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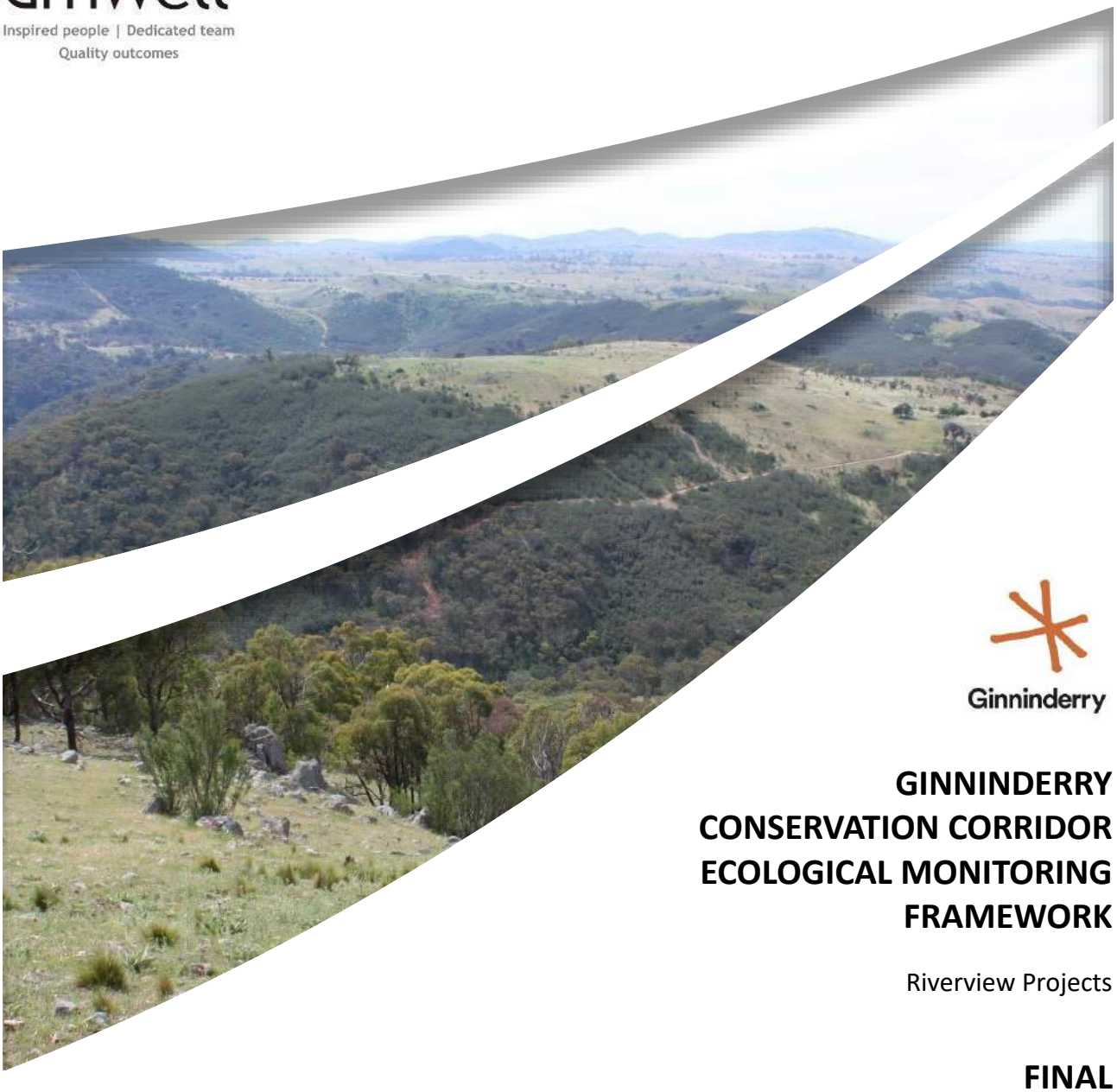

