Restoration Feasibility Assessment of Lake Hawdon North

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NGT Consulting

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Front cover: Black-tailed Native-hens (*Gallinula ventralis*) foraging in shallowly inundated open pan habitat, Lake Hawdon North, 21 November 2008 (photo: Ben Taylor).

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Disclaimer

Respect and Reconciliation

Aboriginal people are the First Peoples and Nations of South Australia. The Coorong, connected waters and surrounding lands have sustained unique First Nations cultures since time immemorial.

The *Healthy Coorong, Healthy Basin* program acknowledges the range of First Nations' rights, interests and obligations for the Coorong and connected waterways and the cultural connections that exist between Ngarrindjeri Nations and First Nations of the South East peoples across the region and seeks to support their equitable engagement.

Aboriginal peoples' spiritual, social, cultural and economic practices come from their lands and waters, and they continue to maintain their cultural heritage, economies, languages and laws which are of ongoing importance.

The Department for Environment and Water (DEW) works across the State with Aboriginal South Australians to conserve and sustain Country. Through this work we seek to improve the relationship between Aboriginal and non-Aboriginal Australians and build respect based on mutual understanding and acceptance of each other.

Acknowledgements

The author would like to acknowledge and thank the following people for their generous assistance with the preparation of this report:

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Australian Government

Government of South Australia

This study was supported by the South Australia Government's Healthy Coorong, Healthy Basin Program, jointly funded by the Australian and South Australian governments.

Executive Summary

Key findings:

- Through construction of a regulator on Drain L, a target hydrograph can be achieved in LHN that maintains WSEL at 4.30 mAHD from late winter and extends inundation to mid-March in an average year, providing shorebird habitat for the entire period that migrating shorebirds are present in the region. The presence of water later in the summer would be particularly valuable, as that is when migratory shorebirds are looking to gain fat reserves for their return flight to the northern hemisphere, yet total regional wetland habitat is declining as seasonal wetlands dry.
- Removal of 650 ha of recently invaded *Melaleuca halmaturorum* shrubland will ensure that a total of 1,763 ha of structurally suitable (open pan) habitat for shorebirds exists at Lake Hawdon North (LHN).
- Restoration (shrubland removal and application of the target hydrograph) increases the carrying capacity of LHN for shorebirds (four migratory species and Red-capped Plover (RCP)) by 531% compared to the current scenario.
- A peak carrying capacity of 39,500 shorebirds is predicted in a restored LHN. For Sharp-tailed Sandpiper and Red-capped Plover, carrying capacity in LHN would regularly exceed current abundances in the Coorong South Lagoon (CSL). For Common Greenshank and Curlew Sandpiper, LHN carrying capacity would regularly be similar to current abundance in the CSL. Thus, for these four species, a restored LHN is effectively equivalent to the current CSL in carrying capacity. For Red-necked Stint, carrying capacity in a restored LHN is 15% of current CSL abundance.

The *Healthy Coorong, Healthy Basin* Project's On Ground Works Regional Bird Refugia component, referred to herein as HCHB RBR, is planning to improve the availability and quality of habitat for migratory and non-migratory shorebirds at priority wetlands in the Lower Lakes and South East of South Australia to provide regional refugia.

The target beneficiaries of the HCHB RBR are the shorebirds listed in the table below.

Common name	Scientific name	Coorong South Lagoon abundance			
		1985 baseline[1]	2015 baseline	2019 census	Ideal foraging depth (cm)[2]
Migratory shorebirds functional group					
Sharp-tailed Sandpiper	*Calidris acuminata*	6,013	3,292	1,823	0.1 - 2
Curlew Sandpiper	*Calidris ferruginea*	9,449	60	41	2 - 4
Red-necked Stint	*Calidris ruficollis*	29,020	6,207	5,480	0.1 - 2
Common Greenshank	*Tringa nebularia*	313	42	22	6 - 10
Non-migratory shorebirds functional group					
Banded Stilt	*Cladorhynchus leucocephalus*	6,208	1,024	116	0 - 20
Red-necked Avocet	*Recurvirostra novaehollandiae*	7,210	847	1,479	0 – 20
Red-capped Plover	*Charadrius ruficapillus*	2,158	624	363	0 (wet)

[1]source: Paton *et al.* (2009)
[2]sources: O'Connor *et al.* (2013), Paton (2010)

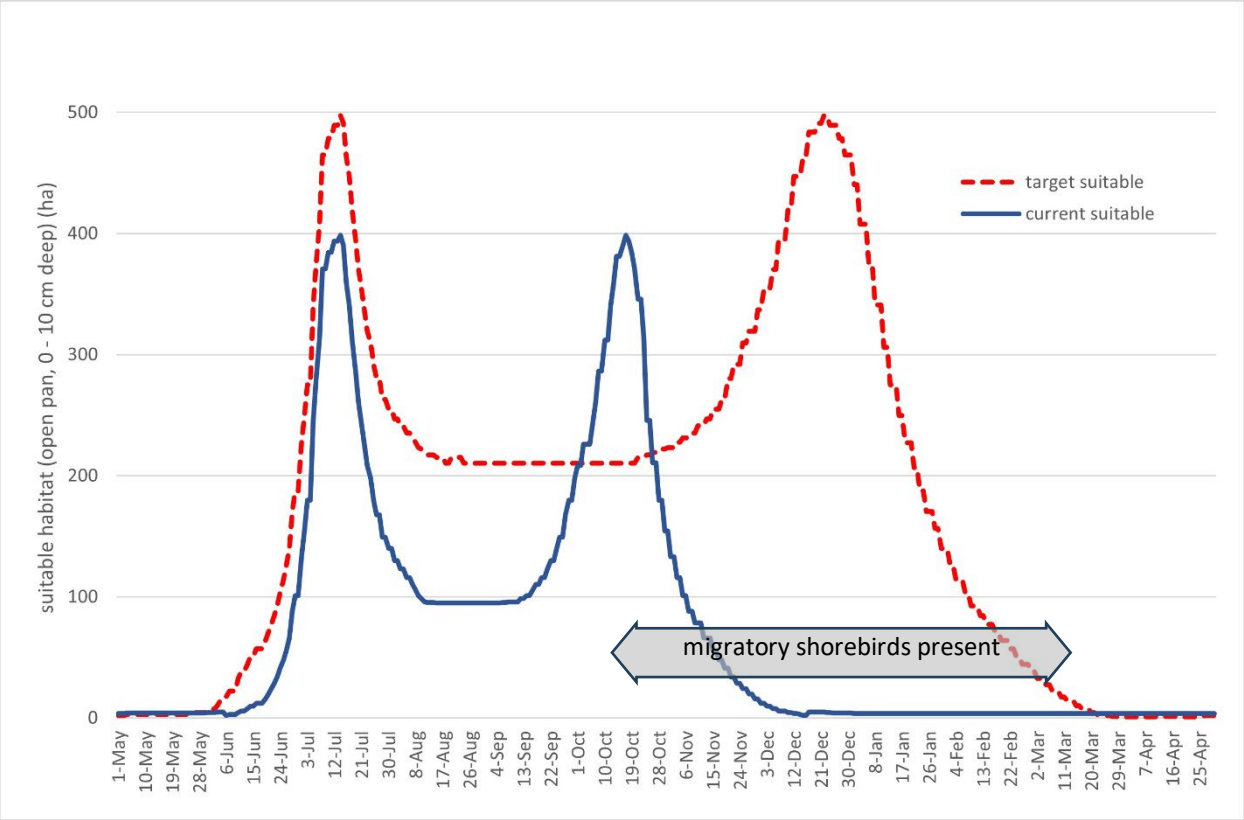
This report is focussed upon the outcomes that can be achieved for these target shorebirds via the restoration of Lake Hawdon North while protecting and/or enhancing other ecological values of the wetland. Survey data indicate that five of the seven HCHB RBR target species (the four migratory shorebirds and Red-capped Plover (RCP)) will benefit from the restoration of Lake Hawdon North.

The volume of Lake Hawdon North when full is 7,920 ML, which is just 13.6 % of the average (22.1 % of median) annual discharge of Drain L, illustrating the high availability of water for hydrological restoration.

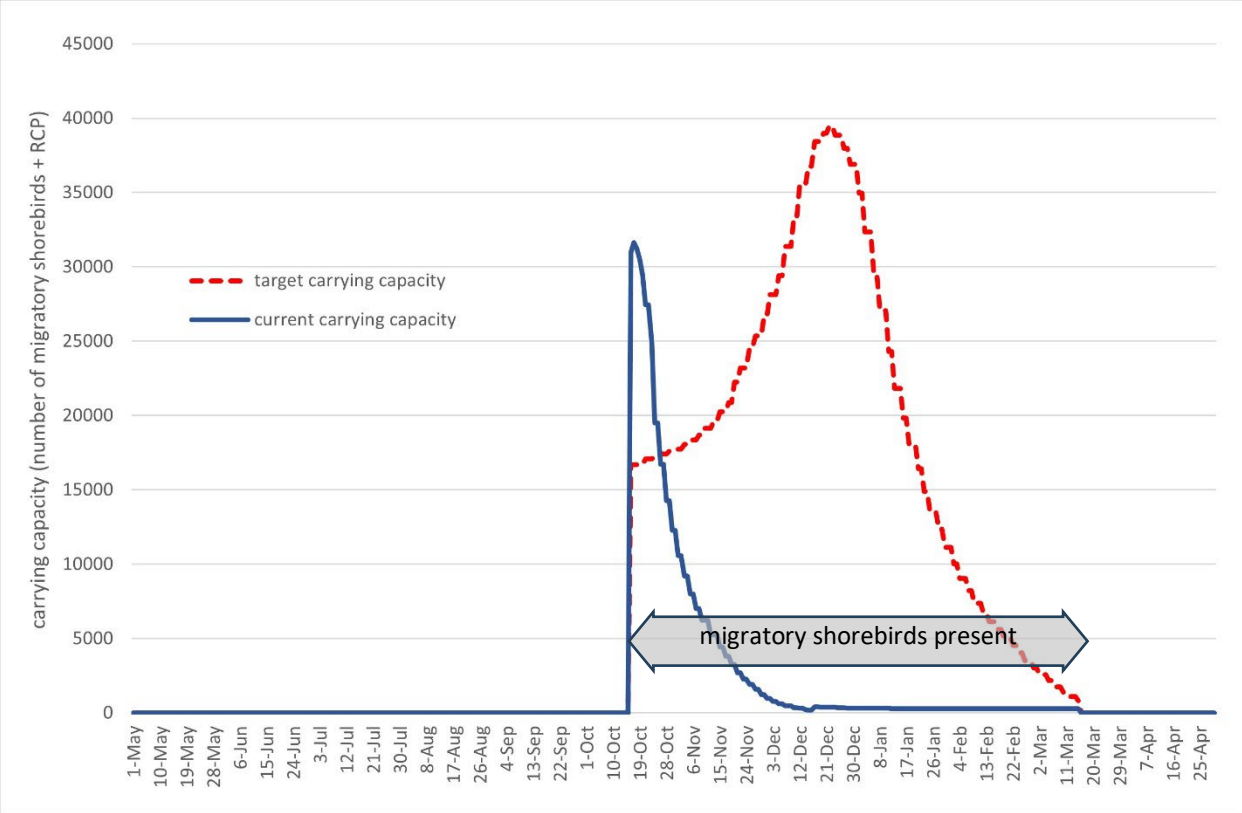
Removal of encroaching perennial vegetation, ideally after completion of a regulator, is proposed to convert 650 ha from structurally unsuitable to structurally suitable foraging habitat for shorebirds.

We have used the following definition of suitable habitat for the HCHB RBR target migratory shorebirds and RCP: open pan habitat inundated to a depth greater than 0 cm and less than 10 cm (0 – 10 cm). To restore a more natural hydrology to Lake Hawdon North, with inundation persisting well into summer to better align with the presence of migratory shorebirds in the region, it is proposed that a regulator be constructed on Drain L to control water levels in Lake Hawdon North.

A comparison of the area of suitable habitat under current versus target restored scenarios is shown below. Under both scenarios the amount of suitable habitat initially increases, then declines, then increases again before declining at the end of the period of inundation. This reflects the fact that much of Lake Hawdon North is inundated to a depth greater than 10 cm, and is therefore unavailable to shorebirds, during the middle weeks of the period of inundation under average conditions.



We have applied the peak density from Lake Hawdon South monitoring data (79.38 birds/ha) to Lake Hawdon North to estimate the carrying capacity under current and restored scenarios. The figure below shows estimated annual carrying capacity of Lake Hawdon North for migratory shorebirds + RCP under both scenarios.



Under the current, unrestored scenario, carrying capacity is estimated at 31,640 migratory shorebirds + RCP in mid-October but declines rapidly, due to rapidly falling water levels, to effectively zero by mid-December under average conditions. Under the restored scenario, carrying capacity increases from 16,700 migratory shorebirds + RCP in mid-October to 39,500 by late December then declines to reach zero by mid-March under average conditions. Considering the bird.day as the unit of carrying capacity (i.e. 1 bird.d implies 1 bird (migratory shorebird + RCP) present for one day), the current scenario provides 540,318 bird.d per year while the restored scenario provides 2,868,947 bird.d per year under average conditions. Thus, on average, restoration increases the carrying of Lake Hawdon North for migratory shorebirds + RCP by 531%.

To progress the restoration of Lake Hawdon North, the following priority actions are recommended for implementation as soon as possible:

- Engagement with the SEWCDB, grazing licensees and Agricola Mining Pty Ltd to explain the proposal and determine what is required to secure the support of these key stakeholders.
- Use the existing hydrodynamic model of the Robe Lakes developed by Taylor *et al.* (2014) to examine the impact of the target annual hydrograph of Lake Hawdon North upon the salinity and water level of the Robe Lakes.
- Commence the hydrological and ecological monitoring described in Section 10 to gather important baseline information that will enable the outcomes of restoration to be measured.

All other recommendations of this report are important and should be implemented when appropriate, however the above actions are fundamental to shaping the project and measuring its outcomes, and are therefore emphasised.

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1. Context

1.1. *Healthy Coorong, Healthy Basin*

The Coorong, and Lakes Alexandrina and Albert Wetland is located at the terminus of the Murray-Darling Basin (MDB) System in South Australia. It is a system of shallow lakes, lagoons and wetlands covering over 140,000 hectares that is extremely diverse and is an important refuge for migratory and non-migratory waterbirds in the Murray Darling Basin. In 1985 the Coorong, and Lakes Alexandrina and Albert Wetland was declared a Ramsar Wetland of International Importance, largely due to its role in supporting a diverse and abundant waterbird community. The site is also subject to a number of international migratory bird agreements including the Japan Australia Migratory Bird Agreement, the China Australia Migratory Bird Agreement and the Republic of Korea Migratory Bird Agreement and is an Icon Site of the Murray-Darling Basin Living Murray Initiative.

It is well documented (e.g. Brookes et al. 2018) that the Coorong and Lower Lakes has undergone ecological decline, which has been exacerbated by unsustainable water extractions in the MDB and the Millennium Drought. The *Healthy Coorong, Healthy Basin* (HCHB) program proposes to implement works to support the long-term health of the Coorong, with a focus on the Coorong South Lagoon. The program is being delivered by the South Australian Government Department for Environment and Water (DEW) and is jointly funded by the Australian and South Australian Governments.

The HCHB program will be achieved through six projects, including the On-Ground Works (OGW) project. The OGW project is proposing to implement on-ground works to support the mitigation of threats to key Coorong biota . The OGW project comprises two components: Coorong Ecosystem Restoration project and Regional Bird Refugia project. The Coorong Ecosystem Restoration project is planning on-ground works within the Coorong itself, to support key biota, primarily aquatic plants (e.g. *Ruppia tuberosa*) and benthic invertebrates. The OGW forming the Coorong Ecosystem Restoration will be discussed in a separate report.

This report discusses on-ground works proposed as part of the Regional Bird Refugia component, referred to hereafter as HCHB RBR, which is planning to improve the availability and quality of habitat for migratory and non-migratory shorebirds at priority wetlands in the Lower Lakes and South East of South Australia to provide regional refugia..

The Australian Government Department of Agriculture, Water and the Environment conducted a due diligence assessment of the *Healthy Coorong, Healthy Basin* On-Ground Works Proposal and determined feasibility assessments are required to demonstrate on-ground works are technically feasible and will provide a material environmental benefit to the Coorong South Lagoon.

During Phase Zero of the HCHB project the Goyder Institute conducted a multi-criteria analysis of wetlands in the Coorong, Lower Lakes and South East to identify wetlands that, subject to on-ground works could provide additional habitat for waterbirds (Hunt et al. 2019). The assessment identified Lake Hawdon North as having high value for waterbirds subject to on-ground works and considered it as the top priority site in the South East for feasibility assessment during Phase One of HCHB.

This feasibility assessment was developed by Nature Glenelg Trust for the Program Development and Coordination Branch, DEW and Landscapes SA Murraylands and Riverland in consultation with the HCHB On-Ground Works Working Group, relevant DEW staff and industry experts.

1.2. *Target Species*

The HCHB RBR project focuses on improving habitat for migratory shorebirds and resident Australian (non-migratory) shorebirds (Table 1) for which the availability and quality of foraging habitat is currently degraded in the Coorong South Lagoon (Hunt et al. 2019, Paton et al. 2019). The abundances of these species in the Coorong South Lagoon (CSL) in 1985 (Paton et al. 2009), 2015 (considered the revised Ecological Character Description baseline) and in 2019 are provided for context. All of these species have been recorded in the Lake Hawdon complex (DEH 2007). Optimal foraging depths for these species are also listed in Table 1, based on previous research (O'Connor et al. 2013, Paton 2010). All four HCHB RBR migratory shorebirds and Red-capped Plover forage within water greater than 0 cm but less than 10 cm (0 – 10 cm) deep, while the two larger non-migratory species, Banded Stilt and Red-necked Avocet, forage within the 0 – 20 cm depth range. Banded Stilt do not fit neatly within this categorisation as they occasionally feed while swimming in deep water (Paton 2010).

Table 1. Target shorebird species list for the restoration of Lake Hawdon North under the Healthy Coorong Healthy Basin program, Regional Bird Refugia component (HCHB RBR).

Common name	Scientific name	Coorong South Lagoon abundance			
		1985 baseline[1]	2015 baseline	2019 census	Ideal foraging depth (cm)[2]
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This report is focussed upon the outcomes that can be achieved for these target shorebirds via the restoration of Lake Hawdon North while protecting and/or enhancing other ecological values of the wetland.

2. Introduction

2.1. *Scope and Justification: Contribute to the Desired State of the Coorong*

The latest scientific evidence shows that the Coorong ecosystem, particularly the CSL, currently supports historically low migratory shorebird abundance (Brookes et al. 2018) and that these declines in abundance can be at least partly attributed to changes in the ecological conditions in the Coorong, not simply to declines in the overall flyway population (Clemens et al. 2016, Gosbell and Grear 2005). Declines in local populations of non-migratory waterbirds in the CSL reinforce this view (Paton et al. 2009). Shorebird declines in the CSL are understood to be due to reduced food resources on seasonally exposed mudflats, related to poor water quality and a changed regime of seasonal water levels caused by reduced spring

flows in the River Murray (Brookes et al. 2018). On the current trajectory, under a do-nothing scenario, shorebird numbers will continue to decline as food availability and diversity becomes more unreliable.

Located 90 km south of the CSL and 15 km from the coast, Lake Hawdon North is one of several large, seasonal to permanent wetlands within the Coorong region of the East-Asian Australasian Flyway. Given that waterbirds are known to respond to wetland habitat conditions within the broader landscape (Ma et al. 2010), a local regional network of well-managed wetlands will help to provide additional complementary foraging habitat that could act as a 'buffer' against worsening conditions in the CSL, particularly during drier periods when waterbirds rely heavily on coastal wetlands. Restoring habitats in the broader landscape near the Coorong will materially benefit Coorong waterbird populations by matching the lessened Coorong habitat niches, and supporting species that are still coming to the region (short-medium term benefits). These populations will then be able to return to the Coorong once the niche habitat is re-established in the CSL. A number of published examples provide evidence that maintaining a functional network of (often restored) wetlands can improve overall waterbird numbers utilising the wetland habitats in a region (e.g. Beatty et al. 2014, Li et al. 2013). Increasing and enhancing suitable habitat for shorebirds at Lake Hawdon North will contribute toward achieving the desired state of the CSL; diverse and abundant waterbird populations, including migratory and non-migratory shorebirds, sustained by productive, seasonally exposed mudflats (DEW 2020). As this feasibility assessment will show, the likely increases in abundance of several shorebirds species targeted by the HCHB RBR project within a restored Lake Hawdon North are equivalent to, or markedly greater than, current abundances in the CSL. The project therefore represents an opportunity to maintain, and potentially increase, populations of these species within the region over the short to medium term, in readiness for the return of improved conditions in the CSL.

2.2. *Site Location and Description*

Lake Hawdon North is a seasonally inundated wetland of 2,475 hectares located approximately 15 km east of the coastal town of Robe in the South East of South Australia (Figure 1) in country that is the southern limit of the Meintangk and northern limit of the Boandik nations. Taking into account adjoining Lake Hawdon South (3,298 ha), the Hawdon complex has a total area of 5,773 ha, making it one of the largest wetland systems in the region. Lake Hawdon North receives surface water inflows from Drain L, the Lake Hawdon Connecting Drain (via Lake Hawdon South) and a network of smaller local drains from adjoining properties to the east and north. It is also recognised as a groundwater dependent ecosystem (Cranswick and Herpich 2018), receiving seasonal groundwater discharge from the regional unconfined aquifer (Harding 2018). Groundwater appears to be within 1 m of the bed of the wetland at all times (SA Government 2020). Policy for the protection of groundwater dependent ecosystems under the Water Allocation Plan for the Lower Limestone Coast Prescribed Wells Area (SE NRM Board 2015) applies to the Lake Hawdon Complex, including setback distances for proposed new irrigation. Drain L, with a catchment of 1,641 km^2, has a mean annual discharge of 59,010 ML/yr (median 36,160 ML/yr), the highest of the South East regions drains, and provides the majority of surface inflows to Lake Hawdon North. In the South East region, coastal catchments such as the Drain L catchment have proved more reliable and been less impacted by declining water tables that have affected runoff further inland in recent decades (Cranswick and Herpich 2018, Harding 2018).

