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UNIVERSITY OF CANBERRA

INSTITUTE FOR APPLIED ECOLOGY

COMMONWEALTH ENVIRONMENTAL WATER OFFICE LACHLAN SELECTED AREA MONITORING, EVALUATION AND RESEARCH PLAN (2019-2022)

APPENDIX D: RESEARCH PLAN

FINAL: MARCH 2020

This document forms part of the Commonwealth Environmental Water Office Lachlan Selected Area Monitoring Evaluation and Research Plan (2019-2022):
https://www.environment.gov.au/water/cewo/publications/mer-plan-lachlan-2019

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ACRONYMS AND ABBREVIATIONS

ACCEPTED ACRONYM	STANDARD TERM (CAPITALISATION AS SPECIFIED)
ANAE	Australian National Aquatic Ecosystem
C&E	Communication and Engagement
CEWH	Commonwealth Environmental Water Holder
CEWO	Commonwealth Environmental Water Office
CPD	Collaborative Pairs *Program*
CPUE	Catch per unit effort
DOIW	NSW Department of Industry- Water
ER	Ecosystem respiration
EWAG	Environmental Water Advisory Group
EWKR	Environmental Water Knowledge and Research
GPP	Gross Primary Production
GS	General Security
HCVAE	High Conservation Value Aquatic Ecosystems
HS	High Security
IMEF	Integrated Monitoring of Environmental Flows
LAP	Land Access Protocol
LRWG	Lachlan Riverine Working Group
LTIM Project	Long Term Intervention Monitoring Project
M&E	Monitoring and Evaluation
MDBA	Murray-Darling Basin Authority
MDMS	Monitoring Data Management System
MER Program	Monitoring, Evaluation and Research Program
NoW	NSW Office of Water
NPP	Net primary production
NPWS	NSW National Parks and Wildlife Service
NSW DPI	NSW Department of Primary Industries
PM	Project Management
QA/QC	quality assurance / quality control
SMWS	Safe Method Work Statement
SOP	Standard Operating Procedure
SRA	Sustainable Rivers Audit
TAGs	Technical Advisory Groups
WHS	Workplace Health and Safety
WRP	Water Resource Plan

D1. REED BED MONITORING RESEARCH

D1.1 INTRODUCTION

Wetlands are one of the most productive ecosystems on earth, providing a range of ecosystem services at local and regional scales, and supporting high levels of biological diversity (Finlayson et al. 2005, Desta et al. 2012). Wetlands are also among the most threatened ecosystems on earth, primarily driven by declines in area (habitat loss), degradation, climate change, and alterations to flow regimes (Finlayson et al. 2005, Dudgeon et al. 2006, Kingsford et al. 2016). The numerous ecosystem services supported by wetlands coupled with their declining condition has prompted a growing need for regular and accurate data collection of wetlands to inform management and implement adaptive management strategies effectively.

Reedbeds are a common and important component of wetlands. They provide important habitat, trap and process sediment and nutrients, and improve water quality (Tanner 1996, Zierholz et al. 2001, MDBA 2012). Reedbeds are typically comprised of the common reed (*phragmites australis* (CAV.) Trin ex Streud.), which is a widely distributed aquatic perennial grass of considerable ecological and economic value (Hawke and José 1996), as well as other macrophytes such as cumbungi (*Typha spp*.). The status of common reed varies between continents. Declines and dieback in common reed have been observed in Europe and Australia, attributed to changes in hydrology, erosion, grazing pressures, mechanical damage, and direct destruction (Ostendorp 1989, Roberts 2000, Thomas et al. 2010). Common reed has experienced range expansions in North America attributed to changes in hydrology and nutrient regimes (Chambers et al. 1999, Galatowitsch et al. 1999). Cumbungi has also increased in distribution and abundance in the northern Everglades attributed to increased nutrients, changes in hydrology (increased water depth and duration), and a recent fire (Newman et al. 1998). Similar range expansions of Cumbungi have occurred in Australia since European settlement, attributed to increased available habitat such as through the development of farm dams and urban wetlands (Roberts and Marston 2011). The economic and ecological implications of both declines and range expansions of common reed and cumbungi, and reedbeds more generally have triggered much international research on how to assess the condition of reedbeds, indicators of reed health, and their response and requirements for watering.