Ginninderry

GINNINDERRY CONSERVATION CORRIDOR ECOLOGICAL MONITORING FRAMEWORK

Riverview Projects

FINAL

April 2021

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Riverview Projects

FINAL

Prepared by
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on behalf of
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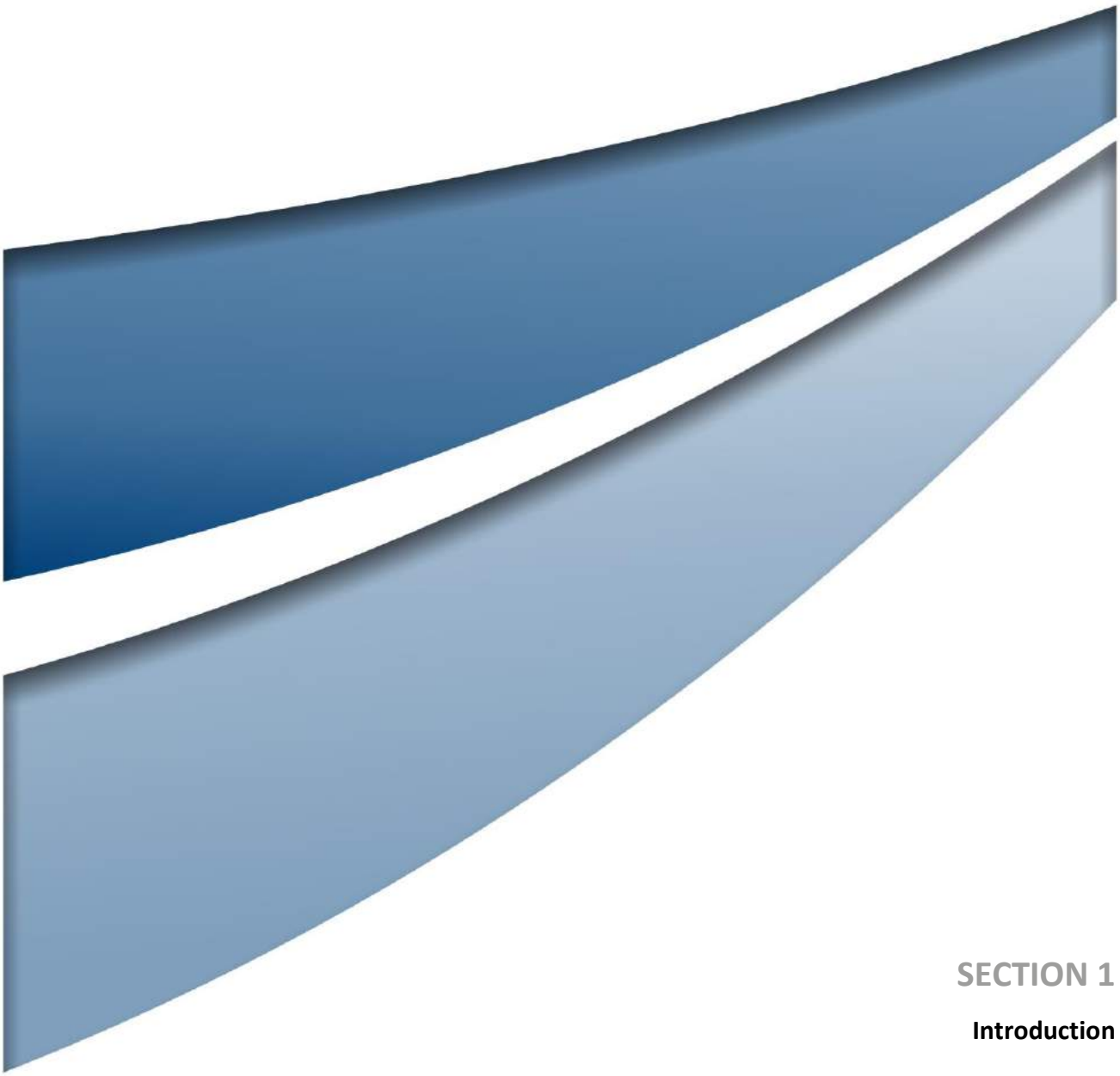


SECTION 1

Introduction

1.0 Introduction

This Ecological Monitoring Framework has been prepared on behalf of Riverview Projects (ACT) (Riverview). It aims to clearly define monitoring requirements established under relevant approvals and management plans and to meet the non-EPBC monitoring requirements (for example, the ACT Conservator of Flora and Fauna) to provide a concise consolidated guide for the ecological survey programme to be undertaken within the ACT portion of the Ginninderry Conservation Corridor (**Figure 1.1**).