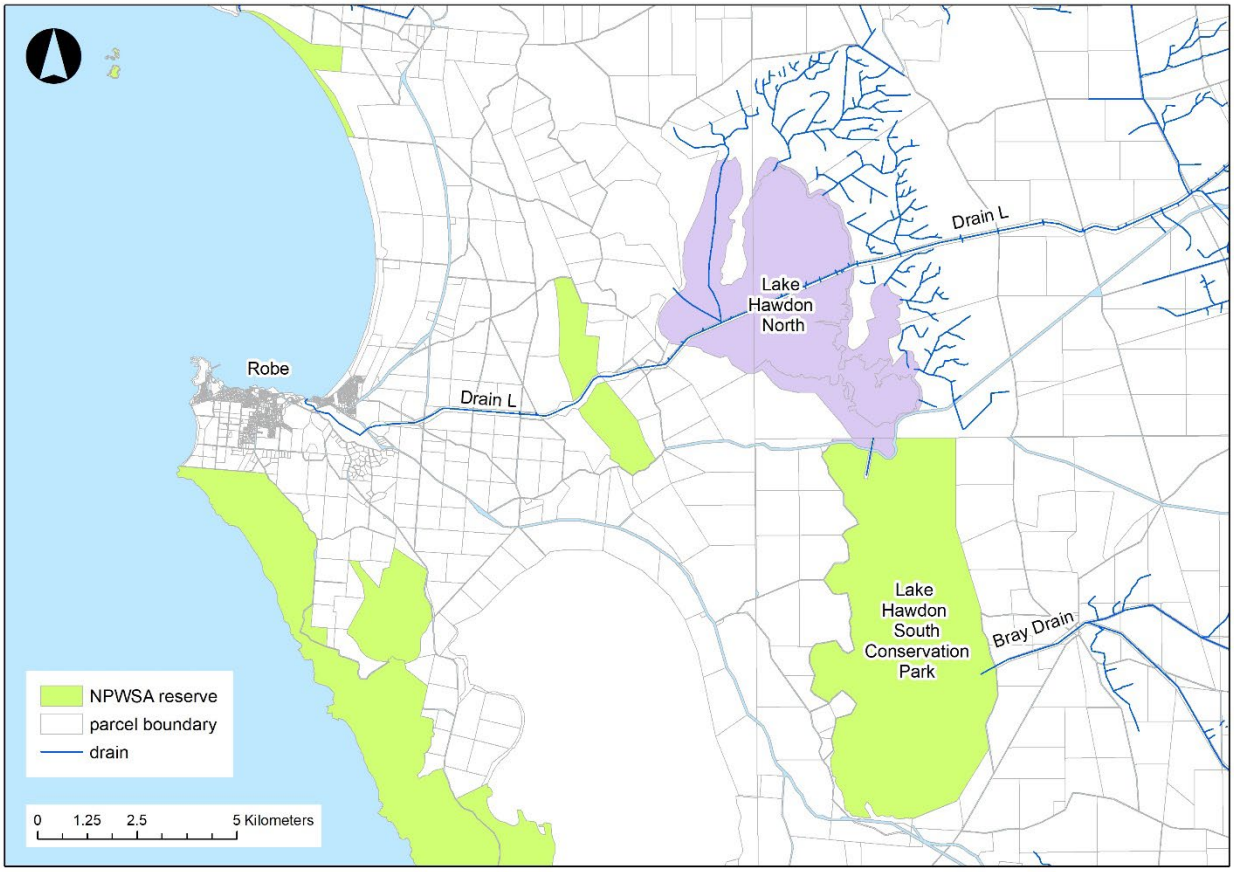

Figure 1. Location of Lake Hawdon North.

Lake Hawdon North is a shallow wetland, typically attaining a maximum depth of approximately 0.5 m when water levels peak in late winter/early spring. The lowest parts of the bed of Lake Hawdon North have an elevation of approximately 3.65 mAHD but most of the bed has an elevation of 3.80 – 4.00 mAHD (Figure 2). At a water surface elevation (WSEL) of 4.40 mAHD the wetland is considered full and is largely contained within its cadastral boundary, except for an area to the north (wetland S0108587) connected via a short drain. Even in its current, unrestored state, Lake Hawdon North regularly attains a water level well in excess of 4.40 mAHD, at which times inundation extends into surrounding agricultural properties. The volume of Lake Hawdon North when full, at a WSEL of 4.40 mAHD is 7,920 ML (Taylor et al. 2014), which is just 13.6 % of the average (22.1 % of median) annual discharge of Drain L, illustrating the high availability of water for hydrological restoration.

Prior to the construction of Drain L in 1915-18, and its enlargement in 1957-58 (SEDB 1980), Lake Hawdon North supported very little perennial vegetation. When dry it was largely a bare, open pan (Taylor et al. 2014) and when inundated it likely supported submerged aquatic plants. Since the late 1950s the bed of the wetland has become increasingly vegetated with a range of perennial plant communities, although some areas of open pan remain. Ecological Associates (2009b) comprehensively mapped the vegetation of Lake Hawdon North and described thirteen native plant associations and one non-native plant association. The displacement of open pan by perennial vegetation is clearly linked to the drying and freshening caused by Drain L, which was excavated through the bed of the wetland. Although it provides large volumes of fresh/brackish water, Drain L has severely compromised the hydrology of Lake Hawdon North, causing it to dry much earlier each year than would otherwise be the case.

Despite its compromised hydrology and related ecological changes that have occurred, Lake Hawdon North continues to support important ecological values, including many that could be enhanced by

restoration. Lakes Hawdon North and South were surveyed in 2000 as part of the comprehensive state-wide Biological Survey of South Australia (Stewart et al. 2001). Several rare and threatened taxa and vegetation communities were recorded and the wetland complex was recommended for reservation as a Conservation Park. The Lower South East Wetland Inventory (Taylor 2006) recognised Lake Hawdon North as a wetland of very high conservation value due to its large size, good condition and provision of habitat for threatened species. Christie and Jessop (2007) recorded internationally significant numbers of double-banded plover, *Charadrius bicinctus*, a migratory shorebird, at Lake Hawdon North in winter. Forty species of wetland-dependent birds have been recorded within the Lake Hawdon complex, including eight migratory shorebird species of the Scolopacidae family (Gosbell and Christie 2007, Stewart et al. 2001). The Lake Hawdon complex is part of the East Asian - Australasian Flyway (EAAF), encompassing Australia, New Zealand and another 21 countries (Hansen et al. 2016). All shorebird species that use the Lake Hawdon complex also utilise the Coorong South Lagoon with the exception of pectoral sandpiper, *Calidris melanotis*, which has not been recorded in the Coorong (Paton 2010) and prefers less saline wetlands. Open pan areas are the preferred habitat for waterfowl and waders, including migratory shorebirds, while *Baumea arthrophylla* sedgelands and *Gahnia filum* sedgelands provide habitat for more cryptic birds including the threatened Australasian bittern (*Botaurus poiciloptilus*), southern emu-wren (*Stipiturus malachurus*) and beautiful firetail (*Stagonopleura bella*), all recorded within the Lake Hawdon complex (Stewart et al. 2001). The nationally vulnerable fish little galaxias, *Galaxiella toourtkoourt*, was recorded in Drain L approximately 800 m downstream of Lake Hawdon North in June 2002 (Hammer 2002) and in high abundance upstream in Lake Hawdon South (Hammer and Tucker 2011). The Australian mudfish, *Neochanna cleaveri*, considered critically endangered in South Australia (Hammer et al. 2009), is also considered likely to use Lake Hawdon North (Hammer and Tucker 2011); the adjoining Lake Hawdon South is a regional stronghold for the species.

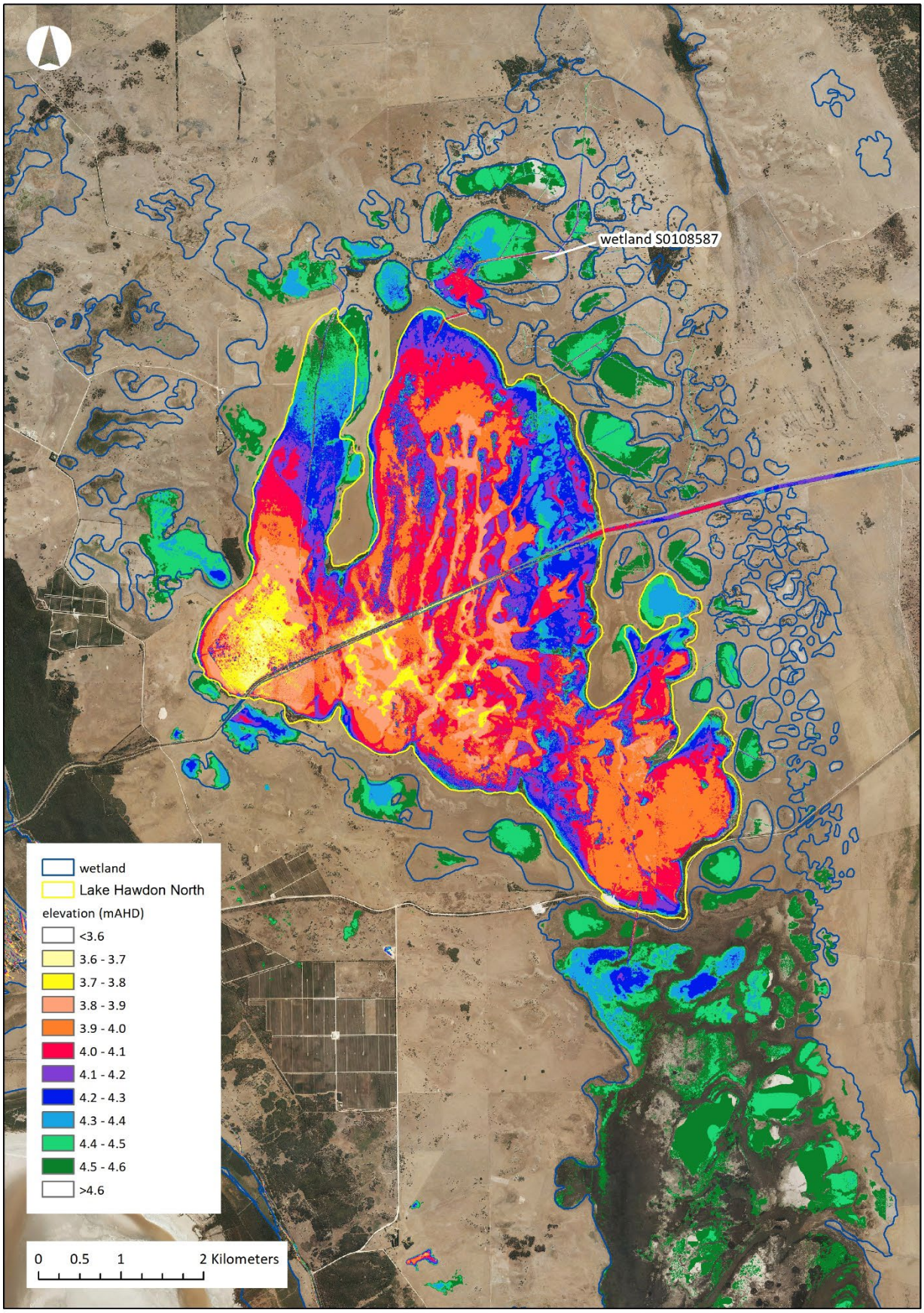

Figure 2. Bathymetry of Lake Hawdon North and adjoining areas, based on 2m² DEM.

2.3. *Historic vs Contemporary Ecohydrology*

In 1847 George French Angas described Lake Hawdon as *"… a flat, swampy plain, which, in the rainy season, is covered with water"* (Angas 1847). This observation was made prior to the alteration of natural drainage patterns in the region. Assuming Angas' description is based on typical conditions, the natural water regime of Lake Hawdon North involved winter/spring inundation and summer/autumn exposure. Originally Lake Hawdon North appears to have presented a localised terminus for surface water. Mapping prepared by the South Eastern Drainage Board (SEDB 1980) indicates that overflow from Lake Hawdon South and inflows from a local catchment to the east and north would have flowed into Lake Hawdon North and been retained there. As indicated by the digital elevation model (DEM) (Figure 3), there is no natural outlet for surface water from the wetland. The Woakwine Range prevented flow to the west and high ground to the north prevented outflows in that direction. It is noteworthy that the bed of Lake Hawdon North sits at a lower elevation than the bed of Lake Hawdon South, as indicated by the DEM (Figure 3). This suggests that, under natural conditions, inundation would have persisted for longer into the drier months in Lake Hawdon North compared to adjoining Lake Hawdon South, situated slightly upslope. Today, with Drain L excavated through the bed of Lake Hawdon North, the reverse situation occurs. Lake Hawdon North is the first of the two waterbodies to dry each summer, approximately 6 weeks earlier than Lake Hawdon South (Stewart et al. 2001).

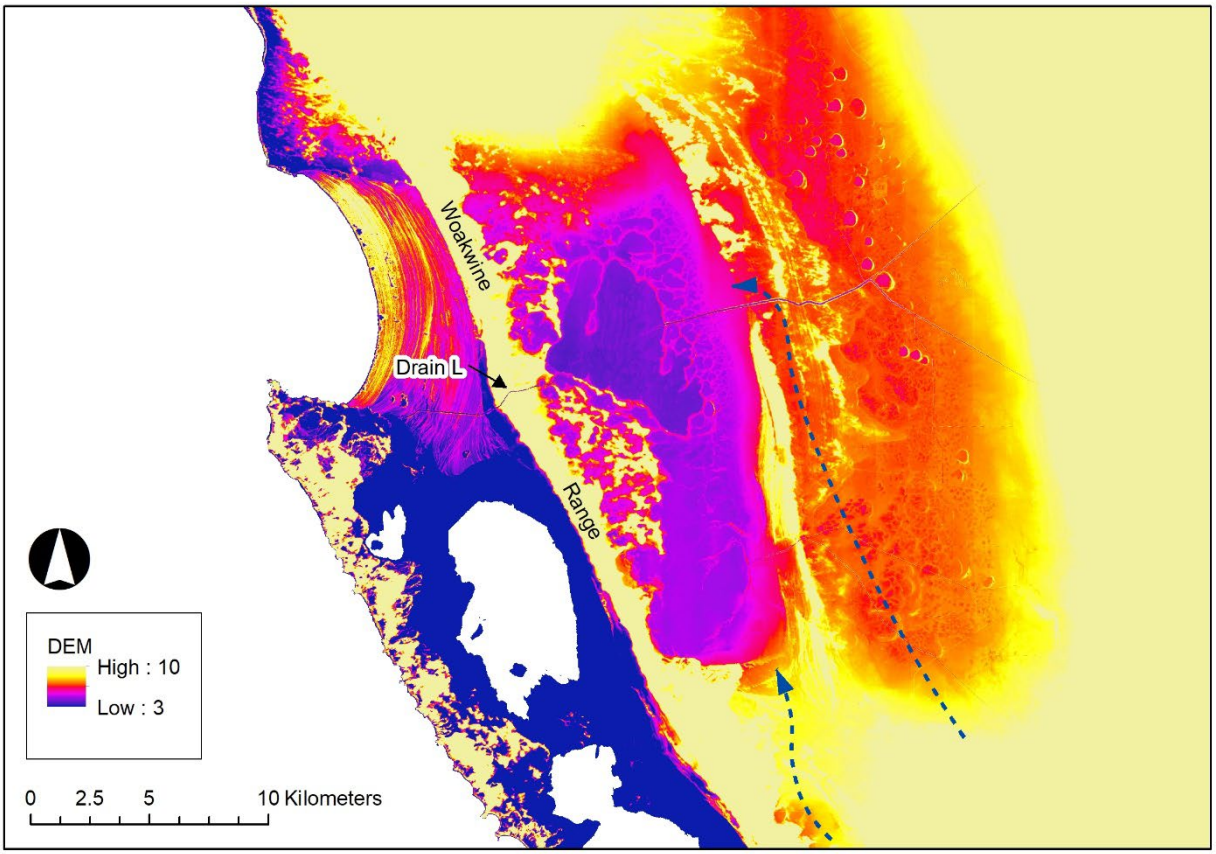

Figure 3. Digital elevation model (DEM) of the Lake Hawdon area. The historic flow paths into Lake Hawdon, as identified by SEDB (1980), are shown (blue dashed arrows).

The absence of an obvious natural outlet is underscored by the effort that was required to drain the Lake Hawdon system. Drain L was constructed in 1915-18 and involved massive excavation through the Woakwine Range (Figure 4). The capacity of Drain L was further enlarged in 1957-58 during the Anderson Scheme period of drain construction in the South East region (SEDB 1980).

Figure 4. Construction of Drain L cutting through the Woakwine Range, c.1915 (source: SEDB 1980).

The impact of Drain L upon the hydrology of Lake Hawdon North is illustrated by Figure 5. Water Observations from Space (WOfS), viewed via the National Maps website (DTA 2020), provides information on the spatial extent of surface water on the Australian Landscape, derived from satellite imagery, from 1986 to the present. Over the 34-year time period there are 593 observations of the Lake Hawdon complex. Figure 5 summarises those observations made from November to March inclusive. The November to March period is significant because it aligns with the period that most migratory shorebirds are present in the region. Figure 5 shows that there are several large basins in Lake Hawdon South that have reliable surface water from November to March. In contrast, inundation occurs rarely to never over much of the northern and western parts of Lake Hawdon North despite these areas including some of the most low-lying ground in the entire Lake Hawdon complex. The more frequently inundated (blue) area in the south of Lake Hawdon North lies within the mining lease and aligns with the void created by mining operations, which has artificially extended duration of inundation by creating deeper water. This map should be interpreted cautiously because dense vegetation appears to have prevented satellite detection of surface water in some areas, e.g. the western side of Lake Hawdon South. However, there are several open pans in the north-west of Lake Hawdon North within which satellite detection of surface water is highly likely if it is present, yet it was not detected.

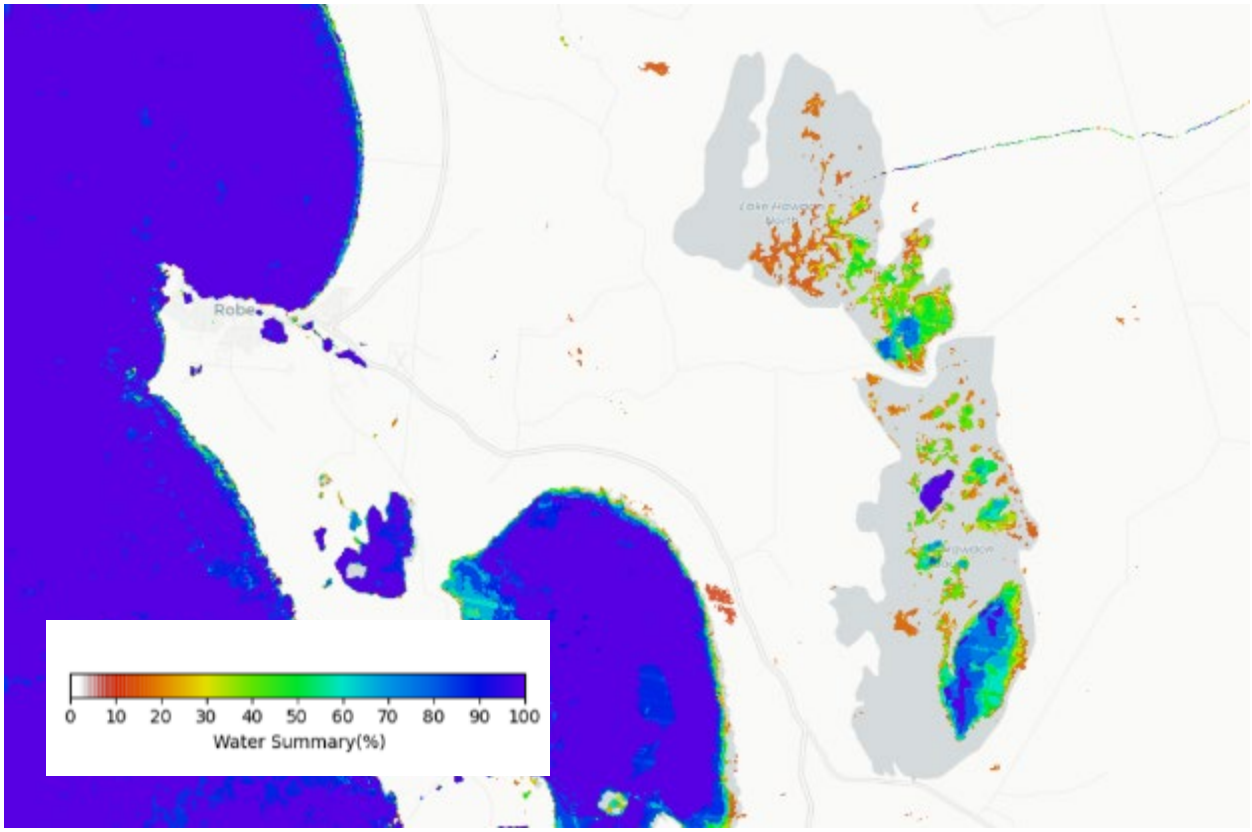

Figure 5. Summary of WOfS November to March observations (1986 – 2020) for the Lake Hawdon complex. The darker blue to purple areas had water present for a high proportion of observations, while red to orange areas had water present for a low proportion of observations. For areas without colour (i.e. the grey background polygons indicating the Lake Hawdon complex) water was never observed from November to March (source: DTA 2020).

Conceptually, Drain L has converted Lake Hawdon North into a floodplain wetland. For most of summer and autumn, low baseflows persist in Drain L, however inflow rates are less than drain capacity, therefore water is confined to the drain (Figure 6). In early winter, water levels rise within the drain, but inflow rates typically remain below drain capacity and water therefore remains confined to the drain. In late winter to early spring, flow rates typically exceed drain capacity and water spills out of the drain, inundating Lake Hawdon North. The depth and extent of inundation increase as the flow rate in Drain L increases. As the flow rate declines in late spring through early summer, water levels recede as the wetland drains back into Drain L. Water levels in Drain L are typically below the bed of Lake Hawdon North by late December (Section 4.1.2 below contains further detail).

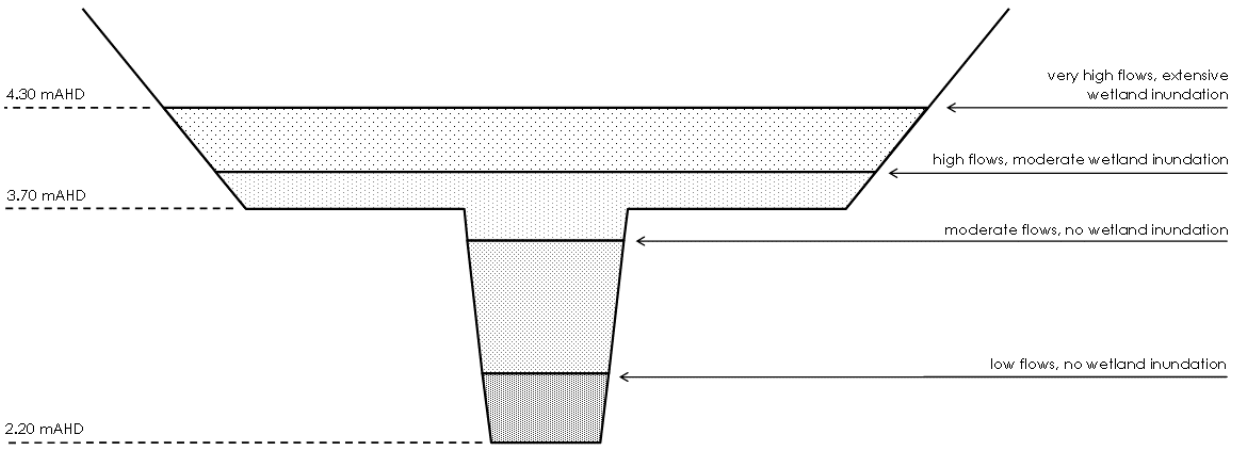

Figure 6. Conceptual cross section of Lake Hawdon North and Drain L.