The Great Cumbung Swamp is a reed swamp that lies at the terminus of the low-gradient Lachlan River system, west of Hay, NSW, where the Lachlan River joins the Murrumbidgee River during floods which occur in 15-20% of years (O'Brien and Burne 1994, MDBA 2012). The Great Cumbung Swamp supports one of the largest areas of common reed and stands of river red gum (*Eucalyptus camaldulensis* Denh.) in NSW (MDBA 2012). The Great Cumbung Swamp also supports or is capable of supporting a large number of water bird species, including species listed as threatened under Commonwealth and state legislation as well as species which are recognized in international migratory bird agreements (Maher 1990, MDBA 2012). The central reedbeds of the Great Cumbung Swamp also provide an important drought refuge for birds (MDBA 2012).

D1.1.1 KNOWLEDGE GAP AND RESEARCH QUESTIONS

The vegetation of the lower Lachlan River system has been monitored as part of the Long Term Intervention Monitoring (LTIM) project (Dyer et al. 2015). The reedbeds of the Great

Cumbung Swamp have not been monitored as part of the LTIM project for logistical and financial reasons and nor are they monitored as part of the MER Program (Dyer et al. 2019). This means it has not been possible to evaluate the outcomes of the watering of the reedbeds. Commonwealth environmental water has been provided to the reedbeds multiple times in the past 5 years and it is expected that they will remain a priority into the future given recent changes in land ownership (the purchase of significant properties by The Nature Conservancy) and expected drought conditions over coming years. In addition, the Basin-wide environmental watering strategy (MDBA 2014) specifies objectives for stands of common reed and cumbungi in the Great Cumbung Swamp and the inability to monitor them is a notable omission.

Monitoring reedbeds poses significant logistical challenges using traditional field-based techniques. Access during inundation is difficult and frequently impossible without causing considerable damage or taking an inordinate amount of time. Methods are being developed across the world (see Section 1.4) to monitor reedbeds using drone imagery and remote sensing and there is an opportunity to invest in the research that would underpin the development of non-standard methods to monitor the response of reedbeds to the provision of environmental water.

The key research questions are:

1) What are the key indicators of condition for reedbeds?
2) What is an appropriate monitoring program for stands of common reed and cumbungi to capture their response to watering?

The benefits of this research would be three-fold:

1. During the development of the monitoring approach, data will be collected that will facilitate the evaluation of the reedbed response to watering during the MER Program, thus enhancing the evaluation provided for the vegetation diversity in the Lachlan Selected Area.
2. Methods will be developed that will underpin monitoring in subsequent programs.
3. Methods will be transferable to other areas in which water is provided to support stands of reeds.

D1.2 STUDY AREA

The Great Cumbung Swamp is a semi-arid environment, which experiences an (mean) annual rainfall of 367.4 mm and a mean maximum temperature of 33.1°C in January and 15.1°C in July respectively (Bureau of Meteorology 2019). The Great Cumbung Swamp is a terminal reed swamp surrounded by floodplain forests, woodlands, and shrublands (MDBA 2012). Terminal wetlands occur on low-energy rivers where flow spreads out and dissipates (Roberts 2000). The upstream reach of the Great Cumbung Swamp is fringed by 1 to 3 m wide belts of cumbungi, which also occurs in the surrounding back swamps of the Great Cumbung Swamp such as Lake Marool (O'Brien and Burne 1994, Driver et al. 2011). The central Great Cumbung Swamp contains a large reedbed dominated by common reed, which is the most extensive environment within the Great Cumbung Swamp (Figure 1;

O'Brien and Burne 1994). In the central reedbeds, common reed surrounds bodies of open water along the channel of the Lachlan River and smaller ephemeral flood channels (O'Brien and Burne 1994, Driver et al. 2011). The main channel of the Lachlan River within the Great Cumbung Swamp ranges from 0.7 m to up to 1.5 m deep (O'Brien and Burne 1994). Surrounding the Great Cumbung Swamp are several lakes not surrounded extensively by common reed, but more so by river red gums and groundsel (*Senecio sp*.) (O'Brien and Burne 1994).