The approved Program, including protection of Matters of National Environmental Significance (MNES) listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) within the Ginninderry Conservation Corridor, is documented in the West Belconnen Strategic Assessment Report (Umwelt, 2017) and the West Belconnen Strategic Assessment Program Report (AT Adams Consulting, 2017a); with relevant survey requirements outlined in the Offset Management Plan (SMEC, 2018), and the Ginninderry Conservation Corridor 2018 – 2023 Management Plan (the Management Plan; TRC Tourism, 2018).To ensure the effectiveness of the approved Program, a framework for monitoring is required for each of the MNES for which actions are proposed to be taken under the program as a direct consequence of the development. The relevant MNES known to occur within the Ginninderry Conservation Corridor are:

- *White Box – Yellow Box – Blakely's Red Gum Grassy Woodland and Derived Native Grasslands* (box – gum woodland) listed as critically endangered under the EPBC Act
- *Natural Temperate Grassland of the South Eastern Highlands* (natural temperate grassland) listed as critically endangered under the EPBC Act, and
- Pink-tailed worm lizard (*Aprasia parapulchella*) listed as vulnerable under the EPBC Act.

1.1 Objectives

This framework is intended to be the point of reference to ensure that there is a clear and agreed monitoring schedule, monitoring approach and thresholds for review of management measures. The framework is intended to remain as a 'live' document, includes standalone sections for annual monitoring of each ecological value, and includes guidance for ongoing update and adaptive management of the framework to ensure it remains consistent, appropriate and implementable. Consultation with relevant ACT Government agencies has been undertaken to ensure that this monitoring framework, wherever possible, is consistent with, and meets, the monitoring requirements for ACT conservation reserves and offsets, including the Conservation Effectiveness Monitoring Program (CEMP) (ACT Government, 2017).

1.2 Responsibilities

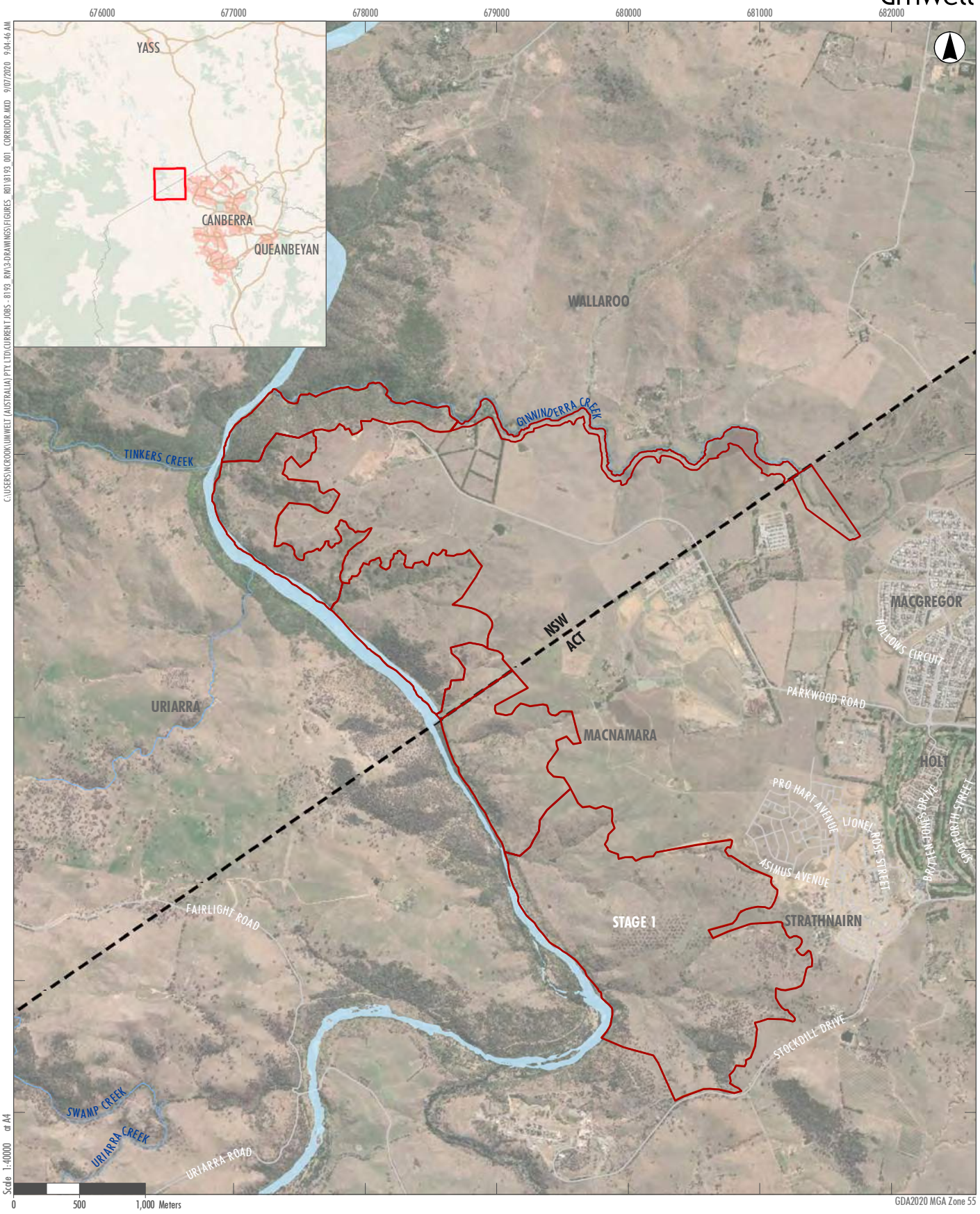
The Ginninderry Conservation Trust is responsible for management of the Ginninderry Conservation Corridor and delivering the actions required in the Management Plan (TRC Tourism, 2018). The Ginninderry Conservation Trust will ensure that the requirements of this Ecological Monitoring Framework are met, and that information collected informs the adaptive management process specified in the Management Plan.