The alteration of the hydrology of Lake Hawdon North by the construction and enlargement of Drain L has corresponded with dramatic changes to the vegetation of the wetland. Taylor *et al.* (2014) investigated vegetation change within Lake Hawdon North from 1958 to 2008, corresponding with the 50 year period following the enlargement of Drain L through the wetland in 1957-58. In 1958 Lake Hawdon North was almost entirely open pan (Figure 7). These open pans existed as bare mudflat when exposed and supported submerged aquatic vegetation when inundated, similar to open pan areas today. Over the following 50 years much of this open pan was displaced by herbland, sedgeland, *Gahnia filum* sedgeland and *Melaleuca halmaturorum* shrubland (Figure 8). In contrast, vegetation change within Lake Hawdon South, which does not have a large drain cut through its bed, was relatively minor during the same period. The dramatic changes to the vegetation of Lake Hawdon North are an example of terrestrialisation; plant species less tolerant of inundation invading a wetland area in response to a drying trend. Terrestrialisation, and invasion by *M. halmaturorum* in particular, has occurred at several other wetlands within the South East region (e.g. Dickson and Bachmann 2015, Tuck et al. 2019).

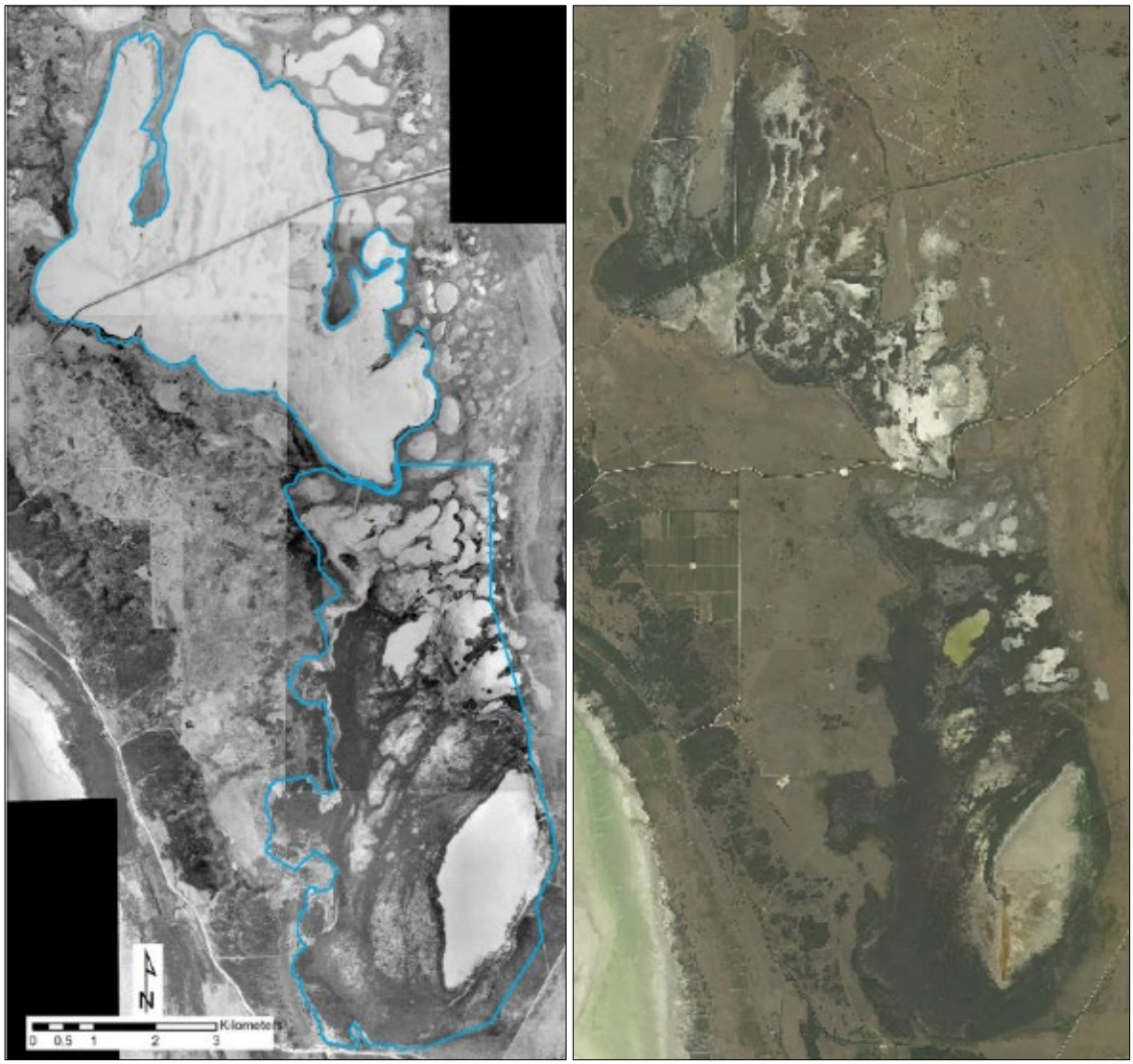

Figure 7. Aerial photography mosaic of the Lake Hawdon complex in 1958 (left) (source: Taylor et al. 2014) and 2019 (right).

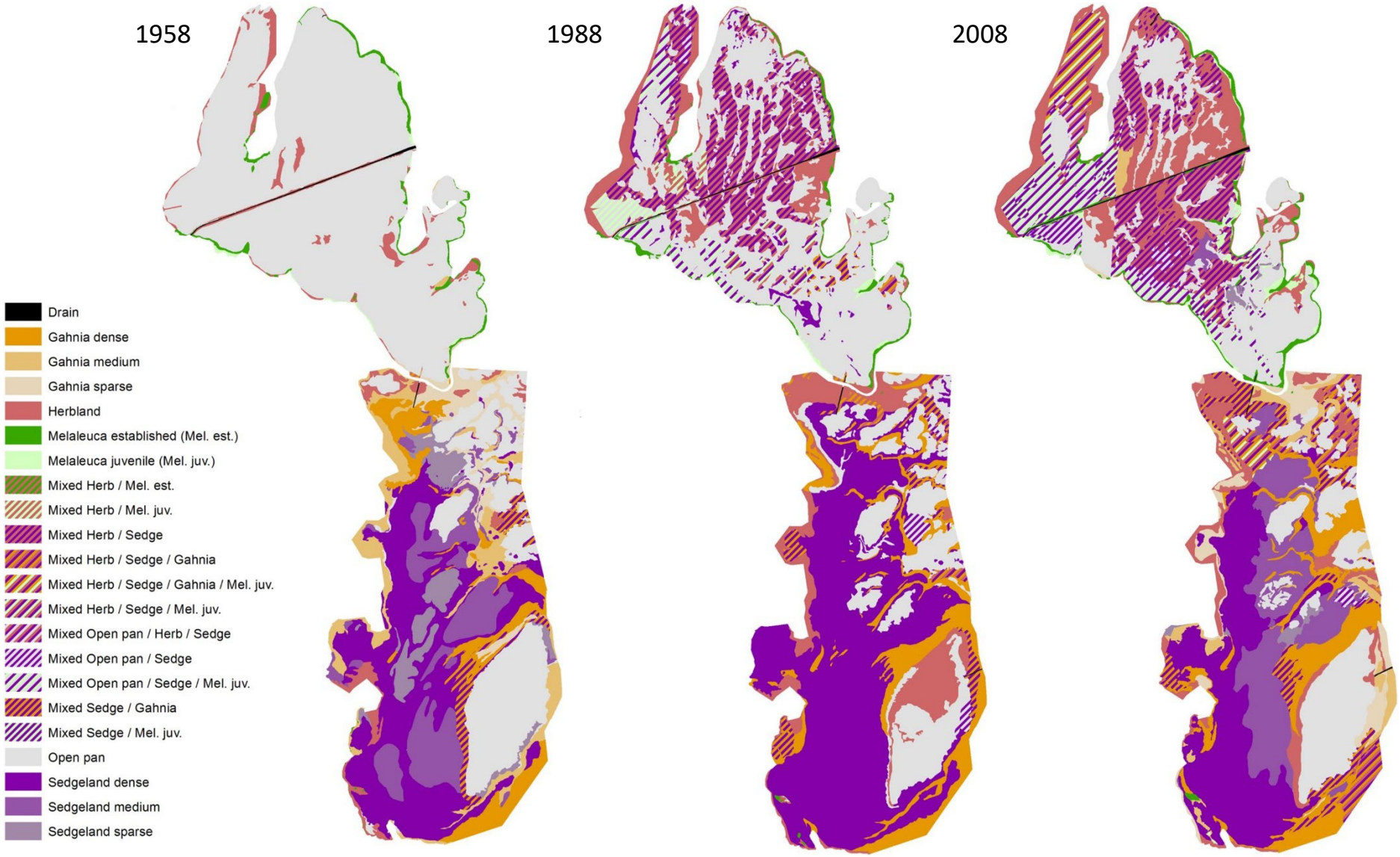

Figure 8. Vegetation of the Lake Hawdon complex in 1958, 1988 and 2008 (source: Taylor et al. 2014).

2.4. *Management*

2.4.1. Recent Management History

The future management of the Lake Hawdon complex was considered under the South East Coastal Lakes Strategy (Lands SA 1991), which recommended that a management plan be prepared, under the guidance of a steering committee, for the consideration of the Minister for Environment and Conservation. Thus, the Lake Hawdon Management Planning Steering Committee (LHMPSC) was established on 9th August 1999 (DEH 2007) and included representatives of the South East Consultative Committee, South Eastern Water Conservation and Drainage Board (SEWCDB), South Australian Field and Game Association Inc., local landholders and the then Department for Environment and Heritage (DEH). In 2007 the final recommendations of the LHMPSC were made via the Management Plan for Lake Hawdon North and South (DEH 2007). A key proposal was that the grazing licence over Lake Hawdon South be cancelled and that wetland be constituted as a conservation park. A grazing phase-out period of two years was allowed. It was recommended that Lake Hawdon North remain as unallocated Crown land and remain open to sheep grazing under occupational licenses. The Management Plan also states that "Drain L, the Bray Drain and the Lake Hawdon Connecting Drain should continue to be managed by the SEWCDB in the manner that it has been for the past decade." The hydrological restoration of Lake Hawdon North would thus be a departure from the recommendations of the LHMPSC. The Management Plan is not a statutory document and as such this does not preclude restoration, but makes comprehensive engagement with all stakeholders an essential element of the process.

2.4.2. Drainage Service

Lake Hawdon North acts as an equalisation basin that has importance in the provision of a drainage service to agricultural properties in the surrounding area. The 'as constructed' plans for Drain L indicate that its capacity immediately upstream of Lake Hawdon North is 44.457 m^3/sec, while immediately downstream of the wetland its capacity is 39.558 m^3/sec. The downstream capacity of Drain L is 4.899 m^3/sec, or 423 ML/day, less than upstream capacity. In addition to Drain L, inflows to Lake Hawdon North also include flows from the Bray Drain catchment, entering via Lake Hawdon South and the Lake Hawdon Connecting Drain, and flows from adjoining agricultural properties in minor drains. Thus at times, inflows to Lake Hawdon North greatly exceed the capacity of Drain L downstream. When this occurs, Lake Hawdon North acts as an equalisation basin, temporarily storing up to c.8,000 ML without compromising drainage of surrounding properties (Figure 9). At times, persistently high inflows cause the volume of water in Lake Hawdon North to exceed this, and drainage of adjoining properties is compromised (Figure 9).

Adjoining landholders are key stakeholders in the restoration of Lake Hawdon North because there is a risk of inundation of private agricultural land around the margins of the wetland.. Thus, the local farming community will have a high level of interest in the project and will need reassurance that their interests will be protected.

Figure 9. Left: Lake Hawdon North (middle ground) completely inundated but with water levels still permitting effective drainage of adjoining properties to the east (foreground), 1st October 2004. Right: similar view on 23 September 2016 with high water levels causing inundation of adjoining properties (photos: Ben Taylor).

2.4.3. Grazing

Grazing in the Lake Hawdon area has likely been continuous since the earliest days of European colonisation. Expanding on the quote from George French Angas cited previously, in a diary entry on April 29th 1844 Angas wrote (Angas 1847):

> *"We reached Lake Hawden – a flat, swampy plain, which, in the rainy season, is covered with water. There is good pasturage in the surrounding country, which rises into gently undulating hills lightly wooded with she-oak. We here fell in with Scott's party, who had brought several thousand sheep, in search of fresh runs for the next season."*

Note that the aforementioned good pasture was most likely located on the *surrounding* country, not the lake itself. The wetland bed was unlikely to have provided feed for livestock until it was drained, as explained in Section 2.3 above.

The wetland is contained within Sections 399 and 398, Hundred of Waterhouse, Section 89 and Allotments 107 and 108, Hundred of Ross, and Section 173, Hundred of Bray (Figure 10). The drain reserves for the Lake Hawdon Connecting Drain and Drain L are also partially within Lake Hawdon North. The sections that are not drain reserve are tenured as unallocated Crown land and grazed under annual occupational licences for sheep only (Table 2).

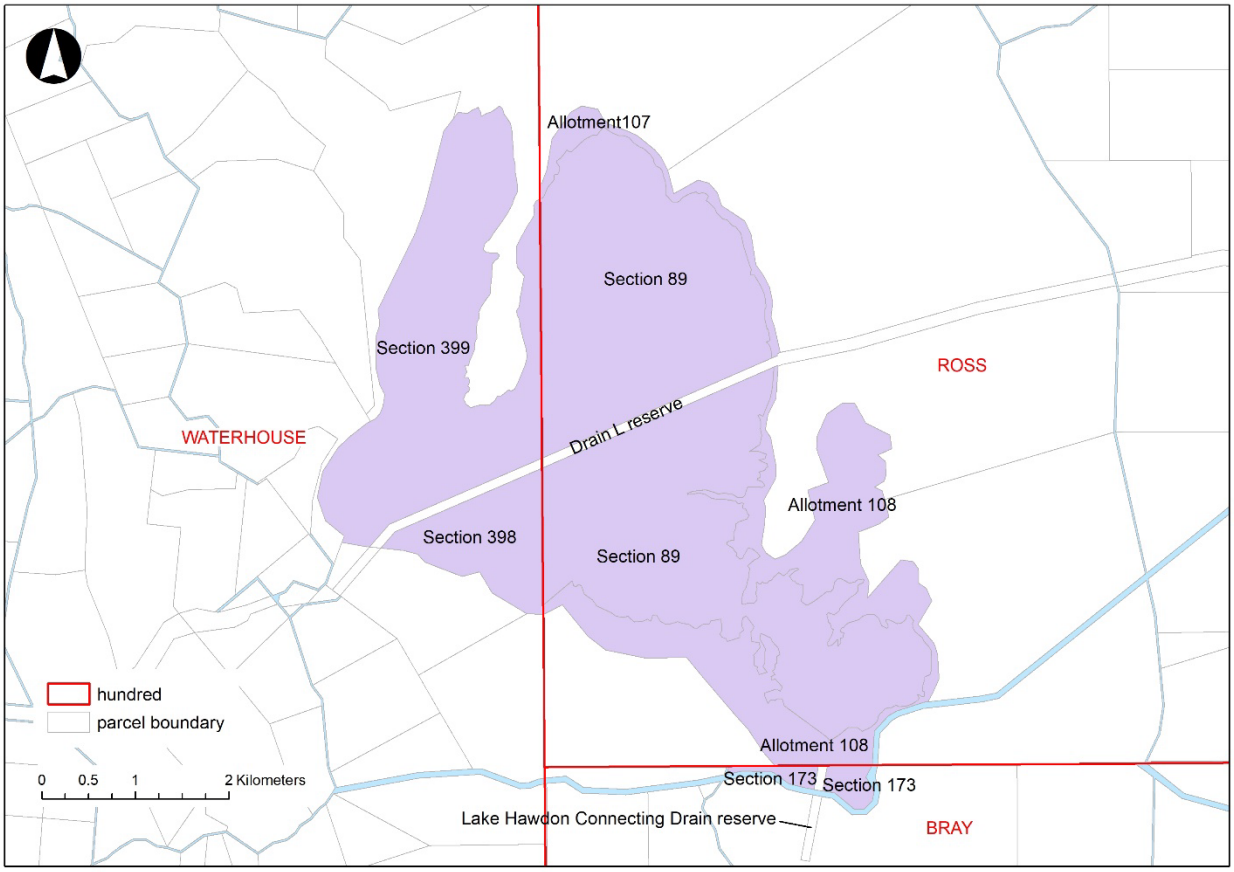

Figure 10. Cadastral information for Lake Hawdon North.

The holders of annual grazing licenses over Lake Hawdon North use the wetland for summer sheep grazing. Constructing a regulator to increase the duration of inundation may lower grazing value. However, parts of Lake Hawdon North, particularly the north-west, have become so dominated by *Melaleuca halmaturorum* shrubland in recent decades (Ecological Associates 2009b, Taylor et al. 2014), that they now have little to no grazing value. The north-west of Lake Hawdon North (Section 399, Figure 10) features two drains cut directly into the bed of the wetland that direct water into Drain L, the only such drains in addition to Drain L (Ecological Associates 2009b). The larger of these was licensed in 1990 (Ecological Associates 2009b) and may have contributed to the encroachment of *M. halmaturorum* shrubland despite ongoing grazing.

Vegetation can be cleared for ecological purposes under the Native Vegetation Act 1991 and clearance of *M. halmaturorum* shrubland within hydrologically restored wetlands in the South East has previously been approved by the Native Vegetation Council for the South East Flows Restoration Project. Hydrological restoration, in combination with strategic clearance of *M. halmaturorum* shrubland, would likely enhance the value of some parts of Lake Hawdon North for both grazing and waterbirds. Ground layer plants would be favoured and future recruitment of *M. halmaturorum* would be suppressed by a combination of increased depth and duration of inundation (in spring/summer) (see Denton and Ganf 1994) and grazing (in summer/autumn) (see Taylor and Brown 2019).

2.4.4. Mining

Agricola Mining Pty Ltd currently holds a mining lease for a 237 ha area of Lake Hawdon North, adjacent the Lake Hawdon Connecting Drain (Figure 11). Dolomitic limestone occurs as the surface material of the wetland bed. The mining process involves direct excavation and stockpiling of this surface material. The

company anticipates that mining will remove 0.3 to 0.8 m (average 0.5 m) of surface material from within the mining lease (Ecological Associates 2009b). It is understood that mining can only occur when the wetland bed is dry. The mining process itself, by making the wetland deeper, increases the depth and duration of inundation within mined areas. Deliberate hydrological manipulation to extend the duration of inundation of unmined areas within the mining lease may narrow the seasonal window during which mining is possible. It will be important to provide an assurance that conditions suitable for mining will still occur annually post-restoration. Complete drying of the wetland will remain a key aspect of any target water regime to support the vegetation (Ecological Associates 2009a, Taylor et al. 2014) and the ensure the water requirements of the Robe Lakes downstream are met (see Section 4.2.1).

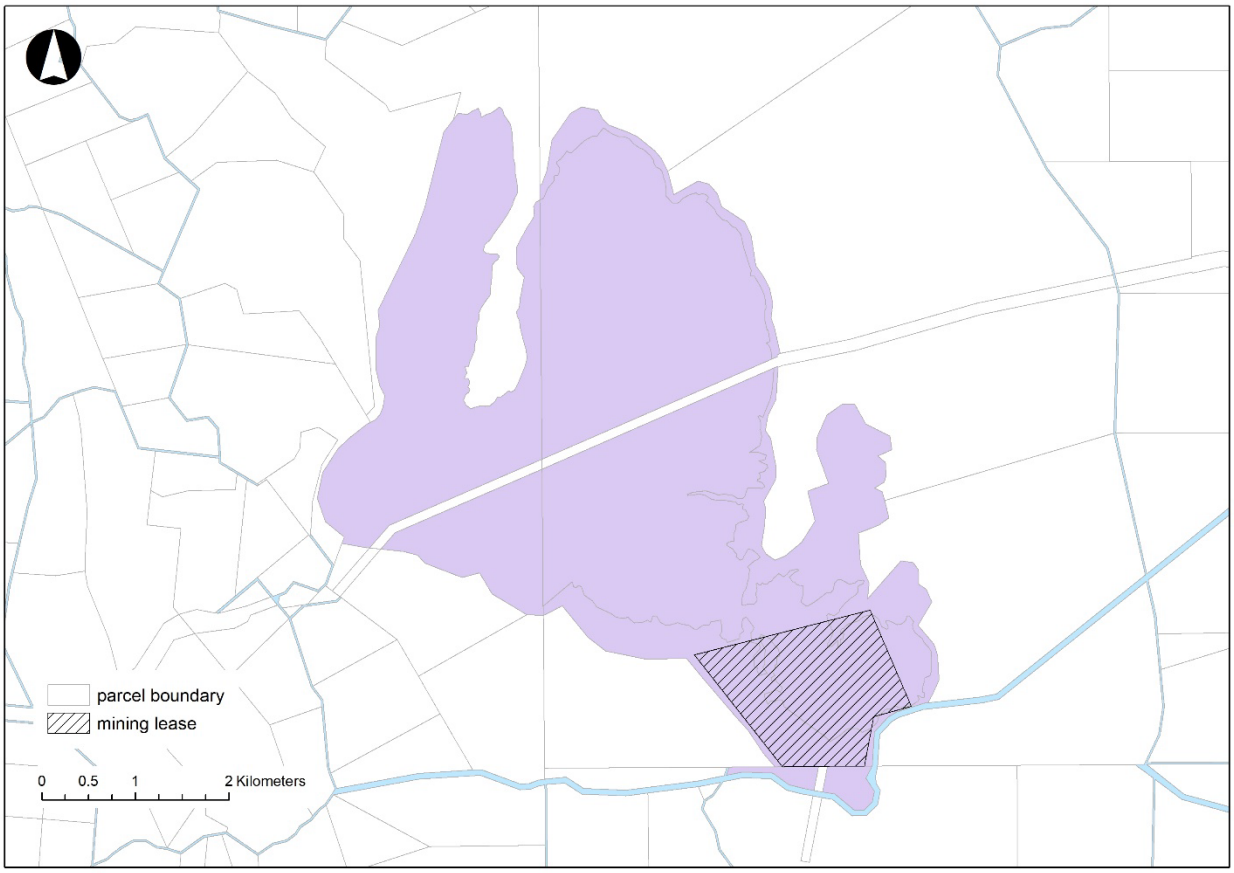

Figure 11. Location of mining lease at Lake Hawdon North.