The typical timing of floodplain inundation in the lower Lachlan River is spring, but lower lying parts of the floodplain can connect to the river throughout the year (Higgisson et al. 2019). Water resource development has intensified in the Lachlan River Catchment, since the construction of the Wyangla Dam in 1935 (Kingsford 2000). Regulation and flow extraction of the Lachlan River has reduced the flow of the Lachlan River (current flows at Oxley (near the Great Cumbung Swamp) are approximately half that under undeveloped flow conditions (Driver et al. 2011)), which has changed the behavior and distribution of floodwaters (Driver et al. 2004, Higgisson et al. 2019).

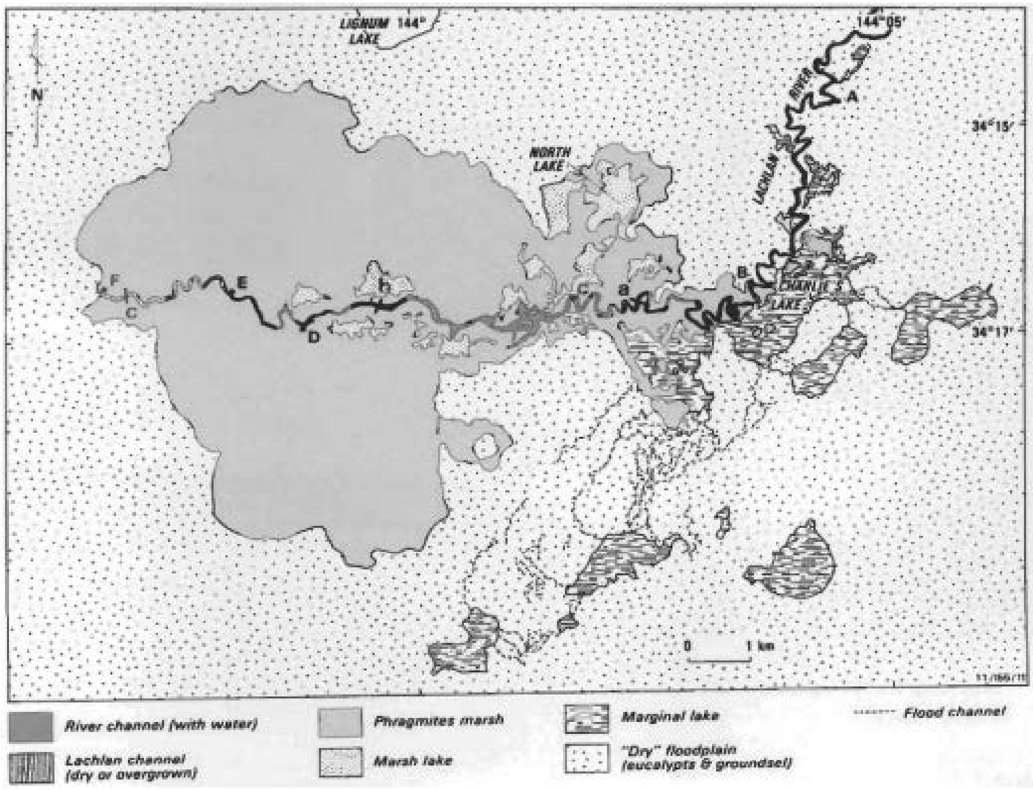

Figure 1 Map of environments of the GCS (O'Brien and Burne 1994).