1.3 Key Source Documents

1.3.1 Commonwealth Strategic Assessment

In July 2014, Riverview and the Commonwealth Government commenced a Strategic Assessment under Part 10 of the EPBC Act. The focus of the agreement was to assess the potential impacts from development of the West Belconnen project area (referred to as 'the development' in this report), on MNES protected under the EPBC Act. The Strategic Assessment Report (Umwelt, 2017) was finalised in March 2017. In September 2017, following endorsement of the Program Report – Urban Development at West Belconnen (AT Adams Consulting, 2017) on 18 July 2017, Riverview received an approval (Commonwealth of Australia, 2017) under the EPBC Act to implement the staged development of the project.

The Program Report (AT Adams Consulting, 2017) requires that a reserve management plan be prepared for the Ginninderry conservation corridor which includes a monitoring program for all MNES affected by the program, as well as other MNES potentially occurring. The reserve management plan (TRC Tourism, 2018) was approved by the ACT Environment Minister in 2018, and includes an adaptive management process based on monitoring results.



Legend

- Ginninderry Conservation Corridor Boundary and Stages
- ACT/NSW Border
- Murrumbidgee River
- Creeklines
- Roads

FIGURE 1.1

Ginninderry Conservation Corridor Location and Staging

Image Source: ESRI Imagery (2020) Data source: ACTMapi (2020), NSW LPI (2019); Riverview Projects

1.3.2 Ginninderry Conservation Corridor Management Plan 2018 – 2023

The Ginninderry Conservation Corridor Management Plan (TRC Tourism, 2018) was prepared as a condition of the ACT and Commonwealth EPBC Act approval for the corridor. The Management Plan provides a framework for achieving the various objectives of the Ginninderry Conservation Corridor, including biodiversity and heritage conservation, ecological restoration and visitor use, which will guide activities as the corridor is gradually acquired and developed. The Management Plan is not a statutory plan, and will remain as such until the 'Murrumbidgee River Corridor Plan' is expanded and incorporates the area of the Ginninderry Conservation Corridor.

The Management Plan specifies that monitoring programs should be developed in the overarching 'Ecological Restoration and Biodiversity Management Plan', monitoring programs to evaluate the success of restoration work and the condition of flora and fauna should be specified. Specifically, the Management Plan commits to monitoring, or demonstration of changes, relating to:

- The extent and condition of initial restoration works
- Areas of significant weed infestation
- Feral animal populations
- Condition of PTWL habitat, condition of the PTWL population
- Condition of natural temperate grasslands
- Condition of box – gum woodland, and
- Condition of the riparian zone and aquatic habitats of the Murrumbidgee River and Ginninderra Creek East.