3. Feasibility Assessment

3.1. *Restoration Actions*

3.1.1. Construct Regulator

To restore a more natural hydrology to Lake Hawdon North, with inundation persisting well into summer to align more closely with the presence of migratory shorebirds in the region, it is proposed that a regulator be constructed on Drain L at the outlet of Lake Hawdon North. This is the highest priority restoration action. The proposed location is on the western side of the wetland, at approximately E400757, N5887499, and is shown in Figure 12.

Figure 12. Proposed location of a regulator on Drain L (yellow star) to manage water levels in Lake Hawdon North. The direction of flow in the drain is also shown (yellow arrow) (photo: Ben Taylor).

The regulator would be open in late autumn/early winter but would be closed in late winter/early spring to achieve a target water level in Lake Hawdon North. During spring and summer, water levels would gradually decline due to a combination of spill over the regulator, and through its associated fishway, evaporation and seepage. A target hydrograph for Lake Hawdon North, and how it could be achieved by a regulator, is discussed in further detail in Section 4.1.2. Combined regulator spill and fishway flows would need to be sufficient to meet the environmental water requirements of the Robe Lakes downstream, discussed further in Section 4.2.1.

Essential design criteria of the proposed regulator are:

- Hydraulic invisibility under high Drain L flows – to ensure the regulator does not exacerbate flooding of agricultural properties adjoining Lake Hawdon North, which already occurs in wet years;
- Capacity to maintain upstream WSEL within the range 3.60 – 4.40 mAHD (target regulated peak level 4.30 mAHD – see Section 4.1.2);
- Permit fish passage across the full range of regulated upstream WSEL for fish size ranges from Galaxias whitebait to adult Black Bream (see Hammer et al. 2012);
- Ability to pass flows, additional to fishway flows, to meet downstream environmental water requirements whilst maintaining target upstream WSEL;

- Resistant to damage from bushfires through choice of construction materials and maintenance of a cleared buffer around the structure.

Desirable design criteria:

- Automated for remote operation but with manual override;
- Minimal operation and maintenance costs.

The regulator would be constructed within the Drain L reserve, land managed by the SEWCDB. The regulator would therefore likely become an SEWCDB asset and the Board would be responsible for its operation and maintenance. The involvement and support of the SEWCDB in all stages of the project, from concept design through community engagement, detailed design, construction, operation and maintenance, is imperative to the success of the project.

Recently constructed regulators in the South East drainage network that provide relevant examples of design and objectives include the Morella outlet regulator and the Blackford diversion weir.

A concept design for the Drain L regulator has been prepared separately by Tonkin.

3.1.2. Clear *Melaleuca halmaturorum* Shrubland

The displacement of open pan habitat by perennial vegetation, particularly *Melaleuca halmaturorum* shrubland, has been extensive at Lake Hawdon North since the late 1950s (Taylor et al. 2014) and is an example of terrestrialisation corresponding with reduced duration of inundation caused by drainage. Shorebirds, and in particular those targeted for the HCHB RBR, forage in shallowly inundated areas of open pan (Geering et al. 2007). The 1958 vegetation mapping presented previously (Figure 8) shows that almost the entire 2,475 ha area of Lake Hawdon North was, at that time, potential shorebird foraging habitat when water levels were suitable. Some of the perennial vegetation associations that have colonised the lake bed in recent decades are unlikely to support shorebird foraging, even when water levels are suitable, as they are too dense. The finest scale vegetation mapping of Lake Hawdon North was undertaken in 2009 (Ecological Associates 2009b), which ground–truthed the 2008 aerial imagery and used the Native Vegetation Information System (NVIS) approach (see NVIS Technical Working Group 2017) to describe the vegetation of the wetland. (Note that although the mapping by Taylor *et al.* (2014) was completed more recently, it is not more up to date as it was also based on the 2008 aerial imagery. Additionally, it used a coarser scale descriptive approach). Ecological Associates (2009b) recognised 13 plant associations at Lake Hawdon North, listed in Table 3 with their total extent and assumed suitability as foraging habitat for the shorebird species targeted by the HCHB RBR, based on structure.

There is a recent precedent for the approval of clearance of *M. halmaturorum* shrubland that has invaded formerly open pan wetland habitat in the South East; such clearance was approved in the Tilley Swamp Watercourse for the South East Flows Restoration Project. Clearance of *M. halmaturorum* shrubland on the bed of Lake Hawdon North would achieve similar objectives. Of the 13 plant associations mapped by Ecological Associates (2009b) (Table 3), four are proposed for clearance:

- (Code B) *Melaleuca halmaturorum* Tall open shrubland over *Gahnia filum* sedges over *Schoenus nitens*, +/- *Selliera radicans* sedges;
- (Code I) *Melaleuca halmaturorum* Tall shrubland over *Gahnia filum* sedges over +/- *Schoenus nitens* sedges;

- (Code N) *Melaleuca halmaturorum*, +/- *Gahnia filum* Mid open shrubland over *Schoenus nitens* sedges; and
- (Code Q) *Melaleuca halmaturorum*, +/- *Gahnia filum* Low open shrubland over *Austrodanthonia setacea* tussock grasses over *Schoenus nitens*, *Selliera radicans* sedges.

These associations are recently established on the bed of the wetland (Ecological Associates 2009b) and their clearance, combined with restored hydrology, ongoing grazing and an appropriate fire regime, is predicted to convert 650 ha from unsuitable to suitable foraging habitat for shorebirds. This clearance is also likely to provide improved sheep grazing outcomes.

Of the remaining nine plant associations:

- Three associations (Codes C, H and K), total area 825 ha, are already suitable as shorebird foraging habitat and would remain so under restoration;
- Two associations (Codes O and R), total area 346 ha, already provide suitable shorebird foraging habitat when subject to extended inundation, which reduces the cover of pasture grasses and creates a more open habitat, and would remain so under a restored scenario; and
- Four associations (Codes D, F, J and M), total area 630 ha, are currently unsuitable as foraging habitat for shorebirds and would likely remain unsuitable under restoration. These associations should not be cleared as they are either pre-Drain L remnant *M. halmaturorum* shrubland, *G filum* dominated associations that are rated as regionally rare (Croft et al. 1999) or, in the case of *B. arthrophylla* dominated associations, provide suitable habitat for nationally threatened species (e.g. Australasian Bittern). Thus, they provide ecological values complementary to the primary objective of restoring shorebird foraging habitat.

The above information is summarised in Table 3. Predicted changes to plant associations under restoration are informed by preferred water regimes identified by previous studies (see Ecological Associates 2009a, 2010) and vegetation monitoring that has documented the response of Lake Hawdon complex vegetation to grazing and fire (Taylor and Brown 2019).

The above estimates of area are approximate because the 2009 vegetation mapping combined some plant associations into mosaics and it is difficult to estimate the total extent of a given association where this has been done. Figure 12 uses the above information and the 2009 vegetation mapping to select the areas most likely to remain unsuitable as shorebird foraging habitat under restoration. The total extent is 662 ha. Under restoration, 1,763 ha of Lake Hawdon North is anticipated to provide suitable shorebird foraging habitat when water levels are appropriate.

Table 2. Plant associations of Lake Hawdon North (Ecological Associates 2009b), suitability as shorebird foraging habitat and predicted changes under restoration.

Code	Plant Association	Extent (ha)	Current suitability for shorebird foraging	Mechanically Clear?	Predicted change under restoration*	Predicted suitability for shorebird foraging under restoration*
B	*Melaleuca halmaturorum* Tall open shrubland over *Gahnia filum* sedges over *Schoenus nitens*, +/- *Selliera radicans* sedges	307	unsuitable	yes	Decline in cover of *M. halmaturorum* and *G. filum*	suitable
C	DRY: +/- *Selliera radicans*, +/- *Wilsonia backhousei*, +/- *Angianthus preissianus*, +/- *Schoenus nitens*, +/- *Lilaeopsis polyantha*, +/- Gramineae sp. Low sparse forbland. INUNDATED: *Myriophyllum verrucosum* Low sparse aquatic bed over +/- *Selliera radicans*, +/- *Wilsonia backhousei*, +/- *Angianthus preissianus*, +/- *Schoenus nitens*, +/- *Lilaeopsis polyantha*, +/- Gramineae sp. forbs	375	suitable	no	Decline in cover of forbs during dry phase	suitable
D	*Gahnia filum* Tall sparse sedgeland over *Baumea arthrophylla*, *Austrodanthonia setacea*, +/- *Danthonia semiannularis* (NC), +/- *Juncus kraussii*, +/- **Lolium rigidum* sedges over *Selliera radicans*, *Schoenus nitens*, *Pratia irrigua*, +/- *Angianthus preissianus*, +/- *Samolus repens*, +/- *Wilsonia rotundifolia*, +/- **Leontodon taraxacoides* ssp. *taraxacoides* forbs	313	unsuitable	no	Decline in cover of *G. filum* and grasses, increased cover of *B. arthrophylla*	unsuitable
F	*Gahnia filum* Tall sedgeland +/- emergent *Melaleuca halmaturorum* over +/- *Angianthus preissianus*, +/- *Wilsonia backhousei*, +/- *Selliera radicans*, +/- *Sarcocornia quinqueflora*, +/- *Wilsonia rotundifolia*, +/- *Deyeuxia minor* forbs	186	unsuitable	no	Decline in cover of *M. halmaturorum* and *G. filum*	unsuitable

Code	Plant Association	Extent (ha)	Current suitability for shorebird foraging	Mechanically Clear?	Predicted change under restoration*	Predicted suitability for shorebird foraging under restoration*
H	DRY: *Angianthus preissianus*, *Wilsonia backhousei*, +/- *Selliera radicans*, +/- *Pratia irrigua*, +/- *Schoenus nitens*, +/- *Wilsonia rotundifolia*, +/- *Deyeuxia minor*, +/- *Sebaea albidiflora*, +/- *Cotula vulgaris* var. *australasica* Low forbland. INUNDATED: *Myriophyllum verrucosum* Low sparse aquatic bed over *Angianthus preissianus*, *Wilsonia backhousei*, +/- *Selliera radicans*, +/- *Pratia irrigua*, +/- *Schoenus nitens*, +/- *Wilsonia rotundifolia*, +/- *Deyeuxia minor*, +/- *Sebaea albidiflora*, +/- *Cotula vulgaris* var. *australasica* forbs.	417	suitable	no	Decline in cover of forbs during dry phase	suitable
I	*Melaleuca halmaturorum* Tall shrubland over *Gahnia filum* sedges over +/- *Schoenus nitens* sedges	117	unsuitable	yes	Decline in cover of *M. halmaturorum* and *G. filum*	suitable
J	*Melaleuca halmaturorum* Tall closed shrubland over *Rhagodia candolleana* ssp. *candolleana* shrubs over +/- *Tetragonia implexicoma*, +/- *Samolus repens* forbs	60	unsuitable	no	No change	unsuitable
K	*Cotula vulgaris* var. *australasica*, **Hordeum marinum*, **Polypogon monspeliensis*, +/- *Samolus repens* Low forbland over *Isolepis cernua*, +/- *Sarcocornia quinqueflora*, +/- *Wilsonia rotundifolia*, +/- *Pratia irrigua* sedges	33	suitable	no	Decline in cover of all species	suitable
M	*Baumea arthrophylla* Low sedgeland over *Selliera radicans*, *Schoenus nitens*, *Pratia irrigua*, *Angianthus preissianus*, *Wilsonia backhousei*, +/- Graminae sp. Forbs	71	unsuitable	no	Increased cover of B. arthrophylla	unsuitable
N	*Melaleuca halmaturorum*, +/- *Gahnia filum* Mid open shrubland over *Schoenus nitens* sedges	206	unsuitable	yes	Decline in cover of *M. halmaturorum* and *G. filum*	suitable

Code	Plant Association	Extent (ha)	Current suitability for shorebird foraging	Mechanically Clear?	Predicted change under restoration*	Predicted suitability for shorebird foraging under restoration*
O	**Lolium rigidum*, **Hordeum marinum*, *Samolus repens*, +/- **Parapholis incurva*, +/- *Sarcorcornia quinqueflora*, +/- *Juncus kraussii*, +/- **Polypogon monspeliensis* Low grassland +/- emergent *Gahnia filum*, +/- emergent *Melaleuca halmaturorum* over *Pratia irrigua*, *Sabaea albidiflora*, +/- *Schoenus nitens*, +/- *Selliera radicans*, +/- *Wilsonia rotundifolia*, +/- *Isolepis cernua* forbs	164	suitable when subject to extended inundation	no	Decline in cover of grassland species, *G. filum* and *M. hamaturorum*. Increased cover of forbs.	suitable when subject to extended inundation
Q	*Melaleuca halmaturorum*, +/- *Gahnia filum* Low open shrubland over *Austrodanthonia setacea* tussock grasses over *Schoenus nitens*, *Selliera radicans* sedges	20	unsuitable	yes	Decline in cover of *M. halmaturorum*, *G. filum* and *A. setacea*.	suitable
R	Non native vegetation: typically exotic pasture grasses +/- sparse native forbs and/or sedges	182	suitable when subject to extended inundation	no	No change	suitable when subject to extended inundation

*restoration = clear selected shrubland associations, increase duration of inundation, maintain grazing and implement appropriate fire regime.

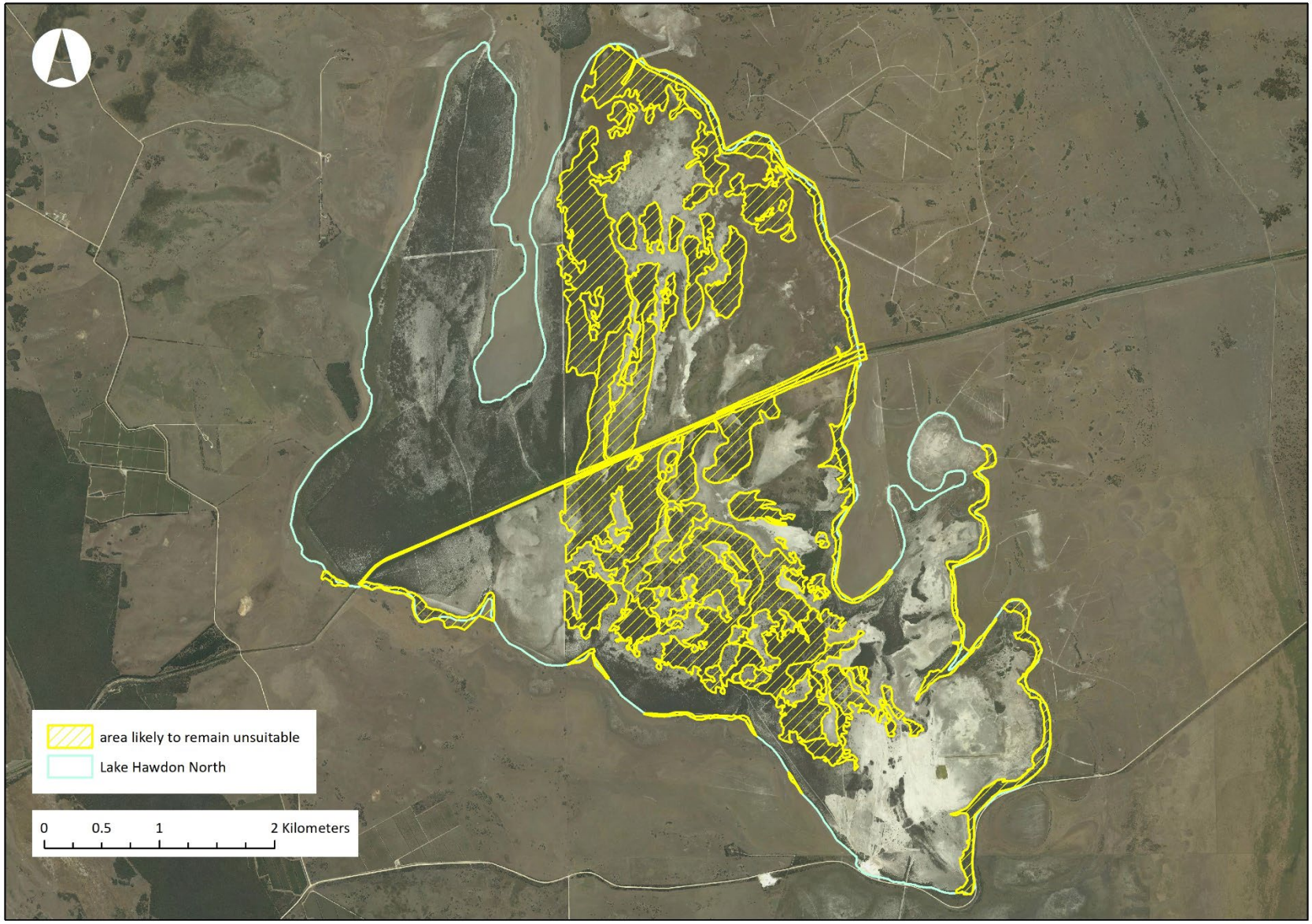

Figure 13. Areas of Lake Hawdon North likely to remain unsuitable as shorebird foraging habitat under restoration (adapted from Ecological Associates 2009b).

3.1.3. Maintain Grazing

The effects of grazing upon the vegetation of the Lake Hawdon complex have been under consideration for several decades. Sheep exclosures were established at four locations in the Lake Hawdon complex in 1984 for this purpose. Monitoring of vegetation within the exclosures and in adjacent control (grazed) quadrats was undertaken but these data have not been obtained for the current assessment. However, a photograph of one of the exclosures taken 18 years after establishment (Figure 14) is informative. Eighteen years of grazing exclusion led to the establishment of dense *Melaleuca halmaturorum* shrubland within the exclosure, while the adjoining control area, subject to ongoing grazing, had little to no *M. halmaturorum* and a much more open structure featuring sparse *Gahnia filum* tussocks. This suggests that grazing has played an important role in suppressing, or at least delaying, the establishment of *M. halmaturourum* shrubland and maintaining an open vegetation structure at Lake Hawdon North and the current hydrology.

Another vegetation monitoring program within the Lake Hawdon complex, which commenced in 2008 (Ecological Associates 2008) and is ongoing, has made similar findings. Monitoring has revealed mass establishment of *M. halmaturorum* in Lake Hawdon South following the permanent removal of sheep in 2009, while control sites in Lake Hawdon North, where grazing has continued, have shown no change in the abundance of *M. halmaturorum* over the same time period (Taylor and Brown 2019) (Figure 15).

Figure 14. Grazing exclosure (left of fence) and adjoining control (grazed) site (right), Lake Hawdon North, 27th February 2002 (photographer unknown).

Extending the duration of inundation of Lake Hawdon North through operation of a regulator on Drain L would likely help supress further establishment of *M. halmaturorum* shrubland (see Denton and Ganf 1994). However, given the likelihood of future dry years with minimal inundation, likely to increase as

climate change intensifies (CSIRO 2018), hydrological restoration alone is unlikely to completely prevent future expansion of *M. halmaturorum* shrubland.

Taylor and Brown (2019) also found that following the cessation of sheep grazing at Lake Hawdon South, herbland vegetation (analogous to Code H, Table 3), was displaced by *Gahnia filum* and *Baumea arthrophylla* sedges (Figure 16). This represents a major change from a low and open structure, likely to provide suitable foraging habitat for shorebirds when shallowly inundated, to a much more dense structure that is less favoured by shorebirds, even when water levels are suitable.

Given the unsuitability of *M. halmaturorum* shrubland, *G. filum* sedgeland and *B. arthrophylla* sedgeland as foraging habitat for shorebirds, and evidence that grazing helps prevent the expansion of these associations and the maintenance of a lower, more open structure, ongoing grazing of Lake Hawdon North is recommended.

Figure 15. Top row: Melaleuca halmaturorum *recruitment monitoring site in Lake Hawdon North (grazed control) in 2013 (left) and 2019 (right). Bottom row:* M. halmaturorum *recruitment monitoring site in Lake Hawdon South (sheep permanently removed May 2009) in February 2010 (left) and April 2019 (right). (photos: Ben Taylor).*

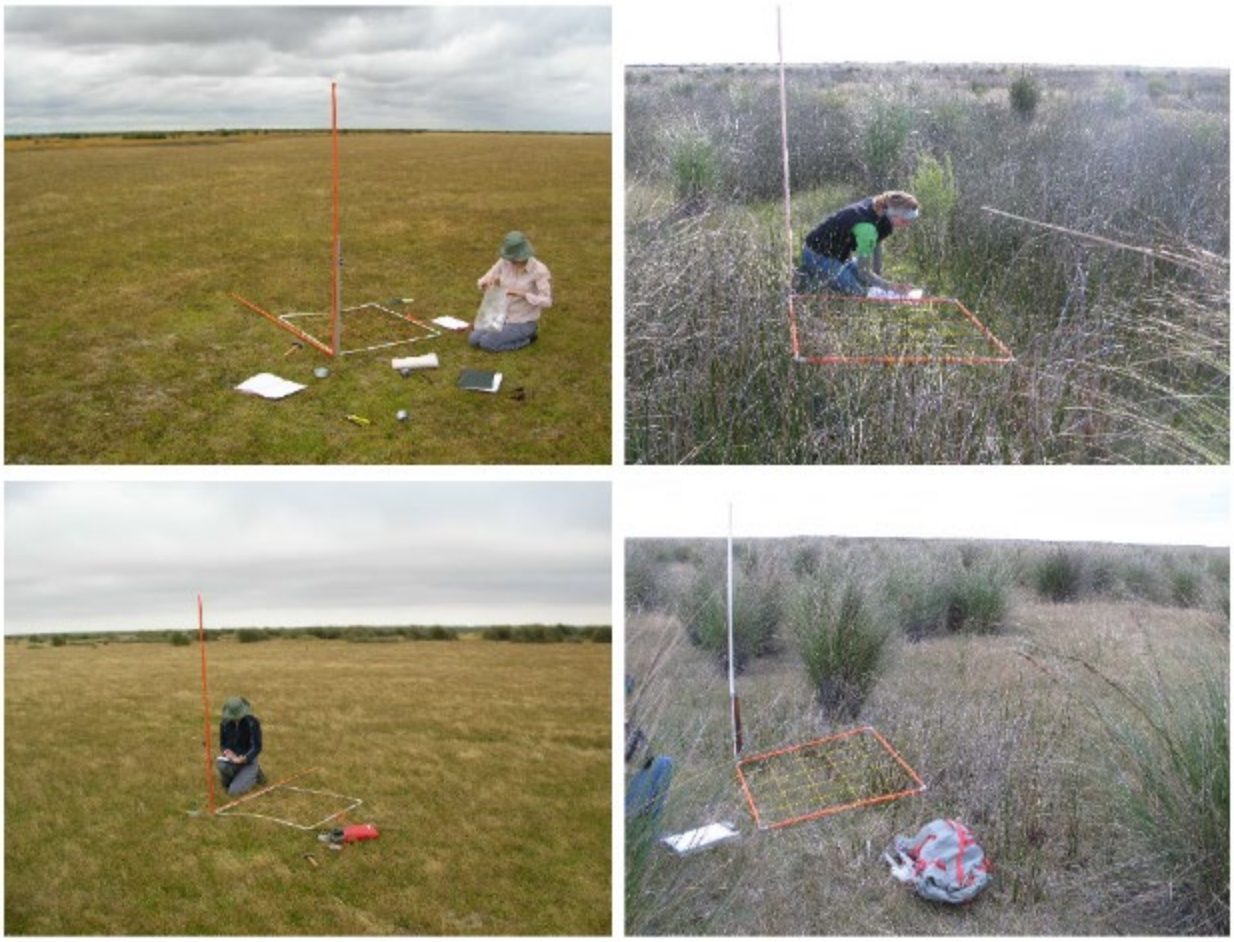

Figure 16. Top row: Lake Hawdon South herbland monitoring site 1 in 2008 (left) and 2019 (right). Bottom row: herbland monitoring site 4 in 2008 (left) and 2019 (right) (photos Ben Taylor).