D1.3 STUDY SPECIES

Common reed and cumbungi are emergent aquatic perennial rhizomatous species (PlantNET 2019), which are both widely distributed across Australia (AVH 2019). In eastern Australia, common reed shoots begin to grow in October, and reach maximum height and biomass in March-April, then gradually senesce over Autumn and Winter (Roberts and Marston 2011). Cumbungi growth increases in spring, and shoots reach their maximum height in early summer (Roberts and Marston 2011). Cumbungi and common reed growing in the Great

Cumbung Swamp have been observed to have varying response to changes in water availability. Cumbungi biomass was observed to rapidly decline when surface water availability reduced, while declines in common reed were more gradual (Driver et al. 2011). Common reed was also observed to respond more quickly to increased surface water availability compared to cumbungi (Driver et al. 2011).

Common reed has been observed to occur across a range of hydrological conditions and tolerate flooding and exposure, while cumbungi generally occurs in permanently flooded and hydrologically stable conditions (Blanch et al. 1999). The recommended watering regime for common reed is flooding every one to two years, to 20 to 30 cm depth, for five to eight months, while the recommended watering regime for cumbungi is flooding annually, depth not critical (0.3 to 1.5 m), for eight to 12 months per year (Roberts and Marston 2011).

D1.4 MONITORING REEDBEDS

Indicators of reedbed condition commonly include height, diameter and density of reeds, height and diameter of green stems, ratio of green to dry reed stems, density of flower heads, the presence of shrubs, and reedbed water levels (Hawke and José 1996, Poulin et al. 2010, Corti Meneses et al. 2017). Assessing reedbed condition typically occurs through field-based assessments and using remote sensing techniques. Field-based assessments typically involve the measurement of physical indicators (such as density, height and diameter of stems) within 1 X 1 m quadrates (Hawke and José 1996) while data collection through remote sensing typically involves the use of satellite or drone imagery and LiDAR and multi spectral cameras (Assmann et al. 2018).

During field-based assessments, Corti Meneses et al. (2017) measured density (stems/m2), stem diameter, number of stems with and without shoots, and the number of green and dried stems. Davranche et al. (2010) measured reed density (by counting the green and dry stems inside four (50 X 50 cm) quadrates within 20 X 20 m plots) as well as water level, plant cover and composition along two diagonals crossing the entire plot.

Multi-spectral cameras deployed on drones have also been successfully used to map landcover and vegetation attributes across a range of vegetation classes, including wetlands (Lebourgeois et al. 2008, Wehrhan et al. 2016, Ahmed et al. 2017). Multi spectral cameras work by filtering all but the desired band wavelength (nm). The data from these spectral bands are typically combined to generate spectral vegetation indices (SVI) which provide an approximate measure of the amount of live and green vegetation. Commonly used spectral vegetation indices include the Vegetation Index (VI) (see Tucker 1979), Normalized Difference Vegetation Index (NDVI) (Rouse Jr et al. 1973), and Soil Adjusted Vegetation Index (SAVI) (Huete 1988). These SVIs can provide useful and accurate data on reedbeds (Davranche et al. 2010, Poulin et al. 2010).

A range of studies have used satellite imagery in mapping wetlands and their associated vegetation communities, reedbed attributes (such as composition, extent, height, density and productivity), and mapping individual wetland species (Arzandeh and Wang 2003, Ghioca-Robrecht et al. 2008, Davranche et al. 2010, Poulin et al. 2010, Corti Meneses et al. 2017), including studies within Australia (Johnston and Barson 1993, Thomas et al. 2010). Aerial photography is generally preferred for detailed mapping of wetland types while satellite imagery are more appropriate for large geographic areas (Johnston and Barson 1993, Ozesmi and Bauer 2002).