1.3.3 Ginninderry Development Offset Management Plan

The Ginninderry Development Offset Management Plan (SMEC, 2018) was prepared as an Appendix to the Ginninderry Conservation Corridor Management Plan (TRC Tourism, 2018) to specify management actions required to offset residual impacts on EPBC Act listed critically endangered White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland (box-gum woodland) ecological community and the EPBC Act listed vulnerable pink-tailed worm lizard (*Aprasia parapulchella;* PTWL) in the Ginninderry Conservation Corridor.

The Offset Management Plan includes monitoring plans for PTWL and box- gum woodland, specifying monitoring requirements, baseline data, monitoring approaches, performance measures, performance targets and performance schedules. Monitoring requirements for pink-tailed worm lizard and box – gum woodland specified in the Offset Management Plan forms basis for relevant sections of this monitoring plan.

1.3.4 Section 303 Licence

A Section 303 licence for use of Unleased Territory Land between the Planning and Land Authority and ACT and Ginninderry Conservation Limited outlines obligations of Ginninderry Conservation Limited applying to Stage 1 of the Conservation Corridor (**Figure 1.1**). Any actions within the Ginninderry Conservation Corridor must be undertaken in accordance with the Section 303 Licence. No specific monitoring obligations are specified under the Section 303 licence, however the Licence refers to the Management Plan and all obligations including monitoring therein.

1.3.5 Conservation Effectiveness Monitoring Program

The ACT Government CEMP (ACT Government, 2017) aims to support development of a consistent approach for evaluation and reporting on management outcomes, to enable effective implementation of an adaptive management process to conservation reserve management in the ACT. It provides a framework for monitoring change in reserve condition, linking this to key drivers of change, and thus using monitoring information to trigger change in management. The CEMP includes the planned development of individual monitoring plans for four ecosystem units which occur within the Ginninderry Conservation Corridor:

- Lowland native grasslands
- Lowland woodlands
- Lowland forests
- Aquatic and riparian ecosystems.

While monitoring plans under the CEMP for each of these components have not yet been finalised by ACT Government, consultation with the ACT Government Conservation Research (CR) team and ACT Government Parks and Conservation Services has been undertaken to achieve consistency with the CEMP and other ACT Government monitoring methods where possible. CEMP indicators have informed the selection of indicators and threshold values.

1.4 Monitoring Commitments

1.4.1 Monitoring requirements under the EPBC Act approval

Conditions related to monitoring of MNES specified in the Program Report (AT Adams Consulting, 2017a) and/or the Plan of Management (TRC Tourism, 2018) are summarised in **Table 1.1**.

Table 1.1 MNES monitoring requirements

MNES	Condition Source	Monitoring Requirement Source

White Box – Yellow Box – Blakely's Red Gum Grassy Woodland and Derived Native Grasslands critically endangered ecological community (box – gum woodland)	• West Belconnen Strategic Assessment Program Report (Final 2017)
	• Ginninderry Conservation Corridor Management Plan 2018 – 2013
	  ○ Establishment of ongoing monitoring programs to assess the condition of remediation measures (in the next 5 years)
	  ○ Ongoing monitoring of the condition and impacts on the habitat
	  ○ Require periodic field research to assess changes in the quality and extent of box – gum woodland utilising data recorded by Nash and Hogg (2013) as baseline data
		Ginninderry Development Offset Management Plan (SMEC 2018)

MNES	Condition Source	Monitoring Requirement Source
Natural Temperate Grasslands of the South Eastern Highlands critically endangered ecological community (natural temperate grassland)	• Ginninderry Conservation Corridor Management Plan 2018 – 2013 ○ Establishment of ongoing monitoring programs to assess the condition of the grasslands, in reference to the baseline condition previously surveyed (in the next 5 years) ○ Ongoing monitoring of the condition and impacts on the NTG ○ Periodic monitoring of the condition of NTG areas utilising the baseline data established by Sharp (2015)	Not defined
Pink-tailed worm lizard (vulnerable)	• West Belconnen Strategic Assessment Program Report (Final 2017) • Ginninderry Conservation Corridor Management Plan 2018 – 2013 ○ Periodic monitoring of the condition of PTWL habitat using the baseline data established by Osborn and Wong (2013) ○ Monitoring of the condition of the PTWL population	Ginninderry Development Offset Management Plan (SMEC 2018)

1.4.2 Non-MNES monitoring requirements

The Ginninderry Conservation Corridor PoM (TRC Tourism, 2018) specified monitoring requirements for a range of environmental factors which are not listed as MNES. Monitoring requirements for non-listed environmental factors are specified in **Table 1.2**.