3.1.4. Fire Management

A prescribed burn in Lake Hawdon South in April 2018 provided the opportunity to examine the effect of this management tool upon the vegetation of the wetland. Mostly *Gahnia filum* sedgeland was burned but some areas of *Baumea arthrophylla* sedgeland were also included. Analysis of before and after monitoring data indicated fire can play a role in maintaining the floristic diversity of this vegetation (Taylor and Brown 2019). While *Gahnia filum* sedgeland is less suitable as foraging habitat for shorebirds than open pan, its optimal management will remain important within a restored Lake Hawdon North. Importantly, the April 2018 fire killed established *Melaleuca halmaturourum* shrubs on the bed of Lake Hawdon South and subsequent recruitment appears to have been relatively limited, though further monitoring is required to confirm this. Fire appears to be another tool, in addition to hydrology and grazing, that can be used to manage *M. halmaturorum* and thereby help prevent the displacement of open pan habitat.

Prior to reservation, regular fire was used by the grazing licensee of Lake Hawdon South to maintain a more open structure and encourage ground layer plants that provide feed for sheep, particularly with *Gahnia filum* sedgeland, (Taylor and Brown 2019). This activity likely also had ecological benefits, helping to maintain floristic diversity and prevent shrub invasion. Enabling more frequent burning of the vegetation of Lake Hawdon North is likely to have similar benefits and may also help win support for restoration from grazing licensees.

3.1.5. Proclaim as a Regional Reserve

The existing ecological values of Lake Hawdon North, and the enhanced values under a restored scenario, warrant formal protection. It is recommended that the tenure of land parcels that comprise Lake Hawdon North be changed from unallocated Crown land to Regional Reserve status under the South Australian *National Parks and Wildlife Act 1972*. The Regional Reserve category of conservation reserve protects the ecological values of land while, at the same time, permitting the utilisation of the natural resources of that land. This category would permit both mining (within the existing mining lease) and grazing to continue. The proclamation of Lake Hawdon North as a Regional Reserve would secure conservation management in perpetuity and thereby provide insurance for the restoration investment.

4. Impact Assessment

4.1. *Environmental Benefits*

4.1.1. Increased Shorebird Habitat Extent

To quantify changes to shorebird foraging habitat availability under current versus restored scenarios, a definition of shorebird foraging habitat is required. Broadly, shorebirds forage in the shallow edges of inundated wetlands (or the intertidal zone of beaches) where vegetation is sparse to absent (Geering et al. 2007). Different shorebird species have different optimal foraging depths, reflecting their different leg and beak lengths (Paton 2010). Optimal foraging depths for HCHB RBR target shorebirds are discussed in Section 1.2.

Past shorebird surveys (see Section 4.1.3 below) illustrate that the Lake Hawdon complex regularly supports internationally significant numbers of migratory shorebirds, specifically Sharp-tailed Sandpipers. It is also apparent that, of the HCHB RBR target shorebirds, only the migratory shorebirds and Red-capped Plover occur in the Lake Hawdon complex in significant abundance. Banded Stilt and Red-necked Avocet have been recorded only occasionally and in very low abundance. This may be due to the timing of past surveys, typically in late January/early February. Banded Stilt and Red-necked Avocet may occur in higher abundance earlier in the season, i.e. late winter to early summer. Note however that neither species were observed in Lake Hawdon South in November or December 1999 (Table 6). We have therefore assumed that restoration is likely to provide benefits for the four migratory shorebird species and Red-Capped Plover (RCP) and have excluded Banded Stilt and Red-necked Avocet from further analysis.

We have used the following definition of suitable habitat for the HCHB RBR target migratory shorebirds and RCP: open pan habitat inundated to a depth of greater than 0 cm and less than 10 cm (0 – 10 cm). The amount of open pan habitat in Lake Hawdon North can be increased via the 650 ha of vegetation clearance described in Section 3.1.1, maintained as open pan thereafter via restored hydrology, ongoing grazing and potentially increased fire frequency. However, to quantify increased shorebird habitat availability, water levels must also be considered. The relationship between water surface elevation (WSEL) and suitable habitat in Lake Hawdon North under unrestored (current) and restored scenarios is shown in Figure 17. The relationship was calculated from the high resolution (2 m^2) DEM obtained from LiDAR flown in 2007. The unrestored scenario includes only the existing open pan vegetation types suitable for shorebird foraging, 1113 ha in total, while the restored scenario includes existing suitable foraging habitat plus currently unsuitable vegetation types proposed for clearance under restoration, 1763 ha in total.

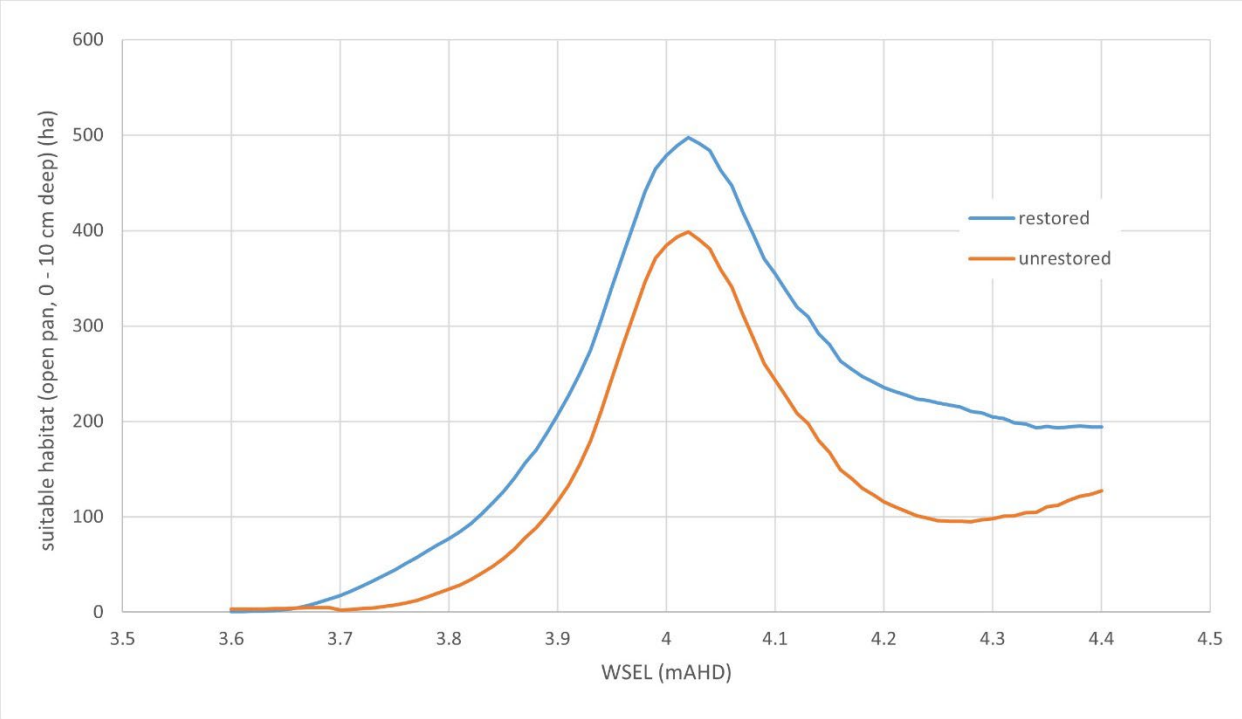

Figure 17. Relationship between WSEL and area of suitable habitat for migratory shorebirds + RCP (open pan, 0 – 10 cm deep) in Lake Hawdon North under unrestored (current) and restored scenarios. The restored scenario assumes clearance of recently invaded Melaleuca halmaturorum *shrubland and its reconversion to open pan.*

Figure 17 shows that, under both unrestored and restored scenarios, as water level increases, the area of suitable habitat increases until it peaks at a WSEL of just over 4.0 mAHD, and thereafter declines as water levels rise to full (approximately 4.4 mAHD). This is because the shape of the area inundated becomes increasingly complex, with more "edge" habitat, as water levels increase from 3.65 to 4.0 mAHD, but simplifies in shape thereafter, with much topographic complexity inundated to a depth greater than 10 cm and therefore unsuitable for migratory shorebirds + RCP. Notably, the area of suitable habitat is consistently approximately 100 ha greater under the restored scenario, with recently invaded *M. halmaturorum* shrubland cleared and maintained as open pan, compared to the unrestored scenario.

4.1.2. Increased Shorebird Habitat Availability

There are no surface water level monitoring data available for Lake Hawdon North. A telemetered water level logger was installed in the wetland in May 2013 but was decommissioned approximately one year later and the small amount of data obtained are considered unreliable. To understand the current hydrology of Lake Hawdon North, and how restoration could better align inundation with the period that migratory shorebirds are present, a modelling approach is required.

Sharath and Gibbs (2012) developed an Australian water balance model (AWBM) rainfall-runoff model of the Drain L catchment and a lake storage model of the Lake Hawdon complex to represent the interactions between the lakes, drains and a proposed regulator, the same regulator proposed for the current study. These models were implemented in the eWater SourceIMS modelling framework (version 3.0.7). The rainfall – runoff model adopted a functional unit approach based on land use and soil type to represent the variability in the rainfall – runoff relationship across the catchment, and surface water – groundwater interactions were considered explicitly. The lake – storage model was used to assess water levels in Lake Hawdon North at a daily time step over a 41-year model period; 1971 - 2011. A full account of model development, calibration and the context of this previous work is provided by Taylor *et al.*(2014).

The current (unrestored) hydrograph of Lake Hawdon North has been determined using Sharath and Gibbs' (2012) model and is shown in Figure 18. The current hydrograph represents the water level for each calendar day averaged for the entire 41-year model period. The standard deviations are also shown. On average, water levels peak in late August at approximately 4.3 mAHD, with the wetland typically dry (WSEL < 3.65 mAHD) by early January. On average, water is present for approximately half the period that migratory shorebirds are present, assumed as mid-October to mid-March (acknowledging that not all species are present for all of this period).

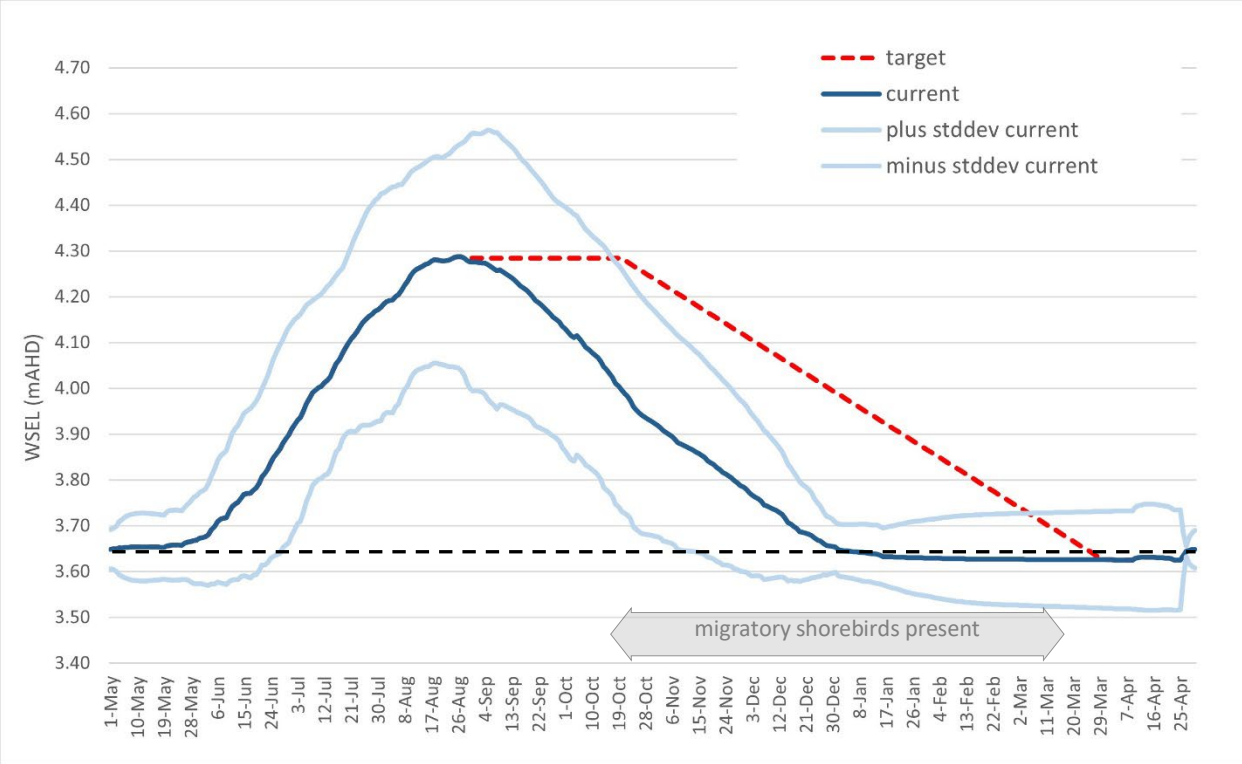

Figure 18. Current (modelled) average annual hydrograph for Lake Hawdon north (daily average water level ± standard deviation, model period 1971 – 2011). Dashed black line represents the lowest elevation of the natural bed of the wetland (3.65 mAHD). Grey double-headed arrow represents the period the migratory shorebirds are present in the region.

Sharath and Gibbs (2012) model was then run with the proposed regulator in place. The regulator was represented as a fixed sill of 4.3 mAHD in place for the entire model period. To allow for the downstream environmental water requirements of the Robe Lakes, the regulator was represented as having a culvert that allows some flow to continue within the drain even when the regulator is in place. Six different culvert capacities were investigated; 0, 20, 40, 60, 80 and 100 ML/day. The results of these model runs upon the Lake Hawdon North hydrograph are presented in Figure 19. A proposed target restored hydrograph, that ensures wetland inundation persists for the entire duration that migratory shorebirds are present in the region, is also shown. The target hydrograph is preliminary and should be further refined if the restoration project proceeds.

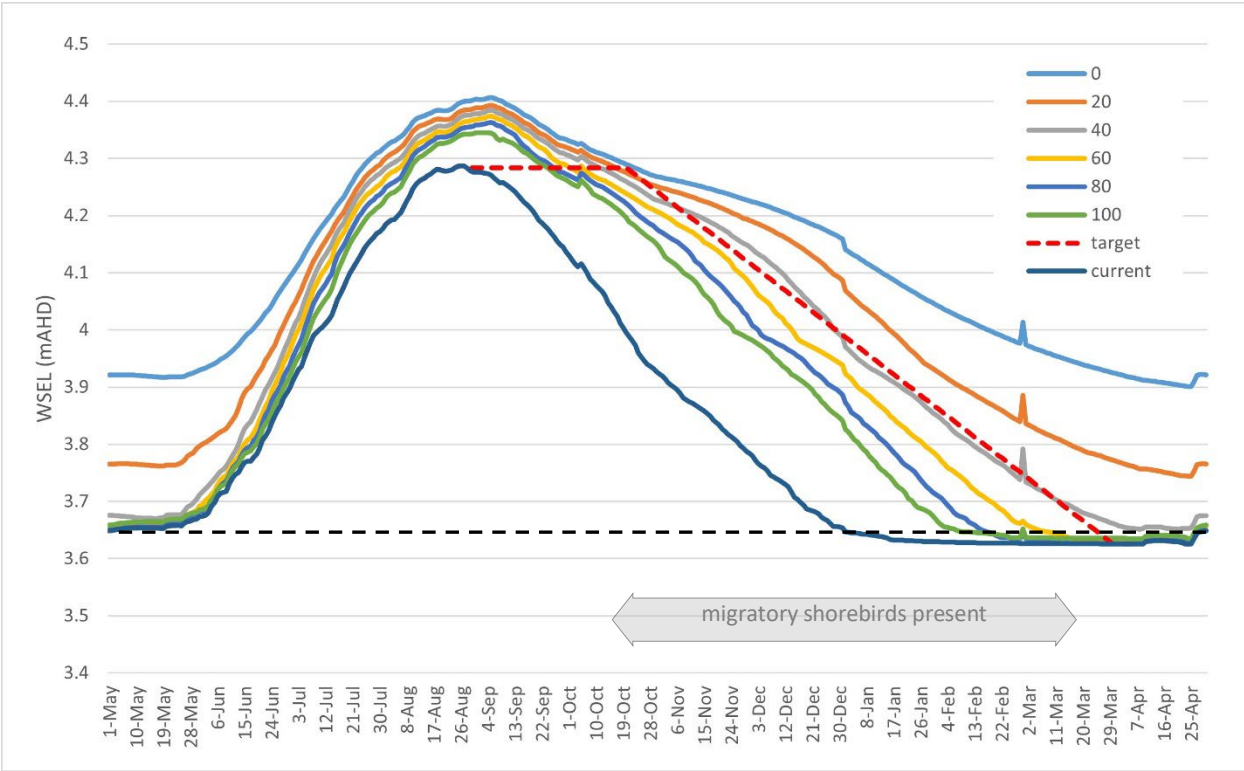

Figure 19. Average annual hydrograph for Lake Hawdon North (modelled daily average water level, model period 1971 – 2011) without (current) and with a regulator in place with 6 different culvert capacities (0 – 100 ML/d). A proposed restored target annual hydrograph (red dashed line) is also shown. Dashed black line represents the lowest elevation of the natural bed of the wetland (3.65 mAHD). Grey double-headed arrow represents the period the migratory shorebirds are present in the region.

Figure 19 shows that the placement of a regulator with a permanent sill of 4.3 mAHD within Drain L at the outlet of Lake Hawdon North causes water levels in the wetland to peak at a higher level than currently. However, the model has oversimplified what would actually occur. The constructed regulator would in fact be adjustable and would be open during the rising limb of the hydrograph so that water levels were not forced above current levels. To achieve the target hydrograph, the regulator would be operated to achieve a water level of approximately 4.3 mAHD from late August in an average year. This level would then be maintained by regulator adjustment until late October, after which water level would recede due to a combination of evaporative losses and flows over the regulator to meet downstream environmental requirements. Figure 19 indicates that, in an average year, the target hydrograph could be achieved while allowing approximately 40 ML/day past the regulator from late October until late March to meet downstream requirements in the Robe Lakes. In an above average year this volume would be higher while in a below average year either the period of inundation could be reduced to maintain flows to the Robe Lakes or the flows over the regulator could be reduced through regulator operation to maintain the target hydrograph. The implications of regulator operation for the Robe Lakes is examined in more detail in Section 4.2.1.

A comparison of the area of suitable habitat for shorebirds (open pan, 0 – 10 cm deep) under current versus target restored scenarios is shown in Figure 20. The current, unrestored scenario assumes the existing vegetation and the current average annual hydrograph. The target restored scenario assumes clearance of recently invaded *M. halmaturorum* shrubland and the restored target annual hydrograph.

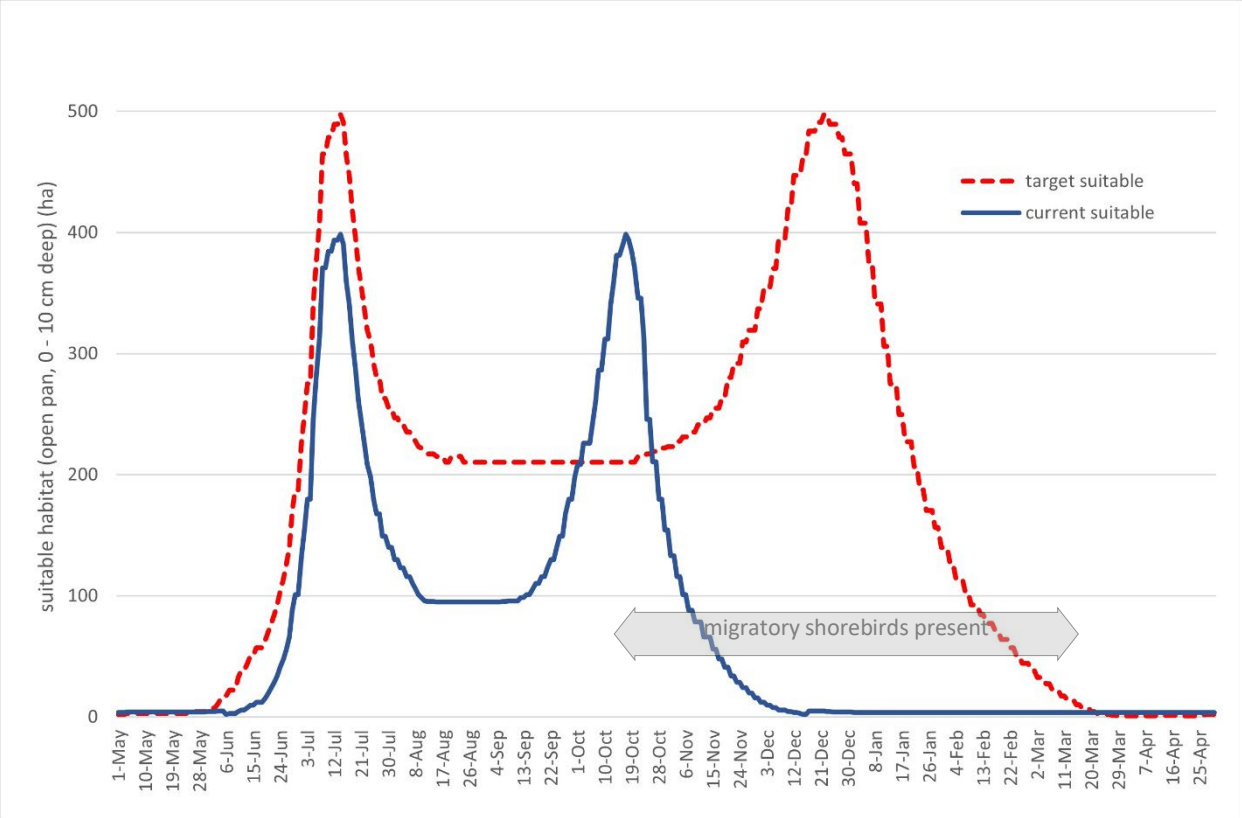

Figure 20. Area of suitable habitat for migratory shorebirds + RCP at Lake Hawdon North through a year under the current average annual hydrograph and the target restored annual hydrograph.