D1.5 STUDY DESIGN

This project will involve on-ground field-based data collection and data collection from drone imagery using a multi spectral camera and satellite multi spectral imagery. Field and drone-based data collection will involve regular monitoring of fixed locations within the central reedbeds of the GCS over the period of October through April annually for two years. Growth rates and biomass in reedbeds varies throughout the year in response to seasonal changes in temperature and water availability (Engloner 2009 and references therein). The Spring/Summer period is the main growth period of common reed (Roberts and Marston 2011). These two years of data will be used to develop a standard monitoring approach which will be implemented as a trial in year 3 of the research program. Thus the year 3 data will complete the research program and will be used to contribute to evaluation in year 3 of the MER Program.

A field trip to the GCS was undertaken in early August 2019 following an environmental watering event in May/June 2019. This trip was undertaken to investigate where the water from this watering event reached within the reedbed and inform the selection of monitoring sites. Within the reedbed of the GCS there were several ephemeral channels off the main channel of the Lachlan River that were inundated and retaining water. These lowering lying parts of the GCS are devoid of reeds. These open sections are surrounding by thick and tall stands of common reed. With increasing distance from the main channel of the Lachlan River and from these ephemeral channels the density and height of the common reed appears to reduce (Figure 2).

Figure 2 The common reed reedbed of the GCS on 31 July 2019. Photo taken from a drone by Mal Carnegie.

Through observations during the field trips in August and October 2019, historic sentinel imagery of the Great Cumbung Swamp during flooding, and LiDAR (Appendix A1) to compare elevation, nine sites were identified as appropriate. Each site is a 50 by 50 m sqaure. These nine sites occur across a hydrological gradient from frequently wet to dry. Three broad hydrological categories were defined (Wet, Medium and Dry) and sites were assigned to each category (Figure 3).