Table 1.2 Non-MNES monitoring requirements

Environmental Factor	Condition Source	Monitoring Requirement
Vegetation Condition Monitoring	Ginninderry Conservation Corridor Management Plan 2018 - 2013	Sharp (2015) undertook a baseline assessment of vegetation condition of the Conservation Corridor, and outlined a suite of survey techniques used and recommended for future assessments. These techniques essentially are a combination of structural and floristic assessments that align with ACT Government methods (which are developed from NSW methods). This polygon-based framework will be adopted to assess trends in vegetation condition across the Corridor through time. Specific monitoring programs of MNES offset commitments (Box-Gum Woodland and Pink-tailed Worm Lizard are outlined in the specific plans attached).
Vegetation Community Mapping	Ginninderry Conservation Corridor Management Plan 2018 - 2013	Vegetation communities and their condition have been mapped across the corridor (Sharp, 2015; RJPL, 2017), with a protocol outlined for future monitoring of condition across the communities. Repeated assessment of the condition of vegetation in each of the polygons identified in the baseline assessment will support management decisions across the corridor including measuring effectiveness of restoration, revegetation and weed management activities. Follow-up community-wide condition mapping will be undertaken in 2020, just prior to the first public access becoming available in the conservation corridor.

Environmental Factor	Condition Source	Monitoring Requirement
Riparian zone - Murrumbidgee	Ginninderry Conservation Corridor Management Plan 2018 – 2013	Monitoring of the condition of the Riparian Zone and recreation impacts – details to be provided in the Murrumbidgee Riparian Zone Plan. Monitoring of the condition of aquatic habitat and fish populations in conjunction with ACT and NSW Agencies – details to be provided in the sustainable fisheries plan.
Ginninderra Gorge Biodiversity Area (NSW)	Ginninderry Conservation Corridor Management Plan 2018 – 2013	Ginninderra Gorge Biodiversity Plan (to be prepared), not applicable to ACT
Woodland Birds	ACT Conservator of Flora and Fauna	Recommended by the Conservator to enable assessment of ecological condition and monitoring of important bird habitat along the Murrumbidgee River corridor and for consistency with past works. Monitoring of the proportion of habitat features occupied by invasive bird species in woodland areas is a requirement of the Ginninderry Development Offset Management Plan (SMEC 2018)

1.5 Monitoring Not Included in this Plan

This framework does not address the following monitoring components for the Ginninderry Conservation Corridor:

- Kangaroo monitoring requirements and method are to be completed in accordance with the Conservation Planning Kangaroo Management Strategy and is not addressed in this plan
- Monitoring requirements associated with conservation obligations outside the ACT component of the Ginninderry Conservation corridor (not yet established as reserve), including:
    - All monitoring associated with the NSW part of the reserve,
    - flora and fauna monitoring requirements specific to the Ginninderra Gorge Biodiversity Area (NSW), or
    - golden sun moth and natural temperate grassland monitoring in the Gooroomon Grasslands Offset reserves.
- Murrumbidgee River riparian zone monitoring to be determined by the Murrumbidgee Riparian Zone Plan
- Aquatic habitat and fish population monitoring to be determined by the ACT Government's sustainable fisheries plan

With respect to the NSW portion of the Conservation Corridor, the intention is for the conservation corridor to be managed as a Biodiversity Stewardship Site under the *Biodiversity Conservation Act 2016* (BC Act). It is anticipated that NSW approvals processes would require monitoring to be completed in accordance with the Biodiversity Assessment Method (BAM) or subsequent relevant legislation (NSW Government, 2017).

