developments will need to consider appropriate buffers to protect the environmental values of the GBSW. Buffer widths should be determined, based on site-specific studies and best available scientific evidence. The buffers should provide for maintenance of ecological and hydrological processes and ensure that the potential for changes to soil and water chemistry from proposed activities or development are minimised. Buffer studies should include consideration of the hydrology, the presence of hydric soils and wetland vegetation, the ecophysiology of the wetland and water-dependent flora and vegetation, and fauna habitat and life cycle requirements.

In situations where buffers are not practicable, proponents should demonstrate how environmental values of the GBSW will be maintained if the proposed development is implemented.

3. Cumulative impacts

The cumulative impacts of existing and proposed activities and development in the area must be explicitly considered to ensure that the environmental values are protected. Biological diversity, ecological integrity and hydrological processes of the GBSW face multiple threats that may interact and be cumulative, such that the impacts are increased in an additive manner (Cresswell *et al.* 2021).

Given that the GBSW are already under pressure from existing activities, development and climate change, the EPA is of the view that avoidance and minimisation of disturbance should be a priority for all proponents.

4 Conclusion

There are multiple threats to the significant environmental values of the GBSW. There is evidence of impacts to environmental values from existing and historical activities and concern about further incremental and cumulative impacts from potential future development.

Although multiple policy and planning processes have recognised the values of the GBSW, land tenure arrangements remain complex, and the associated levels of protection and management are inconsistent. A high level of protection and coordinated management are needed to protect the unique biodiversity, ecological integrity and hydrological processes of the GBSW. Addressing key knowledge gaps is an important aspect in informing and improving the level of protection and environmental outcomes.

The geomorphology and hydrology of the GBSW are critical to the ecology of the area and are not well understood. It is particularly important to understand the interactions between the wetlands, flora and vegetation, and groundwater, as this influences the vulnerability of the wetlands to potential changes in hydrology, water quality and soil chemistry.

Continued piecemeal development without enhancing the protection of the GBSW may result in further degradation of the area's unique and significant environmental values.

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