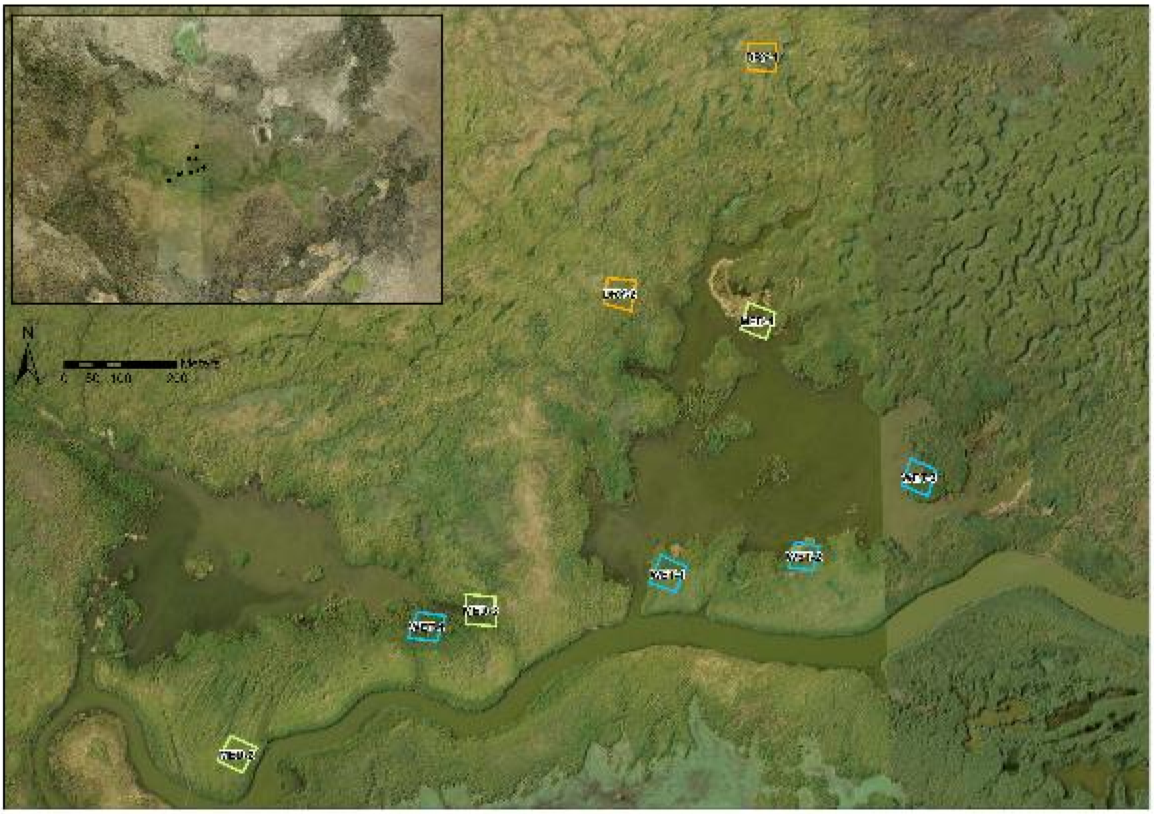

Figure 3 The sites used as part of this study. Each site contains 9 - 1m^2 quadrates. Sites are colored by preliminary watering categories: orange = dry sites, yellow = medium sites, and blue = wet sites.

D1.6 METHODS

Field-based data collection will include the measurement of height, number, and cover of green and dry reeds, number of flower heads, species richness and abundance of other species, percentage of litter, bare ground and water, and average water depth in (9) 1 X 1 m quadrates, situated within each 50 X 50 m site (Figure 4). These 50 X 50 m sites will also be surveyed by a drone using a multi spectral camera. The drone will capture each site, flying at a height of 40 m, taking an overlap of 85% footage. This should take around 11 minutes flight time.

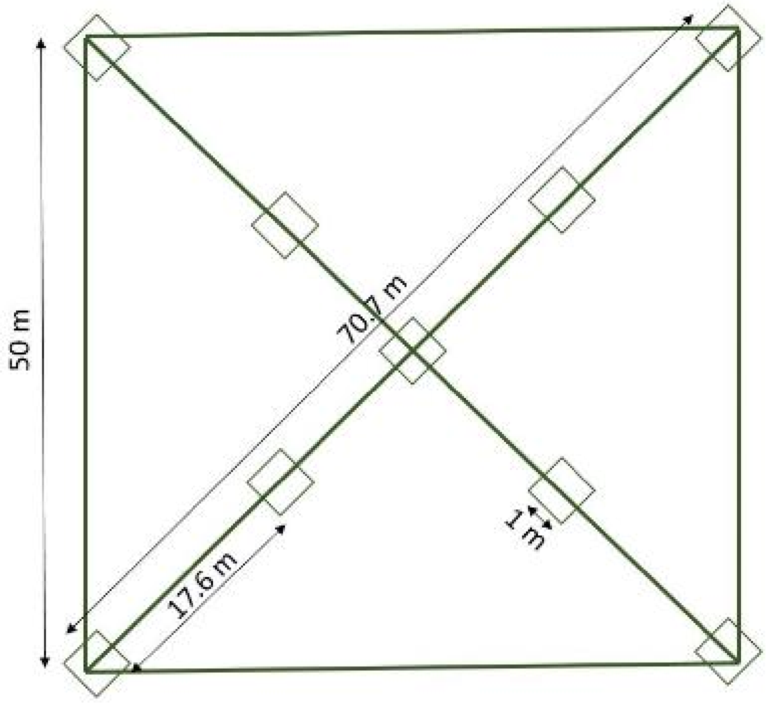

Figure 4 Diagrammatic representation of the study design, showing the layout of the 1 X 1 m quadrates used for field-based assessments within the 50 X 50 m quadrate used for remote sensing.

The drone imagery of each site will be prepared and joined for processing. The mean reflectance values for each spectral band will be extracted for each site using the 'spatial analyst' of ArcGis (as has been done by Davranche et al. 2010, Poulin et al. 2010). Using the mean reflectance values for each spectral band, four spectral vegetation indices (SVIs) commonly found in the literature will be calculated (Table 1). These spectral vegetation indices provide an approximate measure of the amount of live and green vegetation and therefore can be used to detect a response to environmental conditions or a management action such as environment watering. The drone imagery will also be used to produce a DEM (Digital elevation model).