Figure 20 shows that clearance of recently invaded *M. halmaturorum* shrubland combined with application of the target restored annual hydrograph greatly increases habitat availability for shorebirds. Peak habitat availability, at the same optimal water level, is 100 ha greater under the restored scenario. Importantly, habitat availability is markedly higher during the period that migratory shorebirds are present in the region, persisting for the entirety of that period. Considering the hectare.day as the unit of habitat availability (i.e. 1 ha.d implies 1 hectare of suitable habitat available for one day), and considering only the period when migratory shorebirds are present (assumed as 16 October to 15 March as migrating shorebirds are not usually present outside this time period), the current scenario provides 6,807 ha.d while the restored scenario provides 36,142 ha.d. Thus, on average, restoration increases habitat availability for migratory shorebirds in Lake Hawdon North by 531%.

4.1.3. Increased Shorebird Abundance

Estimation of the increase in shorebird abundance at Lake Hawdon North, indeed at any site, as a consequence of restoration is less confident, primarily because available habitat may not always be utilised. As will be shown below, shorebird abundance in the Lake Hawdon complex is highly variable and not directly correlated with habitat availability. Nonetheless, for the purpose of this feasibility assessment, we have endeavoured to estimate the increase in carrying capacity using the logic that follows.

Only one shorebird count specific to Lake Hawdon North has been reported to our knowledge. This was undertaken on 26/06/2003 and was reported by Christie and Jessop (2007). The survey was conducted in the southern part of Lake Hawdon North within the mining lease (Maureen Christie, pers. com.). The results of this survey are shown in Table 5. These data are difficult to interpret because the water level

and size of the survey area are unclear. The survey detected a high abundance of Double-banded Plover, which breeds in New Zealand and migrates to Australia for the winter months (Hansen et al. 2016). These data are provided to clarify that Lake Hawdon North does support shorebirds in its unrestored state, indeed internationally significant numbers of Double-banded Plover have been recorded.

Table 3. Waterbird survey results for Lake Hawdon North, 26th June 2003 (source: Christie and Jessop 2007).

Common name	Scientific name	abundance
Red Knot	*Calidris canutus*	1
Red-necked stint	*Calidris ruficollis*	120
Curlew Sandpiper	*Calidris ferruginea*	30
Red-capped Plover	*Charadrius ruficapillus*	30
Double-banded Plover	*Charadrius bicinctus*	600
Masked Lapwing	*Vanellus miles*	6

internationally significant abundance

Lake Hawdon South has received much greater shorebird survey effort than Lake Hawdon North. An open basin of approximately 320 ha adjacent to mouth of the Bray Drain (Figure 21) has been surveyed for shorebirds on a number of occasions since 1999. The data for these surveys are provided in Table 6 and were generously provided by Maureen Christie, Australasian Wader Study Group, except data for 1999, which was sourced from Stewart *et al.* (2001). The area surveyed in 1999 was confirmed by a member of the survey team (Graham Carpenter, DEW, pers. com., 05/2020).

Table 4. Shorebird survey data for Lake Hawdon South (320 ha basin at mouth of Bray Drain). Sources: Australasian Wader Study Group (unpublished) and Stewart et al. (2001) for 1999 data. For methodology to estimate extent of inundation of surveyed area, see text.

Year	1999	1999	2002	2004	2005	2006	2009	2010	2017	2019	2020
survey date	19/11/1999	13/12/1999	29/01/2002	30/01/2004	17/01/2005	2/02/2006	5/02/2009	27/01/2010	15/02/2017	20/01/2019	5/02/2020
WOfS date				15/01/2004	25/01/2005	5/02/2006	13/02/2009	31/01/2010	11/02/2017	24/01/2019	4/02/2020
inundated extent (ha) of surveyed area	unreliable	unreliable	unreliable	211.6	142	1.7	10.8	119.5	331.2	329.7	233.8
Migratory shorebirds functional group											
Bar-tailed Godwit	0	0	0	0	0	0	0	0	0	0	5
Latham's Snipe	2	0	0	0	0	0	0	0	0	0	0
Marsh Sandpiper	0	0	20	230	67	0	0	34	2	0	0
Common Greenshank	5	12	82	150	21	0	11	2	16	29	20
Red-necked Stint	215	50	660	20	457	32	0	0	1530	337	908
Pectoral Sandpiper	1	1	0	0	0	0	0	0	0	0	0
Sharp-tailed Sandpiper	1540	1800	2340	20	6440	1	0	7860	2990	16430	8
Curlew Sandpiper	0	0	0	0	10	0	1	15	6	0	0
TOTAL migratory shorebirds	1763	1863	3102	420	7085	33	12	7911	4544	16796	941
Non-migratory shorebirds functional group											
Black-winged Stilt	1100	200	150	30	1138	0	0	195	8	446	100
Banded Stilt	0	0	0	1	1	0	0	0	0	0	0
Red-necked Avocet	0	0	0	0	0	0	0	0	2	1	0
Red-capped Plover	1	3	11	30	87	16	26	6	29	56	93
Black-fronted Dotterel	0	0	0	0	0	0	0	0	0	0	0
Red-kneed Dotterel	2	0	0	0	0	0	0	0	7	19	0
Masked Lapwing	24	1	55	26	30	18	84	29	105	13	52
TOTAL non-migratory shorebirds	1125	204	216	87	1166	34	110	230	151	535	245
TOTAL shorebirds	**2888**	**2067**	**3318**	**507**	**8251**	**67**	**122**	**8141**	**4695**	**17331**	**1186**

internationally significant abundance

nationally significant abundance

The extent of inundation of the surveyed area at the time of each survey was estimated using Water Observations from Space (WOfS) remote sensing data obtained from the online NationalMap application (DTA 2020). Remotely sensed images of inundation extent of the survey area for dates as close to the shorebird survey date as possible were obtained from NationalMaps. These images were georectified in ArcGIS Desktop 10.6.1, polygons drawn to align with their extent and areas of polygons calculated. An example, for the 2020 survey, is provided in Figure 22. For survey dates in 1999 and 2002 this approach was not possible because the WOfS imagery was highly variable around the date of these three surveys and was deemed unreliable.

Figure 21. Area of Lake Hawdon South regularly surveyed for shorebirds.

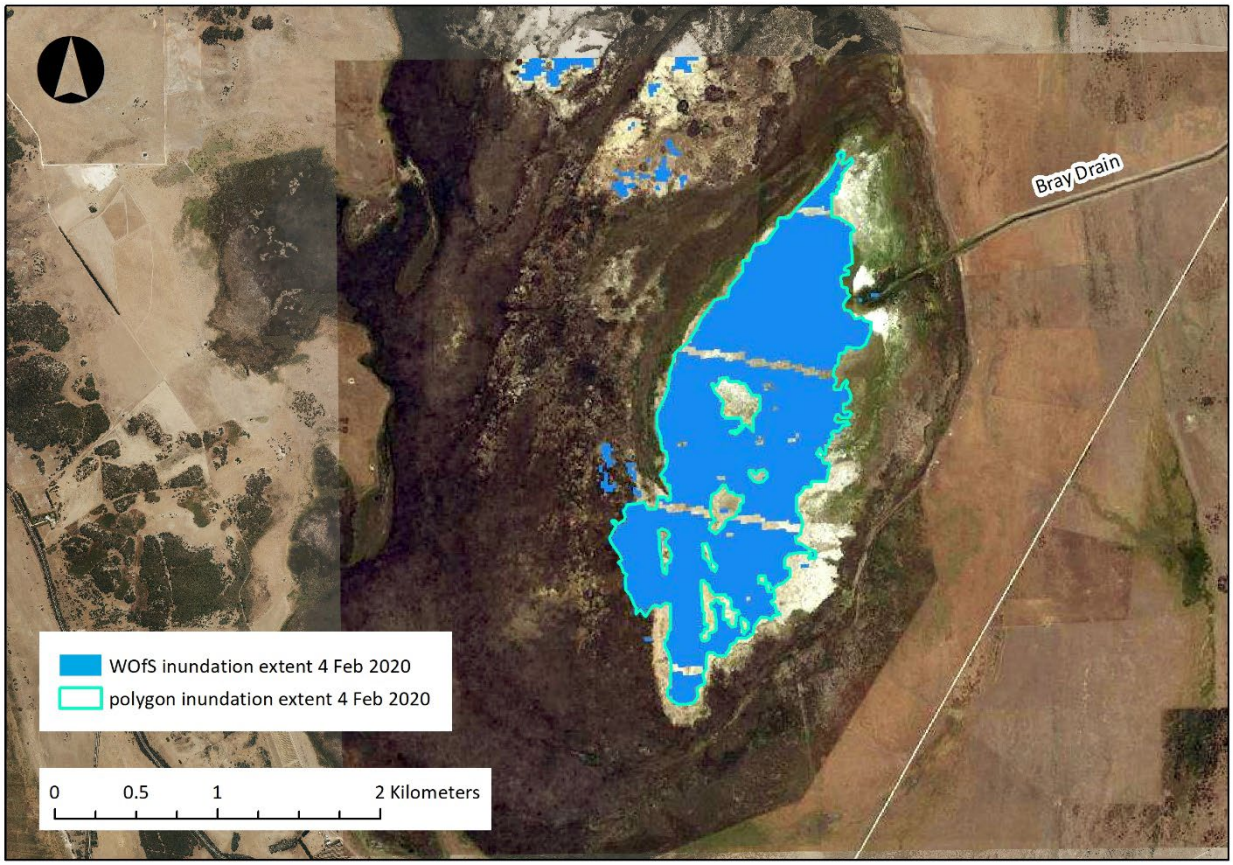

Figure 22. WOfS based estimate of inundation extent, Lake Hawdon South shorebird survey area, 4th February 2020.

Unfortunately, accurate DEM for the regularly surveyed basin of Lake Hawdon South does not exist, likely because this basin was inundated at the time the regional LiDAR was flown. We have therefore estimated the extant of 0 – 10 cm deep water on the date of the shorebird survey from the total area inundated. In Lake Hawdon North, the relationship between total surface area inundated and surface area inundated to a depth of 0 – 10 cm is linear up to approximately 1000 ha of total area (Figure 23). This relationship describes the shallow, open basins that fill first and dry last.

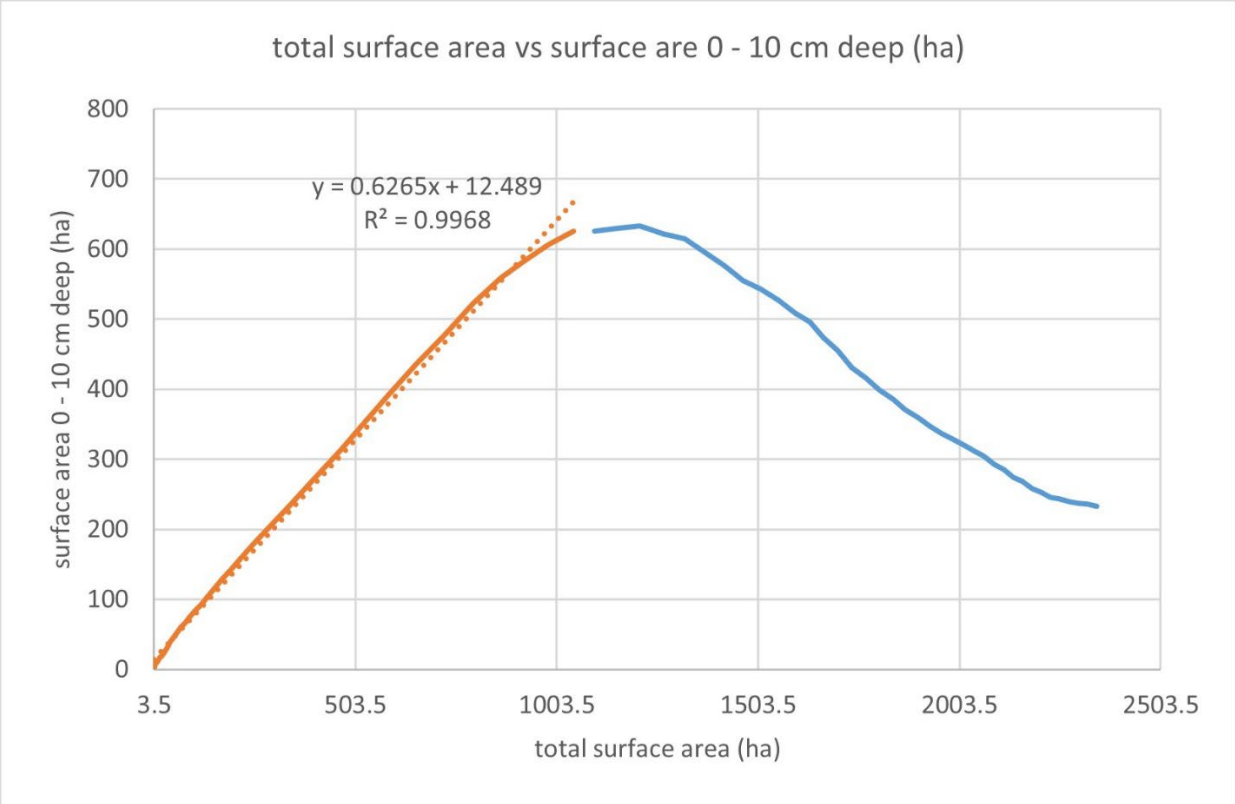

Figure 23. Relationship between total surface area inundated and surface area inundated to a depth of 0 – 10 cm for Lake Hawdon North. A linear relationship holds for total surface area up to approximately 1000 ha (orange line) but breaks down thereafter (blue line). Calculated from high resolution (2m^2) DEM.

The basin within Lake Hawdon South that is regularly surveyed for shorebirds is shallow, open, roughly elliptical in shape and has a total surface area of 320 ha. It is therefore comparable to the low lying basins of Lake Hawdon North described by the orange line in Figure 23. We have therefore used the same linear relationship to estimate the area of Lake Hawdon South inundated to a depth of 0 – 10 cm on the shorebird survey dates, based on the total surface areas obtained from WOfS. These estimates are provided in Table 7 along with the total count of migratory shorebirds + RCP at these times and the density of migratory shorebirds + RCP in suitable habitat (open pan, 0 – 10 cm deep) at these times. The estimates show considerable variability in bird density, highlighting the inconsistency between habitat availability and shorebird abundance. For example, the years 2017 and 2019 have very similar habitat availability but very different abundances of migratory shorebirds + RCP. These differences likely reflect large variability in habitat availability at a landscape scale from year to year and also the lack of repeat surveys in a single year.

Because of the inconsistency in the density of migratory shorebirds + RCP, we have used the three years of highest density (2005, 2010 and 2019) to estimate a density indicative of the carrying capacity of the Lake Hawdon complex for these species (Table 8). The mean density of these three years is 79.38. In other words, there were on average 79.38 migratory shorebirds + RCP per hectare of suitable habitat (open pan, 0 – 10 cm deep) in Lake Hawdon South at these times of peak abundance. Table 8 also shows each migratory shorebird species + RCP as a proportion of total abundance. These numbers show that sharp-tailed sandpiper are the dominant shorebird of the Lake Hawdon complex, comprising 96.2% of total migratory shorebird + RCP abundance at times of peak abundance.

Table 5. Estimated area of depth 0 – 10 cm, total abundance and total density of migratory shorebirds + RCP, Lake Hawdon South.

Year	2004	2005	2006	2009	2010	2017	2019	2020
survey date	30/01/2004	17/01/2005	2/02/2006	5/02/2009	27/01/2010	15/02/2017	20/01/2019	5/02/2020
WOfS date	15/01/2004	25/01/2005	5/02/2006	13/02/2009	31/01/2010	11/02/2017	24/01/2019	4/02/2020
inundated extent (ha) of surveyed area	211.6	142	1.7	10.8	119.5	331.2	329.7	233.8
Estimated extent with depth 0 – 10 cm	145.1	101.5	1.7	10.8	87.4	219.9	219	159
TOTAL migratory shorebirds + red-capped plover	450	7172	33	38	7917	4573	16842	1034
TOTAL migratory shorebird + RCP density (birds/ha 0 – 10 cm)	3.10	70.66	19.41	3.52	90.58	20.66	76.90	6.50

Table 6. Density and species composition of migratory shorebirds + RCP at times of peak abundance in Lake Hawdon South.

Year	2005	2010	2019	**mean**	**proportion (%)**
survey date	17/01/2005	27/01/2010	20/01/2019		
WOfS date	25/01/2005	31/01/2010	24/01/2019		
inundated extent (ha) of surveyed area	142	119.5	329.7		
Estimated extent with depth 0 – 10 cm	101.5	87.4	219		
TOTAL migratory shorebirds + RCP	7172	7917	16842	**10,643.7**	
TOTAL migratory shorebird + RCP density (birds/ha 0 – 10 cm)	70.66	90.58	76.90	**79.38**	
Marsh Sandpiper	67	34	0	**33.7**	**0.3**
Common Greenshank	21	2	29	**17.3**	**0.2**
Red-necked Stint	457	0	337	**264.7**	**2.5**
Sharp-tailed Sandpiper	6440	7860	16430	**10,243.3**	**96.2**
Curlew Sandpiper	10	15	0	**8.3**	**0.1**
Red-capped Plover	87	6	56	**49.7**	**0.5**

We have applied the peak density from Lake Hawdon South (79.38 birds/ha) to Lake Hawdon North to estimate the carrying capacity of the latter. Figure 24 shows estimated annual carrying capacity of Lake Hawdon North for migratory shorebirds + RCP under the current unrestored scenario and the target restored scenario. Only the period when migratory shorebirds are typically present, 16 October to 15 March is shown. Carrying capacity of Lake Hawdon North has been estimated by multiplying the peak density from Lake Hawdon South by the estimates of habitat availability within Lake Hawdon North calculated previously (Figure 20).

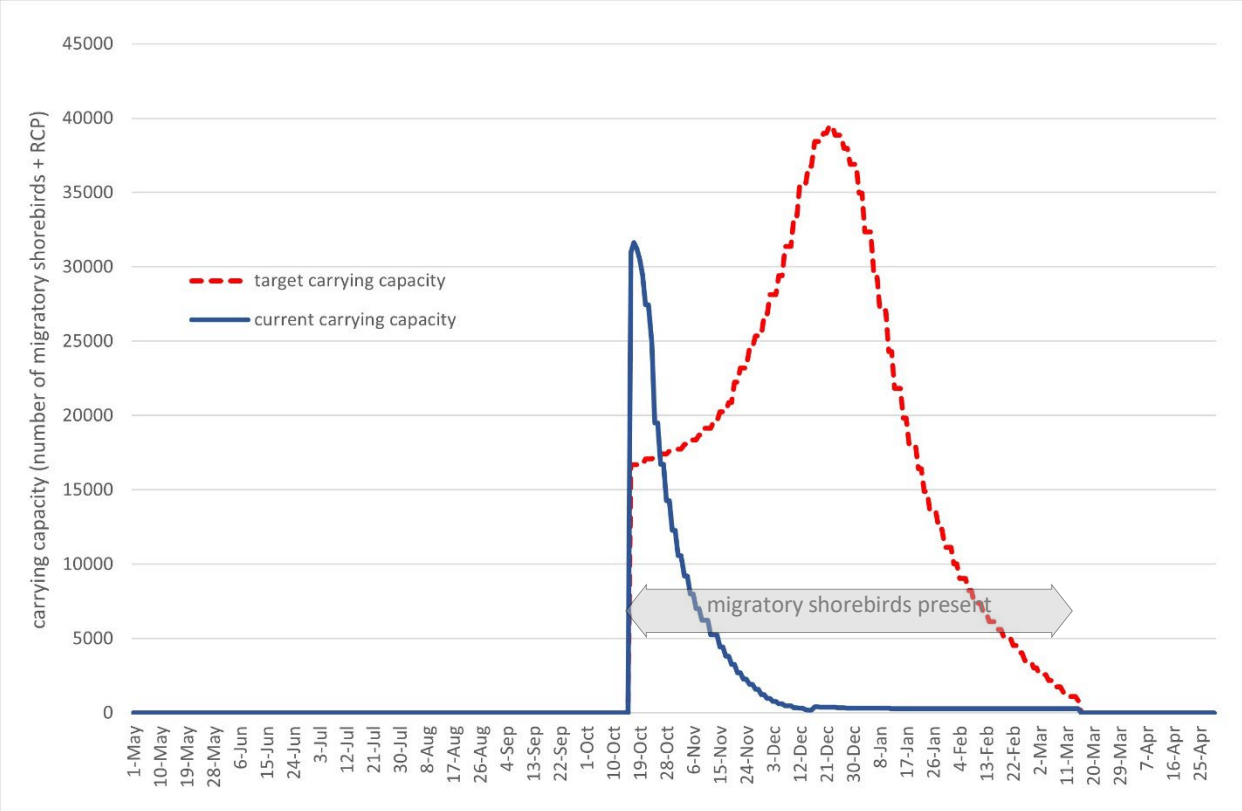

Figure 24. Estimated annual carrying capacity (abundance of migratory shorebirds + RCP) of Lake Hawdon North under current unrestored and target restored scenarios.

Figure 24 shows that restoration (i.e. clearance of recently invaded *M. halmaturorum* shrubland combined with application of the target restored annual hydrograph) greatly increases the carrying capacity of Lake Hawdon North for shorebirds. Under the current, unrestored scenario, carrying capacity is estimated at 31,640 migratory shorebirds + RCP in mid-October but declines rapidly, due to rapidly falling water levels, to effectively zero by mid-December under average conditions. Under the restored scenario, carrying capacity increases from 16,700 migratory shorebirds + RCP in mid-October to 39,500 by late December then declines to reach zero by mid-March under average conditions. Considering the bird.day as the unit of carrying capacity (i.e. 1 bird.d implies 1 bird (migratory shorebird + RCP) present for one day), the current scenario provides 540,318 bird.d per year while the restored scenario provides 2,868,947 bird.d per year under average conditions. Thus, on average, restoration increases the carrying of Lake Hawdon North for migratory shorebirds + RCP by 531%. This is the same percentage increase estimated for habitat availability, which is anticipated given carrying capacity is calculated as habitat availability multiplied by maximum density.

Estimated peak carrying capacity of the HCHB RBR target species in Lake Hawdon North, assuming a 39,500 combined peak carrying capacity and the direct translation of Lake Hawdon South proportions by species, are shown in Table 9.

Table 7. Estimated peak carrying capacity of HCHB RBR target shorebird species in Lake Hawdon North under the restored scenario.

HCHB RBR Target species	Proportion (%)	Peak abundance
Common Greenshank	0.2	79
Red-necked Stint	2.5	988
Sharp-tailed Sandpiper	96.2	38,000
Curlew Sandpiper	0.1	40
Red-capped Plover	0.5	1,975

These estimates of carrying capacity, particularly for sharp-tailed sandpiper, are very high and should be used with caution. They include several potential sources of error.