Table 1 Spectral vegetation indices used as part of this study.

Vegetation index	**Formula**	**References**
Vegetation Index (VI)	NIR / Red	Rouse Jr *et al.* (1973)
Normalized Difference Vegetation Index (NDVI)	(NIR – Red) / (NIR + Red)	Rouse Jr *et al.* (1973)
Differential Vegetation Index (DVI)	NIR – Red	See: Tucker (1979)
Soil Adjusted Vegetation Index (SAVI)	((NIR – Red) / (NIR + Red) + 0.5) X 1.5	Huete (1988)

The field-based indicators (such as height, number and cover of reeds, ratio of green to dry reeds) and multispectral indices (such as NDVI) obtained with the drone will be analysed with respect to hydrological conditions to determine the contribution of environmental water to these indicators and reedbed condition more broadly. The hydrological conditions, including the number of inundation events, and the timing and duration of events over the previous year will be calculated for each site using sentinel imagery. The sites which received environmental watering will be compared to those sites which did. The field-based indicators and vegetation indices derived from drone imagery will be assessed and compared to investigate each indicators response to watering/environmental conditions.

satellite imagery of the entire GCS (approx. 14 km X 10 km in area) will be obtained and analyzed using the Geoscience Digital Earth Australia platform. The classification and differentiation of the two target wetland species (common reed and cumbungi), bare ground and open water will be undertaken. A number of 'reference points' of common reed and cumbungi, along with sites of non-target vegetation and open water will be used to provide field validation, and assess the accuracy of remotely identifying each category using the accuracy matrix defined by Congalton (1991). These reference points will be visited during field-based assessments where the vegetation class will be assigned based on the tallest vegetation layer and the location will be taken with a GPS. The mean reflectance values for each spectral band will be calculated for each species across the GCS, and the SVIs outlined in table 1 will be calculated. The data obtained from the satellite imagery will provide an estimated total coverage area for: common reed and cumbungi, water, and bare ground across the entire GCS over the available satellite imagery (mid-1980s to present).

D2. APPROVALS, LICENSING AND REVIEW

The University of Canberra has the appropriate permissions and protocols in place for drone-based monitoring and Alica Tschierchke (an LTIM and MER team member) is the Universities chief drone pilot. Will Higgisson will undertake pilot training in May 2020.

Permission has been granted to monitor reedbeds within the Great Cumbung Swamp on the Northern side of the Lachlan River within the property owned by The Nature Conservancy. The Nature Conservancy does not run livestock within their part of the Great Cumbung Swamp or burn the reedbeds. Therefore, focusing our research within this property will improve our ability to detect a response of the reeds to watering.

A steering committee will be established for the research program that will involve Dr Rachel Thomas (NSW DoPIE), Dr Sharon Bowen (NSW DoPIE) and Dr Patrick Driver (NSW DoPIE).

D3. OUTPUTS AND OUTCOMES

D3.1 INFORMING ENVIRONMENTAL WATERING

The research is expected to inform environmental watering through the collection of primary monitoring data on the response of the reedbeds to environmental water throughout the MER program. It is expected that the evaluation reports in years 2 and 3 of the MER program (and possibly year 1) will be able to use these data in the technical reporting provided to the CEWO thus enhancing the evaluation provided for the vegetation diversity in the Lachlan Selected Area.

The research will also contribute to the broader knowledge base around the response of reedbeds to water and the types of methods used to monitor the responses.

D3.2 PUBLICATIONS

Three types of publications will be generated from the research:

1. Scientific publications
2. Methods documents, including standard operating procedures for methods that may be used in subsequent monitoring programs.
3. Technical report chapters.