- The high bird densities recorded in Lake Hawdon South may be unique to that location and may not be replicated in a restored Lake Hawdon North. Both locations are very similar ecologically, supporting similar vegetation, fed directly by drains from catchments with similar landuse (Taylor et al. 2014). Salinities of 2000 – 4000 $\mu S.cm^{-1}$ have been recorded in Lake Hawdon South while in Lake Hawdon North a salinity range of 2000 – 8000 $\mu S.cm^{-1}$ is more typical (Hammer and Tucker 2011, Hammer et al. 2012, Veale and Whiterod 2019). This difference in salinity between the two wetlands is minor and unlikely to result in different shorebird food availability, noting that both are considerably fresher than the Coorong South Lagoon where the management objective has been to maintain salinity between 30,000 and 130,000 $\mu S.cm^{-1}$ (Phillips and Muller 2006). The ecological similarity between Lake Hawdon South and North is likely to increase under restoration as the hydrological regime of the two wetlands becomes more similar. However, there may be unknown factors that enable Lake Hawdon South to support a higher density than Lake Hawdon North, even under optimal vegetation and water levels.
- Our estimates of bird density at Lake Hawdon South may be inaccurate due to problems with our method of estimating inundated area (total and/or 0 – 10 cm deep) using WOfS. However, we have cross referenced these estimates with field notes on water levels made by the shorebird surveyors and found general agreement.
- Our estimate of peak carrying capacity may not manifest as a peak abundance because it is higher than the abundances of the target species, particularly sharp-tailed sandpiper, present annually in the region. However, the capacity of Lake Hawdon North to support this abundance would exist even of the population to achieve it did not.

Even if we have over-estimated carrying capacity by, for example, 50%, potential peak abundances of 20,000 migratory shorebirds + RCP in Lake Hawdon North can still be anticipated. Such shorebird numbers, at the mid-point of their annual presence in the region, combined with habitat availability for the duration of that period, highlights the enormous restoration potential of this wetland. The presence of water later in the summer would be particularly valuable, as that is the time when migratory shorebirds are looking to gain fat reserves for their return flight to the northern hemisphere (Geering et al. 2007) yet total regional wetland habitat is declining as seasonal wetlands dry.

For Sharp-tailed Sandpiper and Red-capped Plover, for most of the spring/summer period, carrying capacity in Lake Hawdon North would regularly exceed the 2015 baseline and 2019 abundances in the Coorong South Lagoon. For Common Greenshank and Curlew Sandpiper, carrying capacity would regularly be similar to 2015 baseline abundance in the Coorong South Lagoon. Thus for these four species, a restored Lake Hawdon North has the capacity to provide an important refuge, effectively equivalent to

the current Coorong South Lagoon in carrying capacity, while conditions in the Coorong remain degraded. For Red-necked Stint, carrying capacity in Lake Hawdon North would represent approximately 15% of 2015 baseline abundance in the Coorong South Lagoon. As discussed previously, the remaining two HCHB RBR target shorebird species, Banded Stilt and Red-necked Avocet, are irregular visitors to Lake Hawdon North and therefore are not anticipated to benefit significantly.

4.1.4. Protecting and/or Enhancing Other Ecological Values

In addition to benefits for shorebirds, the restoration of Lake Hawdon North would, through increased habitat availability and improved habitat condition, provide benefits for a suite of other biota that occur in the Lake Hawdon complex (see DEH 2007). These include:

- cryptic waterbirds that utilise the dense habitats of *Gahnia filum* and *Baumea arthrophylla* sedgelands, such as the nationally endangered Australasian Bittern (*Botaurus poiciloptilus*) and state rare Southern Emu-wren SE (*Stipiturus malachurus polionotum*);
- migratory shorebirds not targeted by the HCHB RBR project, including Lathan's Snipe (*Gallinago hardwickii*), Marsh Sandpiper (*Tringa stagnatilis*) and Pectoral Sandpiper (*Calidris melanotis*);
- larger resident waders such all three Australian species of ibis, Pied Stilt (*Himantopus himantopus*), Royal Spoonbill (*Platalea regia*), Yellow-billed Spoonbill (*Platalea flavipes*), Black-fronted Dotterel (*Elseyornis melanops*), Red-kneed Dotterel (*Erythrogonis cinctus*) and others;
- piscivorus waterbirds including the state rare Fairy Tern (*Sternula nereis nereis*), other terns, cormorants and egrets;
- Black Swan (*Cygnus atratus*), which breeds in Lake Hawdon North when water of sufficient depth is present (B. Taylor, pers. obs.) and a range of ducks including Hardhead (*Aythya australis*), Musk Duck (*Biziura lobata*), Pink-eared Duck (*Malacorhynchus membranaceus*), Australasian Shoveler (*Spatula rhynchotis*) and teal;
- reptiles including various species of snake and the Common Long-necked Tortoise (*Chelodina longicollis*);
- native fish, including the nationally vulnerable Little Galaxias (*Galaxiella toourtkoourt*) and state critically endangered Australian Mudfish (*Neochanna cleaver*).

Restoration will also increase groundwater recharge, helping to protect this ecologically important resource.

The increased residence time of water within Lake Hawdon North under the restored scenario is likely to improve the water quality of flows exiting the Lake Hawdon complex, with likely benefits for the downstream ecosystems of the Robe Lakes and the marine environment of Guichen Bay.

4.2. *Environmental Risks and Risk Mitigation*

4.2.1. Degradation of the Robe Lakes

The Robe Lakes consist of five lakes artificially connected to each other and to the sea by Drain L, forming an estuary of ecological, social and economic importance within the town of Robe. The estuary consists of Lake Ling, Lake Battye, Lake Nunan, Pub Lake and Fox Lake (Figure 25). While the estuary is artificial,

its ecological values include its fish community (Hammer et al. 2012) and its provision of habitat for migratory shorebirds, particularly Latham's Snipe (Christie and Jessop 2007).

Figure 25. The Robe Lakes comprise a chain of connected lakes receiving water from Drain L to the east and water flowing north-west to exit to the ocean north of Fox Lake.

The restoration of Lake Hawdon North will reduce Drain L inflows to the Robe Lakes at times. Key ecological parameters of the Robe Lakes potentially affected by reduced inflows from Drain L include:

- salinity;
- nutrient concentrations;
- water levels; and
- mouth openness, which itself influences all the above parameters.

Key to the avoidance of degradation of the ecological and other values of the Robe Lakes will be the provision of sufficient Drain L flows to maintain the above parameters within a range that maintains their values. Taylor *et al.* (2014) developed a hydrodynamic model of the Robe Lakes using the TUFLOW-FV platform and adopting a 3-D finite volume mesh of the system. The model was used to test the influence of a regulator on Drain L at the outlet of Lake Hawdon North in combination with diversions out of the Drain L catchment upstream of Lake Hawdon North, upon salinity and water levels in the Robe Lakes. This work was done to inform diversion rules in the Drain L catchment under the proposed South East Flows Restoration Project (SEFRP). The SEFRP proposed to divert run-off, either permanently or seasonally, from 554 km^2 of the headwaters of the 1,641 km^2 Drain L catchment, out of the catchment (towards the Coorong). The Drain L regulator was proposed to maintain the pre-existing hydrograph of Lake Hawdon

North under reduced inflows. The key question was how much water to allow past the Drain L regulator to maintain pre-existing salinity, water level and mouth openness in the Robe Lakes.

Taylor *et al.* (2014) found that the combined Drain L rainfall-runoff model (Sharath and Gibbs 2012) and Robe Lakes hydrodynamic model used to test scenarios was unreliable in dry years as the rainfall-runoff model over predicted pre-existing inflows in those years. However, in medium and wet years, the models showed a minimal departure from pre-existing salinity and water level in the Robe Lakes when Drain L flows in the envelope 80 – 600 ML/d were diverted away from the lakes. The authors concluded that the Drain L regulator should allow flows of up to 100 ML/day to pass through to meet the environmental water requirements of the Robe Lakes. It was also recommended that reductions in the flow that bypasses the Lake Hawdon North regulator be permitted when desirable for the needs of Lake Hawdon North and when requirements for the Robe Lakes have otherwise been met.

A key difference between the scenarios examined by Taylor *et al.* (2014) and the current study is the current study assumes the Drain L catchment remains intact, i.e. it is not reduced in area by 554 km^2 (34%). Thus the current proposal was not examined by Taylor *et al.* (2014) but its potential to impact the Robe Lakes will, in comparison, be tempered by the absence of diversions out of the catchment.

Inflows to the Robe Lakes (measured at the Boomaroo Park gauging weir located 4.8 km upstream, 3.9 km downstream of Lake Hawdon North, with no tributaries between the two) were modelled for the current study using Sharath and Gibbs (2012) model described in Section 4.1.2. Results are presented in Figure 26. These results are averaged for each calendar day across the 41-year model period. “Current” represents the existing, unrestored scenario with no Drain L regulator. The other scenarios represent flows with a regular permanently in place with a fixed sill of 4.30 mAHD and a culvert in the base of the regulator with a capacity of 0, 20, 40, 60, 80 and 100 ML/day to mimic the provision of water for the Robe Lakes. The results confirm that under all restored scenarios, high inflows to the Robe Lakes will continue, with peak flows reduced only slightly, from approximately 670 ML/d to no less than 630 ML/d under average conditions. The total volume of the Robe Lakes has been estimated at 400 ML (Taylor et al. 2014). Table 10 shows the modelled total average annual flow to the Robe Lakes currently versus under the restoration scenarios for the 41-year model period. These inflows flush the estuary and are ecologically important, particularly for the maintenance of water quality. Average annual flow represented as a multiple of the total volume of the Robe Lakes is also shown in Table 10 for current and restored scenarios. These numbers indicate the very high turnover rates currently occurring in the Robe Lakes and continuing under the restoration of Lake Hawdon North under average conditions, suggesting salinity will continue to be controlled by Drain L inflows during the winter months. Interestingly, inflows to the Robe Lakes are slightly higher than the current scenario under most of the restored scenarios through December and January under average conditions (Figure 26). This reflects increased water storage in Lake Hawdon North and its more gradual release under restoration.

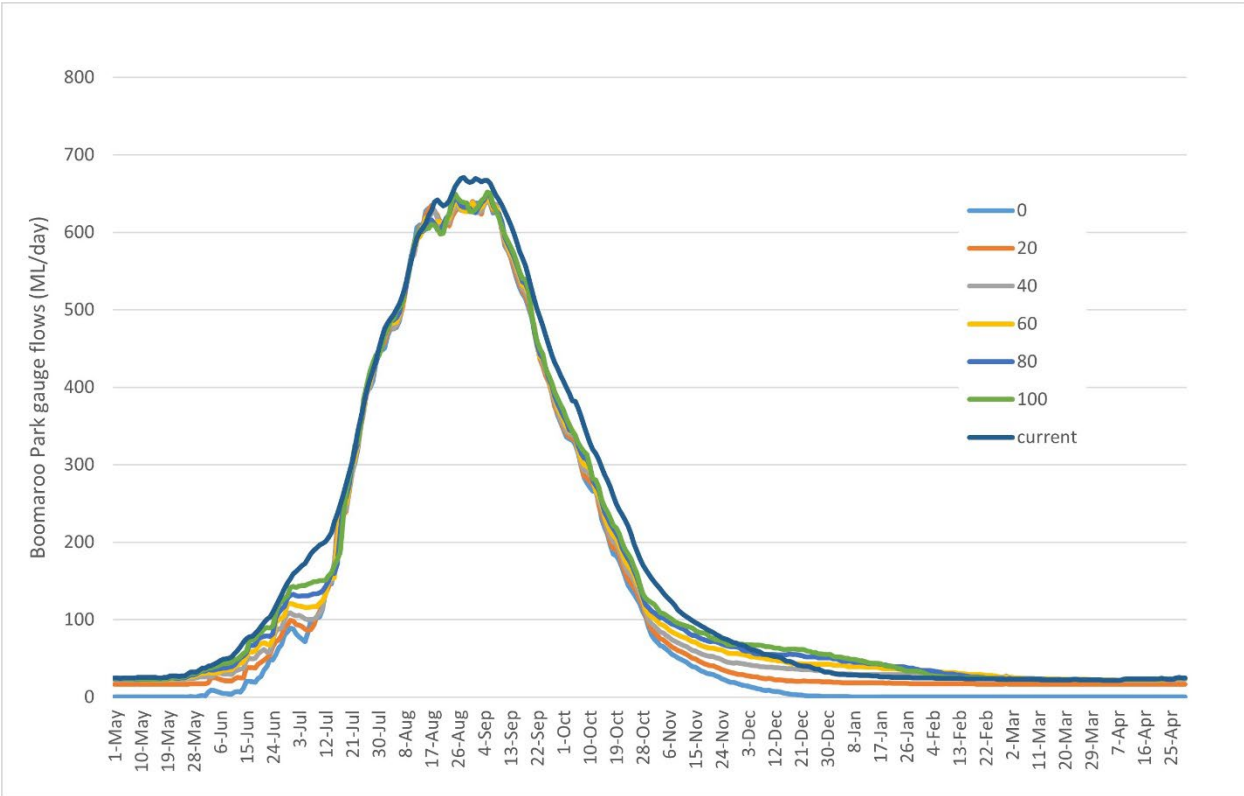

Figure 26. Modelled daily flows (averaged for each calendar day across the 41-year model period) into the Robe Lakes under current and restored scenarios.

Table 8. Modelled total average annual flow to the Robe Lakes under current and restored scenarios, represented in ML and as a multiple of Robe Lake total volume.

	restoration scenario (regulator culvert capacity (ML/d))						**current scenario**
	0	**20**	**40**	**60**	**80**	**100**	
average annual flow (ML)	49712	53799	56393	58058	59306	60309	63213
average annual flow as multiple of Robe Lakes total volume	124	134	141	145	148	151	158

Less certainty exists for the impact of Lake Hawdon North restoration upon the Robe Lakes under low flows outside the winter/early spring period. Reduced flows on the rising limb of the curve (Figure 26) are somewhat misleading as it is unlikely the regulator would be closed at this time of year as modelled. However, reduced flows on the falling limb, from mid-September to early January, are more likely to align with these model results as the regulator would likely be operating during this period. As shown in Section 4.1.2, under average conditions, achieving the proposed target hydrograph for Lake Hawdon North requires flows past the regulator to be reduced to around 40 ML/d from mid spring until late March. This is something of a departure from the previous recommendation of Taylor *et al.* (2014) to regulate only flows above 100 ML/d. However, as noted above, Taylor *et al.* (2014) only modelled restoration scenarios for which the catchment area of Drain L was reduced by 34%.

For inflows to the Robe Lakes under average conditions, restoration of Lake Hawdon North appears to present minimal risk to the Robe Lakes. However, drier years may present higher risks. The year 2007 was a dry year, with total annual flows at Boomaroo Park gauging weir of 20,796 ML (modelled), which is 33% of the modelled average. Modelled daily flows into the Robe Lakes for 2007-08 flow season, under current

and restored scenarios, are shown in Figure 27. For reference, modelled daily water levels in Lake Hawdon North for the same period and under the same scenarios are shown in Figure 28. The influence of the regulator and various bypass culvert capacities upon inflows manifests as reduced flows in early winter, followed by sudden peaks in mid-late winter, reflecting the sudden overtopping of the regulator once a WSEL of 4.30 mAHD has been achieved in Lake Hawdon North, as observable in Figure 28. As discussed in Section 4.1.2, in reality the regulator would likely be open during early winter, with inflows to the Robe Lakes actually more closely resembling the current scenario. However, in mid-late winter the regulator would be closed to achieve the target WSEL of 4.30mAHD in Lake Hawdon North and inflow rates to the Robe Lakes would resemble those indicated in Figure 27 from early August onwards. As can be seen, inflows are considerably reduced initially (early August to mid-September), but depending upon the capacity of the bypass culvert, are maintained higher than current (historic) during the October to November period. This reflects increased water storage in Lake Hawdon North and more gradual release under the restored scenarios and could provide a benefit to the Robe Lakes. From early January, low baseflow rates in Drain L are the same under the current and all restoration scenarios (except the 0 ML/d bypass culvert capacity scenario, which is unrealistic and only shown for comparison). In a dry year such as 2007, a flexible approach to regulator operations will need to be taken that balances the environmental water requirements of the Robe Lakes with the provision of shorebird habitat in Lake Hawdon North. This could involve setting a lower target maximum WSEL in dry years. As Figure 28 shows, even in a dry year a considerable increase to habitat availability in Lake Hawdon North is achievable under restoration compared to the current scenario, although the target hydrograph, with inundation extending into late March, may not be achievable in years as dry as 2007.

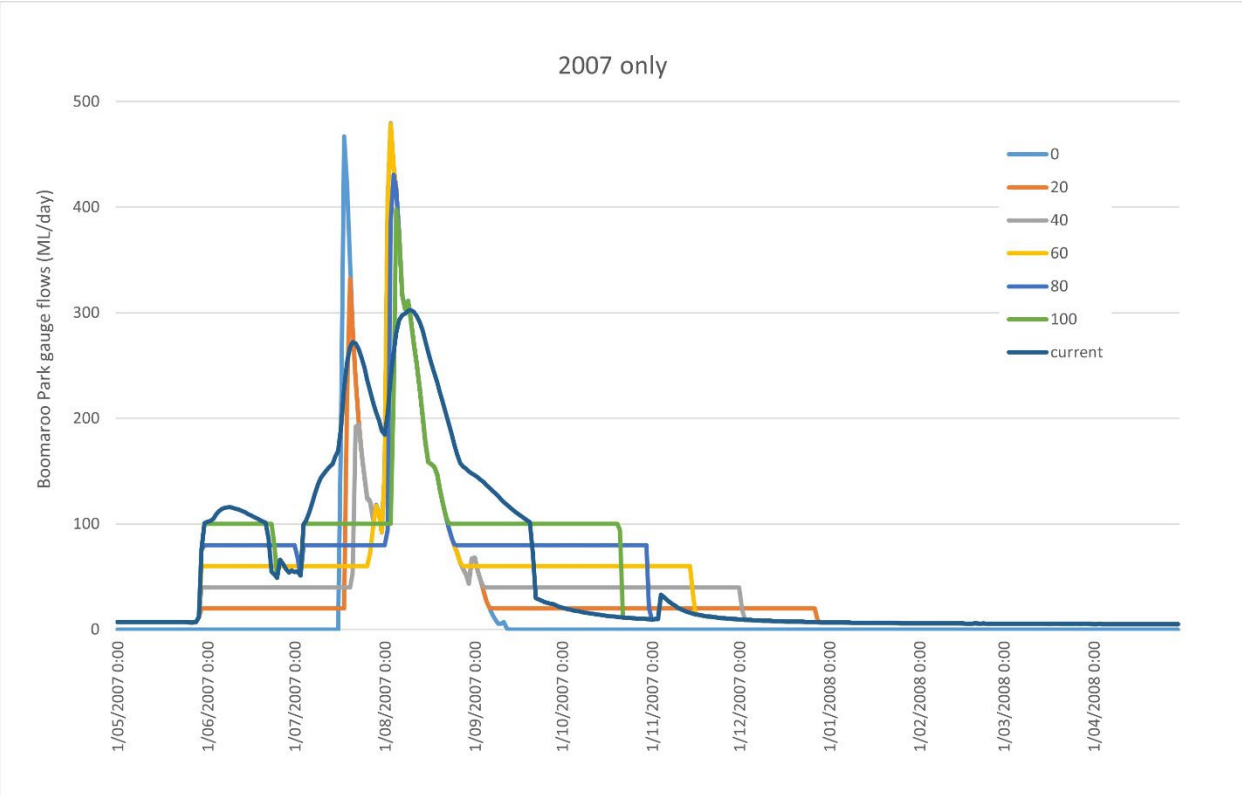

Figure 27. Modelled daily flows into the Robe Lakes in 2007 (dry year) under current and restored scenarios.

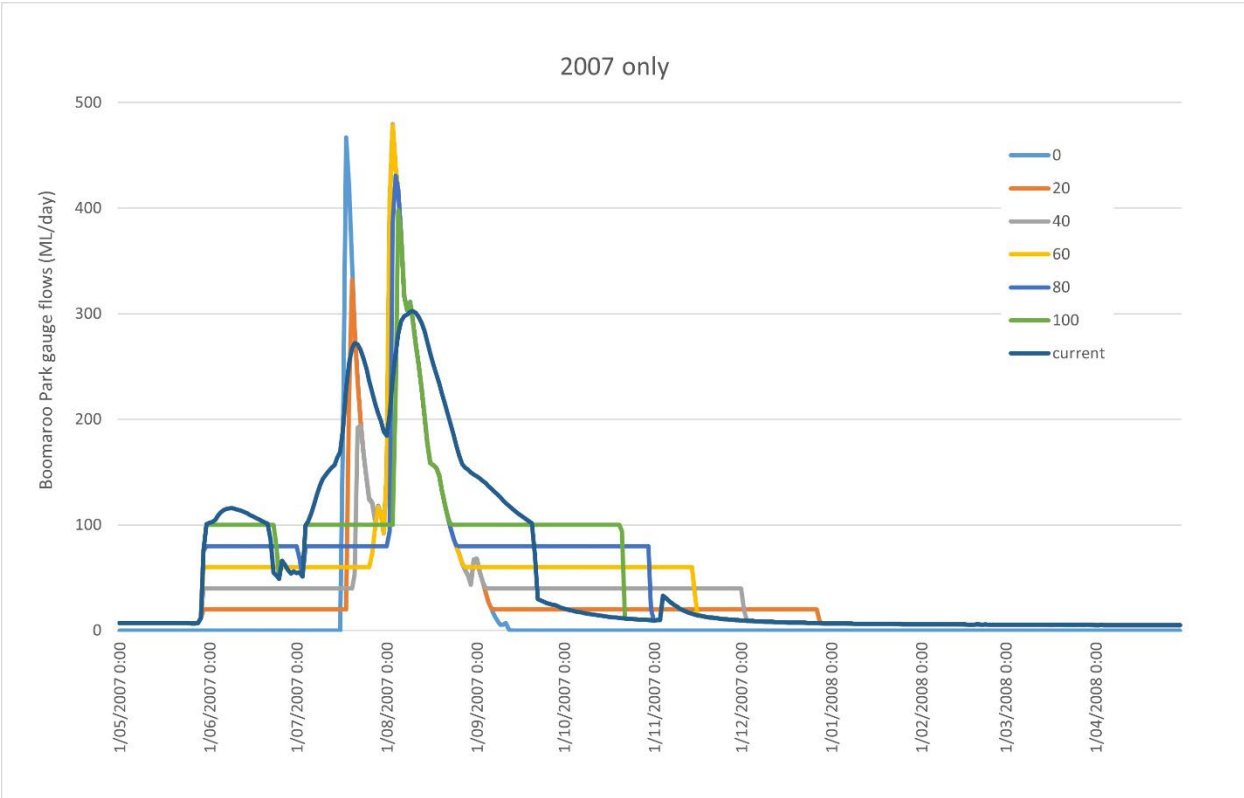

Figure 28. Modelled daily water level in Lake Hawon North in 2007 (dry year) without (current) and with a regulator in place with 6 different culvert capacities (0 – 100 ML/d).