D4. REFERENCES

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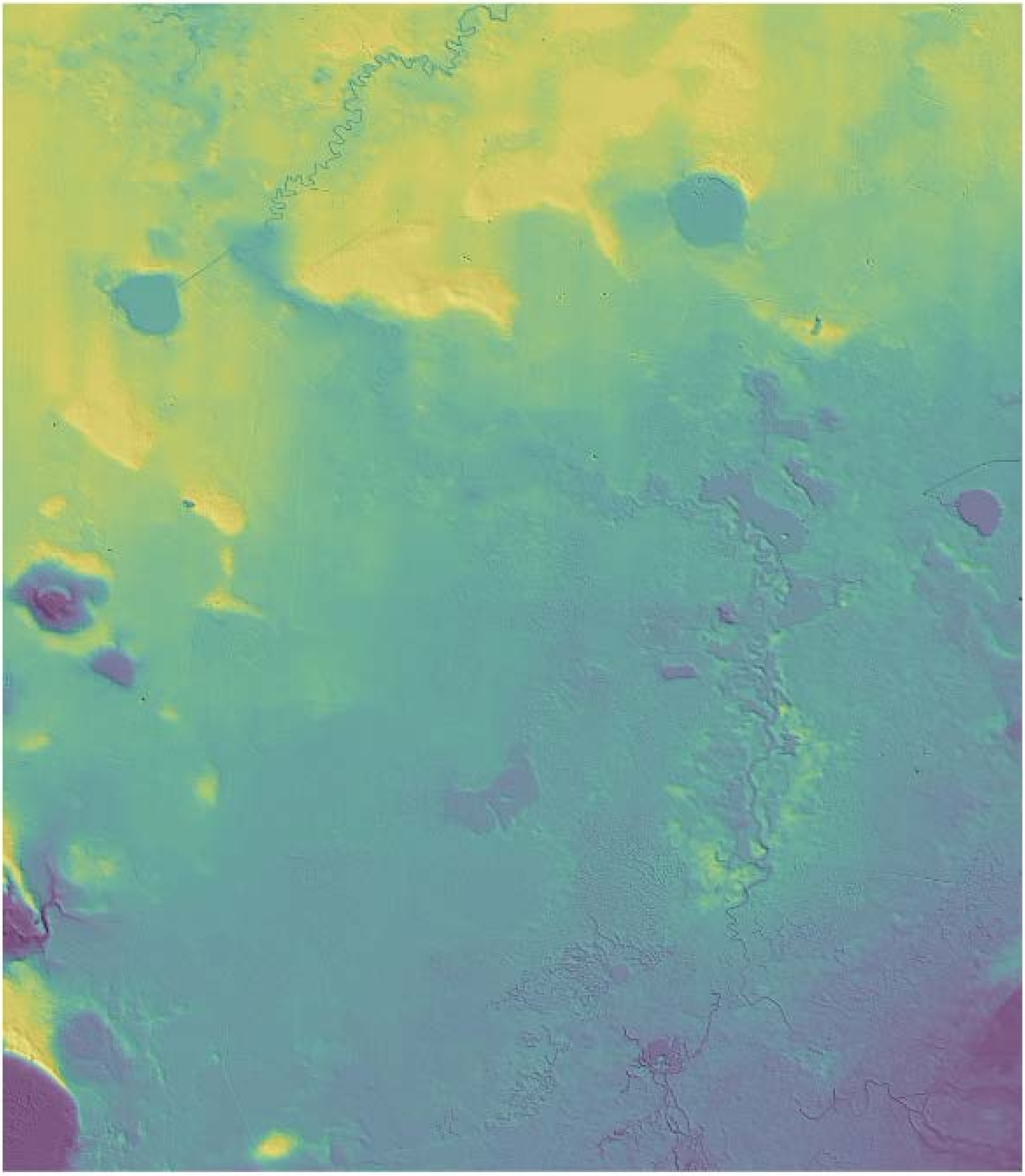
D5. SUPPLEMENT



1. LiDAR Image of the Great Cumbung Swamp and surrounding area.