Given the uncertainties relating to the impact of reduced spring and early summer flows, and the impact of dry years, further investigation of the current proposal, using the hydrodynamic model developed previously (Taylor et al. 2014) is recommended. Taylor *et al.* (2014) stated that *"it is expected that adaptive management based on water quality monitoring of the Robe Lakes can be used to adjust water levels and salinities if water is available/required"*. This approach remains valid under the current proposal.

4.2.2. Prevention of Fish Movement

The Drain L catchment, within which the Lake Hawdon complex is located, is a rare example of a catchment in south eastern Australia that is free of pest fish species (Whiterod and Gannon 2017). As discussed in Section 3.2.1 above, lower Drain L supports an estuarine ecosystem that relies upon inflows from Drain L and connection to the sea via a permanently open mouth. A number of diadromous fish species have been recorded in the Drain L catchment at locations upstream of the proposed regulator to manage water levels in Lake Hawdon North, including Common Galaxias, Yelloweye Mullet, Pouched Lamprey and Congolli (Hammer and Tucker 2011, Hammer et al. 2012).

An important population of Australian Mudfish (*Neochanna cleaveri*), a species identified as critically endangered in South Australia (Hammer et al. 2007), occurs in Lake Hawdon South. The population is large (Hammer and Tucker 2011) and at the edge of the geographic range of the species. An investigation to determine the diadromy of this population proved inconclusive, however facultative diadromy, that is occasional, event driven movement between freshwater and marine environments, cannot be ruled out for this population (Hammer et al. 2012).

There are also diadromous fish species that have been recorded within the Drain L catchment only downstream of the proposed regulator location but that may make regular movements further upstream that have not yet been detected by surveys. These include Climbing Galaxias, Black Bream Jumping Mullet and Sea Mullet (Hammer et al. 2012). Additionally, there are populations of obligate freshwater species in the catchment that may at times make movements within Drain L past the proposed regulator location. These include Southern Pygmy Perch and the nationally vulnerable Dwarf Galaxias (Hammer et al. 2012).

When the proposed Lake Hawdon North regulator is operating, a considerable head difference is anticipated between head- and tail-waters. The regulator is therefore likely to impede fish movement. To maintain populations of diadromous fish species upstream of the proposed regulator location and to avoid the geographic division of populations of obligate freshwater fish species within this ecologically important catchment, fish passage must be integrated into the design of the regulator. A fish ladder able to pass the full suite of species referred to in this section, in both adult and juvenile forms, under the full range of head- and tail-water levels and flow rates anticipated, will be required.

Note that the Boomaroo Park flow gauging weir, located on Drain L between the Robe Lakes and Lake Hawdon North, is acting as a partial barrier to fish movement. Large aggregations of fish occur downstream of this structure under moderate flows (Hammer et al. 2012), although the distribution of diadromous species upstream provides evidence that it is able to be passed by some species. The gauging weir is recommended for upgrade to a more fish-friendly design.

4.2.3. Invasion of Open Pan Habitat by Perennial Vegetation

As discussed in Section 3.1, clearance of *M. halmaturorum* shrubland combined with hydrological restoration, continued managed grazing and potentially increased fire frequency, is anticipated to convert shrubland to open pan habitat and maintain it as such. Two other associations, *Gahnia filum* sedgeland and *Baumea arthrophylla* sedgeland, could potentially expand within a restored Lake Hawdon North. These two plant associations are not proposed for clearance as they provide valuable habitat and approval is unlikely given their conservation status. Unlike *M. halmaturorum* shrubland, hydrological restoration will favour *G. filum* and *B. arthrophylla* sedgelands. Therefore, sheep grazing and fire will be the primary management tools available to limit their invasion into open pan habitat. Vegetation monitoring of Lake Hawdon South (Taylor and Brown 2019) indicates that sheep grazing may be effective in this role for these associations (see Section 3.1.3).

4.3. *Economic Benefits*

4.3.1. Regulator Construction

Construction of the Lake Hawdon regulator would provide short-term economic benefits to the South East region in the form of:

- Supply of construction plant and equipment;
- Supply of construction materials;
- Supply of fuel; and
- Food and accommodation services for construction workers.

4.3.2. Ecosystem Services

Globally, floodplains, of which Lake Hawdon North can be considered an example, contribute somewhere between 25% (Constanza et al. 1997) and 40% (Zedler and Kercher 2005) of all terrestrial ecosystem services, although they cover only 1.4% of the land surface area. Translating this global perspective to the local scale, it is likely that Lake Hawdon North makes a disproportionately higher contribution to the ecosystem services provided to the surrounding area than the local remnant terrestrial (non-wetland) vegetation.

Ecosystem services provided by wetlands include (Millennium Ecosystem Assessment 2005):

- Recharge of groundwater;
- Improvement of water quality;
- Flood control through water retention and attenuation of flows;
- Carbon storage;
- Recreation and tourism opportunities;
- Provision of habitat for wild game species;
- Spiritual and psychological wellbeing;

The economic value of the ecosystem services provided by Lake Hawdon North, under current and restored scenarios, has not been calculated. However, it is likely that restoration will enhance the value of particular ecosystem services provided.

The regional tertiary limestone (unconfined) aquifer underlying Lake Hawdon North is a valuable agricultural resource. Increased recharge of groundwater arising through restoration of Lake Hawdon North is likely to contribute positively to the fertility and productivity of surrounding pasture that draws directly from the groundwater table (SE NRM Board 2019). Additionally, increased recharge will help replenish groundwater extracted for irrigation.

Restoration will increase the residence time of water in Lake Hawdon North. This is likely to improve water quality by allowing suspended solids to drop out of the water column and dissolved nutrients to be taken up by wetland vegetation rather than exported downstream to the Robe Lakes and marine environment.

By providing additional habitat for waterfowl, the restoration of Lake Hawdon North will help maintain regional populations of target game species. Duck hunting, while not permitted at Lake Hawdon itself, is valued by some members of the community.

The increased volume of water present in Lake Hawdon North in late winter early spring under restoration will provide thermal mass that may influence the surrounding area. For example, during community engagement for the SEFRP, the manager of a vineyard located 1 km west of Lake Hawdon North expressed the view that frost damage to vines was less severe when more water was present in the wetland. This benefit may apply to other productive land such pasture.

The restoration of Lake Hawdon North has the potential to attract increased visitors seeking nature-based experiences to the South East region. Although the restoration project itself is not currently proposed to include visitor facilities, without restoration the current extremely low visitation is unlikely to change. The future construction of visitor facilities, designed to minimise any impact to ecological values, could add

value to that provided by restoration itself. The proximity of the Lake Hawdon complex to the popular coastal holiday town of Robe, approximately 20 minutes' drive away, makes it highly likely that visitor numbers to the wetlands would increase if they were promoted and appropriate facilities provided. This could provide a measureable benefit to the tourism economy of Robe and surrounding areas. Notably, the timing of the peak in shorebird abundance under the restored scenario (see Sections 4.1.2 and 4.1.3) coincides with the Christmas/New Year period, when visitor numbers to Robe and surrounding coastal centres are also at their annual peak.

4.4. *Economic Risks and Risk Mitigation*

This section identifies preliminary risks that have been identified. Should the project proceed beyond a Feasibility Assessment phase, these risks will be further explored and mitigation strategies put in place.

4.4.1. Reduced Income from Grazing

As discussed in Section 2.4.3, restoration has the potential to reduce the capacity of Lake Hawdon North to support sheep grazing. Therefore, restoration presents potential economic impacts for grazing licensees, even though ongoing grazing of the wetland is recommended. This impact may not be distributed evenly across the wetland, with some licensees more adversely affected than others. Given the scale of grazing in the region and the proportionally very minor contribution of Lake Hawdon North to the regional agricultural economy, the broader economic impacts of reduced grazing capacity over parts of Lake Hawdon North are likely to be very minor. However, impacts for the individual licensees could be more significant.

4.4.2. Reduced Income from Mining

By narrowing the annual window available for mining operations on the bed of Lake Hawdon North, restoration has the potential to reduce the amount of material mined annually and thereby reduce the income derived from mining. Much uncertainty remains in relation to this risk but it is identified and should be a focus of future stakeholder engagement. Reduced income from mining has the potential to impact interdependent parts of the local economy.

4.4.3. Degradation of Robe Lakes

In addition to their intrinsic ecological values, the Robe Lakes, or Drain L estuary, provide economic values. They are used recreationally for fishing and boating by locals and tourists and thereby help support businesses that support these activities. They also contribute to the aesthetic appeal of the town of Robe and likely contribute to tourism and local property values. Degradation of the Robe Lakes could impact these values. Extreme degradation has the potential to cause not only visual impacts but the release of unpleasant odours, such as hydrogen sulphide, from lake sediments. While risks relating to degradation of the Robe Lakes are considered readily avoidable and unlikely (see Section 4.2.1), potential consequences are high. Risk management should therefore be a high priority.

4.4.4. Inadequate Resources for Operation, Maintenance and Monitoring

It is assumed that the SEWCDB will be the future owners of the regulator and responsible for its ongoing operation and maintenance and the real-time monitoring required. An economic risk to the project is the ability of the SEWCDB to fund on-going operation, maintenance and monitoring. It is recommended that, through early engagement of DEW, SEWCDB and, potentially, the Limestone Coast Landscape Board,

recurrent funding arrangements for ongoing operation, maintenance and monitoring are resolved prior to construction.

5. Social Risks and Risk Mitigation

A key social risk to the project is lack of support from the community, in particular the grazing licensees and mining company. Recommendations to mitigate this risk include:

- early stakeholder engagement;
- developing an adaptable approach to wetland water regime that balances ecological outcomes with grazing and mining operations;
- lease variation, i.e. reduction in lease fees or other compensation models (see Section 6.3).

6. Inputs and Costs

6.1. *Implementation Costs*

This section has been prepared collaboratively with DEW.

DEW engaged the services of Liquid Gold Hydrology Services to develop cost estimates to an accuracy of +/- 30% for implementation (construction) of the concept design.

As discussed in Section 3.2.1, the restoration of Lake Hawdon North involves the clearance of 650 ha of *Melaleuca halmaturorum* shrubland that has established in the formerly open mudflats of Lake Hawdon North in recent decades. In 2017/18 clearance by private contractors, predominantly of the same vegetation type for the same ecological purposes, under the South East Flows Restoration project was undertaken as follows (Mark de Jong, SEWCDB, pers. comm., 25/6/2020):

- 131 ha on the “Bonneys Camp” property at a rate of $1,336/ha.
- 123 ha on the “Banff” property at a rate of $1,584/ha.

During the Implementation Planning phase (September – December 2020), the project will review various removal methods, identify high priority areas for clearance and consider value for effort.

The implementation cost estimate includes establishment of hydrological monitoring infrastructure to measure project outcomes, enable real-time management of the regulator and inform ongoing adaptive management of flows for the benefit of both Lake Hawdon North and the Robe Lakes (see Section 10). The minimum requirement consists of

- Real time telemetered water level monitoring stations at a minimum of three locations in Lake Hawdon North.
- Real time telemetered flow rate monitoring station at Boomaroo Park on Drain L, located downstream of Lake Hawdon North and upstream of the Robe Lakes. A gauging weir and telemetry already exist at this location, however upgrading of the gauging weir is required.
- Salinity and water level monitoring in the Robe Lakes at a minimum of two locations. These data should be collected continuously (e.g. daily) but need not be telemetered.

- Two new obswells for groundwater level monitoring and regular salinity monitoring located east of Lake Hawdon North. Groundwater level data should be collected continuously (e.g. daily) but need not be telemetered. Groundwater salinity data should be collected regularly but less frequently (e.g. quarterly).

Baseline ecological monitoring and the development of a management plan for Lake Hawdon North and the Robe Lakes to enable the measurement of project outcomes and to inform ongoing adaptive management (see Section 10) is included as an implementation cost.

6.2. *Operation and Maintenance Costs*

This section has been prepared collaboratively with DEW.

Liquid Gold Hydrology Services developed a cost estimate for operation and maintenance of the regulator and fishway for the next 50 years.

The cost estimate has considered:

- Budget prices from suppliers used for Concept Design Cost Estimate.
- The prices used are current at July 2020 - no allowance has been made for cost escalation over the estimate period.
- Based on salinity levels of less than 5,000 EC, AWMA expect (anecdotally) the service life of all equipment to be 25+ years. Based on salinity levels of less than 10,000 EC, AWMA expect (anecdotally) the service life of all equipment to be 15+ years. Replacement of the seals may be required every 10-15 years (AWMA). All gates can be manufactured from various grades of stainless steel including: Grade 304 (low salinity), Grade 316 (moderate salinity), Grade 2205 (high salinity), Grade 2507 (super duplex - very high salinity).
- A major cost of the O&M cost is the replacement of the flow regulating components - with regular maintenance the life can be extended potentially to a replacement each 25 years (typically) - potentially reducing the total estimated cost for 50 years by greater than $1,000,000.

In relation to hydrological and ecological monitoring, O&M costs include:

- Maintenance, data download and data management of all monitoring infrastructure essential for effective regulator operation via four sites visits per year (DEW standard) to each of the eight hydrological monitoring locations;
- Ongoing (cf baseline) ecological monitoring, based on average consultancy rates and including provision for local travel and equipment costs.

6.3. *Minimising Financial Impacts to Grazing Licensees*

Consideration should be given to minimising the financial impacts to grazing licensees for potential loss of income arising from restoration. The current licensees have a long association with the wetland and the assumption of available summer/autumn grazing is likely to be embedded in their overall farming operations. Although ongoing grazing is recommended, parts of the wetland may be less productive for grazing under the restored scenario (noting that other areas may become more favourable). As mentioned in Section 3.1.4, more frequent burning of the vegetation of Lake Hawdon North is likely to

have both ecological and grazing benefits and may also help win support for restoration from grazing licensees.

7. Traditional Owner Engagement

The South East Aboriginal Focus Group (SEAFG) provides a forum for engagement with Traditional Owners in relation to natural resource management in the South East Region. In the words of the SEAFG Charter (SEAFG 2012):

> *"The SEAFG will take a lead role in Aboriginal natural resources management issues in the South East. The SEAFG will provide advice and input into regional natural resources management processes and provide a link to the wider Aboriginal community*."

The hydrological restoration of Lake Hawdon North was previously considered as part of the South East Flows Restoration Project (SEFRP) and the SEFRP Augmentation project. Engagement with the SEAFG for the SEFRP and SEFRP Augmentation included briefings, site visits, roles in project governance, the preparation of position papers (Hemming and Rigney 2008, SEAFG 2017, Watson 2012) and ultimately, in the case of the SEFRP, employment through cultural heritage surveys (EBS Heritage 2016) and cultural heritage monitoring during construction. The position papers expressed in principle support for the SEFRP and SEFRP Augmentation objectives of wetland restoration. The restoration of Lake Hawdon North was specifically referred to by SEAFG (2017), which states:

> *"The SEAFG endorses proposals which aim to provide wetland outcomes for Lake Hawdon North, the Robe Lakes, the West Avenue Watercourse, the Taratap Wetlands, Tilley's Swamp and the Morella Basin."*

The position papers emphasised the importance of engagement with Traditional Owners in all stages of these projects through (SEAFG 2017):

- Representation on any management or project committee.
- Involvement in all future consultations to ensure that the project progresses in an inclusive and ethical direction.
- Regular project updates to the SEAFG.
- Opportunity to read and comment on draft reports.
- Opportunity to advise on employment opportunities for Aboriginal Peoples as traditional owners.
- Resourcing to participate in the design, development and implementation of the project.
- Involvement in the operational decision-making (prioritisation) process.

Although the hydrological restoration of Lake Hawdon North was ultimately not pursued under the SEFRP or SEFRP Augmentation, it is anticipated that the SEFRP position in relation these projects applies to the restoration project as currently proposed. However, it is recommended that engagement with the SEFRP be resourced and recommence at the earliest possible time.

8. Stakeholder Engagement

8.1. *Key Groups*

- South Eastern Water Conservation and Drainage Board
- Grazing Licensees
- Mining Company
- Limestone Coast National Parks and Wildlife Service
- Adjoining Landholders
- Relevant Authorities
- Volunteer Shorebird Community
- General Community

9. Approvals

Legislated approvals will be identified, prepared and submitted in the detailed design phase, as required. A preliminary approvals plan (Table 12) has been prepared and identifies the likely process and timeframes relevant to the project.

Table 9. Preliminary approvals plan.

Legislation	Approval	Timeframe	Comment
Native Title Act 1993	ILUA	2 months	Plan works to avoid impact or sensitive areas.
Aboriginal Heritage Act 1988	Cultural Heritage Survey	2 months	Cultural Heritage Assessment (CHA) required.
Crown Land Management Act 2009	Section 56A	1 month	Approval/note on TABS to conduct activity on Crown land
Planning, Development and Infrastructure Act 2016	Development Authorisation S131	3 months	Local Council or SCAP
Environment Protection 1993 *Waste Disposal*	Licence	Engage a contractor with appropriate licences for transport and disposal of waste.	Waste disposal is a prescribed activity. Material testing and classification will be required prior to disposal (~20 days for sampling and testing).
Environment Protection 1993 *Waste Disposal* *Environment Protection and Biodiversity Conservation Act 1999*	N/A		Minor construction and operation noise anticipated. No sensitive receivers within 2km. Approvals not required. Manage through Construction Environmental Management Plan.
	Self-assessment	2 months	Works are unlikely to have a significant impact on matters of NES or ecological character.

Legislation	Approval	Timeframe	Comment
Environment Protection and Biodiversity Conservation Act 1999 *Harbours and Navigation Act 1993*	EPBC Referral to Commonwealth	2 to 18 months	If self-assessment deems referral is required, undertake assessment to determine if works could have significant impact on the ecological character. Submit an application to the Commonwealth Environment Minister to determine.
	N/A		
Landscape South Australia 2019	Water affecting activities permit	2-3 months	
Landscape South Australia 2019	Water Resource Works Approval	1-2 months	
Local Government Act 1999	N/A		All works on crown land
National Parks and Wildlife Act 1972	N/A		Works not within a National Park.
Native Vegetation Act 1991	Approval	3 months	Clearance could be approved in accordance with Reg 11(25).
River Murray Act 2003	N/A		
State - Heritage Places Act 1993	N/A		The site is not a State or Commonwealth Heritage Place.
South Eastern Water Conservation and Drainage Act 1992, *Or* *Land Acquisition Act 1969*	Land Management Agreement	Up to 4 months	If construction of the regulator and fishway extend into adjacent private property a LMA will be required.
South Eastern Water Conservation and Drainage Act 1992	Board Management Plan Variation		This is the enabling legislation for the project, and any works can only be considered if they are contemplated in the Board's Management Plan (or directed by the Minister). Div 1, sect 34 'work by the Board' does not require licence. However, it needs to be included in Board Management Plan, which is reviewed annually.

10. Knowledge Management

10.1. *Management and Monitoring Plan*

If restoration proceeds, a new Management Plan for Lake Hawdon North and the Robe Lakes should be prepared. This is the case whether Lake Hawdon North is proclaimed as a Regional Reserve or remains as unallocated Crown land. The Management Plan will need to address, as a minimum:

- A conceptual understanding (e.g. state and transition model) of the influence of key drivers (water regime, grazing, fire for Lake Hawdon North; salinity, water level, mouth openness for Robe Lakes) upon the ecological values (vegetation, shorebird populations, etc);
- Operational rules for the regulator;
- Grazing guidelines;

- Fire management;
- Hydrological and ecological monitoring; and
- Governance arrangements.

10.2. *Hydrological Monitoring*

Hydrological monitoring, that is the monitoring of surface water levels, groundwater levels, flow rates and water quality, will be essential to measure restoration outcomes and for the operation of the regulator in real time. The following is recommended as the minimum requirement:

- Continuous telemetered water level monitoring in Lake Hawdon North:
    - Immediately upstream of the regulator (in Drain L);
    - In the north-east of the wetland; and
    - Within the Lake Hawdon Connecting Drain immediately downstream of the Old Naracoorte Road culverts.
- Continuous telemetered flow rate monitoring in Drain L at the Boomaroo Park gauging weir. This requires an upgrade of the gauging weir.
- Continuous water level and salinity logging (need not be telemetered) in the Robe Lakes in:
    - Lake Battye; and
    - Lake Fox.
- In addition to the existing obswell (WAT009), two new obswells for continuous groundwater level logging (need not be telemetered) and regular salinity monitoring located east of Lake Hawdon North.

10.3. *Ecological Monitoring*

Ecological (flora and fauna) monitoring is essential to measure restoration outcomes and inform an adaptive management approach to regulator operations. The following is recommended:

- Baseline (pre-restoration) waterbird counts of Lake Hawdon North in the early (late October), mid (late December) and late (late February) parts of the migratory shorebird season. Ideally, more than one year of baseline monitoring would be undertaken prior to restoration if possible. Methods should be standardised and repeatable. Following restoration, this monitoring should be repeated for 2-3 years or until the effect of restoration upon waterbird abundance can be confidently determined. Thereafter, monitoring would ideally be repeated at least once annually at a time of year coinciding with peak abundance, likely to be late December/early January if the target hydrograph is achieved.
- Baseline and post-restoration wetland vegetation transects and quadrats at 3-4 sites in Lake Hawdon North using the SEWCDB methodology used at sites throughout the region (e.g. Tuck et al. 2019).
- Pre- and post-restoration re-surveying of the vegetation of the four biosurvey 30 × 30 m quadrats established by Stewart *et al.* (2001) in Lake Hawdon North using the same methodology.

- Pre- and post-restoration re-surveying of the grazing exclosures (and associated control quadrats) in Lake Hawdon North.
- Pre-restoration complete re-mapping of the vegetation of Lake Hawdon North using the Native Vegetation Information System approach (NVIS Technical Working Group 2017). To understand vegetation change through time complete re-mapping is recommended once per decade. It was last undertaken at Lake Hawdon North in 2008 using aerial imagery from February 2008, ground truthed in November 2008 (Ecological Associates 2009b).
- Pre- and post-restoration re-surveying of the fish monitoring sites established in Lake Hawdon North by Hammer *et al.* (2012).

11. Priority Recommendations

To progress the restoration of Lake Hawdon North, the following priority actions are recommended for implementation as soon as possible:

- Engagement with the SEWCDB, grazing licensees and Agricola Mining Pty Ltd to explain the proposal and determine what is required to secure the support of these key stakeholders.
- Use the existing hydrodynamic model of the Robe Lakes developed by Taylor *et al.* (2014) to examine the impact of the target annual hydrograph of Lake Hawdon North upon the salinity and water level of the Robe Lakes.
- Commence the hydrological and ecological monitoring described in Section 10 to gather important baseline information that will enable the outcomes of restoration to be measured.

All other recommendations of this report are important and should be implemented when appropriate, however the above actions are fundamental to shaping the project and measuring its outcomes, and are therefore emphasised.

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