1.6 Baseline Information

Baseline information on the extent and condition of MNES, as well as non-listed vegetation, within the Ginninderry Conservation Corridor has been collected during the impact assessment and approvals process, and during preliminary surveys of the Ginninderry Conservation Corridor. Existing monitoring completed at the site falls into the following categories:

- *Box – gum woodland*: mapping and plot data collection by David Hogg Pty Ltd (DHPL) in 2013 (Nash and Hogg, 2013), and additional preliminary mapping and biometric plot data in accordance with the baseline monitoring procedure (Sharp, 2015) by Robert Jessop Pty Ltd (RJPL) in 2014 (RJPL, 2015).
- *Natural temperate grassland*: preliminary mapping and biometric plot data in accordance with the baseline monitoring procedure (Sharp, 2015) by RJPL in 2014 (RJPL, 2015) was collated and analysed against criteria for the 2016 updated EPBC Act listed critically endangered ecological community by Sarah Sharp (Sharp, 2017), detailed mapping in accordance with the 2016 guidelines and monitoring plot establishment was completed by Capital Ecology in 2020 (Capital Ecology, 2020).
- *Pink – tailed worm lizard*: initial habitat mapping and surveys by Wong and Osborne (2012); updated habitat mapping completed by Capital Ecology (2018; 2019).
- *Woodland birds*: no systematic survey, results of bird studies between 2006 and 2013 collated in Kevin Mills & Associates (2013).
- *Non-listed vegetation*: all vegetation throughout the Ginninderry Conservation Corridor classified into vegetation units based on management boundaries and broad-scale characteristics in 2014 (RJPL, 2015); biometric plots data collected in each vegetation zone in accordance with the baseline monitoring procedure (Sharp, 2015) in 2014 (RJPL, 2015).
- *Riparian vegetation*: riparian vegetation zones mapped and biometric plot data collected in accordance with the baseline monitoring procedure (Sharp, 2015) in 2014 (RJPL, 2015); detailed aquatic and riparian assessment of Stream E completed in 2018 and 2019 (Roberts and Sharp, 2019; 2020).

1.6.1 Box – gum woodland

Baseline data relating to the extent of box – gum woodland throughout the Ginninderry Conservation Corridor is not consistent throughout the reserve. Detailed mapping of the EBPC Act listed White Box – Yellow Box – Blakely's Red Gum Grassy Woodland and Derived Native Grasslands critically endangered ecological community in the Ginninderry Conservation Corridor adjacent to the development boundary was completed by David Hogg Pty Ltd (DHPL) in 2013 (Nash and Hogg, 2013) (**Figure 1.2**). This study was restricted to areas of box – gum woodland identified during earlier studies completed during the impact assessment processes for the West Belconnen development and did not include surveys for box – gum woodland elsewhere in the Ginninderry Conservation Corridor. Additional areas of vegetation meeting EPBC Act listing criteria for inclusion in the listed box – gum woodland ecological community were identified during broad-scale vegetation surveys throughout the Conservation Corridor by Robert Jessop Pty Ltd (RJPL) in 2014 (RJPL, 2015). Boundaries of additional areas of box – gum woodland identified by RJPL were mapped into broad scale units based on general vegetation characteristics and management, and do not represent the exact boundaries of areas meeting criteria for EPBC Act listed box – gum woodland (**Figure 1.2**).

Baseline data on the condition of box – gum woodland areas has been recorded in 2012 by (Nash and Hogg, 2013) and in 2015 (RJPL, 2017). Data collected by Nash and Hogg (2013) comprises 20 x 20 m floristic diversity plots and independent transects. Seven floristic plots were completed in identified areas of EPBC Act listed box – gum woodland (**Figure 1.2**)**.**While there are some differences in plot structure and metrics recorded, floristic diversity data recorded in these plots is largely comparable with data collected as part of the baseline monitoring protocol for the conservation corridor (Sharp, 2015), and with data collected for woodland monitoring in ACT Government managed offset reserves.

RJPL (2017) completed baseline assessments at a total of ten plots identified as box – gum woodland. Five plots were completed in the EPBC Act listed box – gum woodland identified by DHPL, and five plots in additional areas meeting criteria for classification as the box – gum woodland critically endangered ecological community elsewhere in the Ginninderry Conservation Corridor, including one in NSW (**Figure 1.2**). These plots were completed in accordance with the monitoring protocol for the conservation corridor (Sharp, 2015), and data is largely consistent with that collected for woodland monitoring in other offset reserves across the ACT.

Updated mapping of box – gum woodland consistent with current ACT Government methodology throughout the Ginninderry Conservation Corridor is recommended to determine the baseline extent of box – gum woodland. Plot data collected by Nash and Hogg (2012) and RJPL (2015) provides baseline floristic diversity data, and plot data collected by RJPL (2015) provides baseline structural information.

1.6.2 Natural temperate grassland

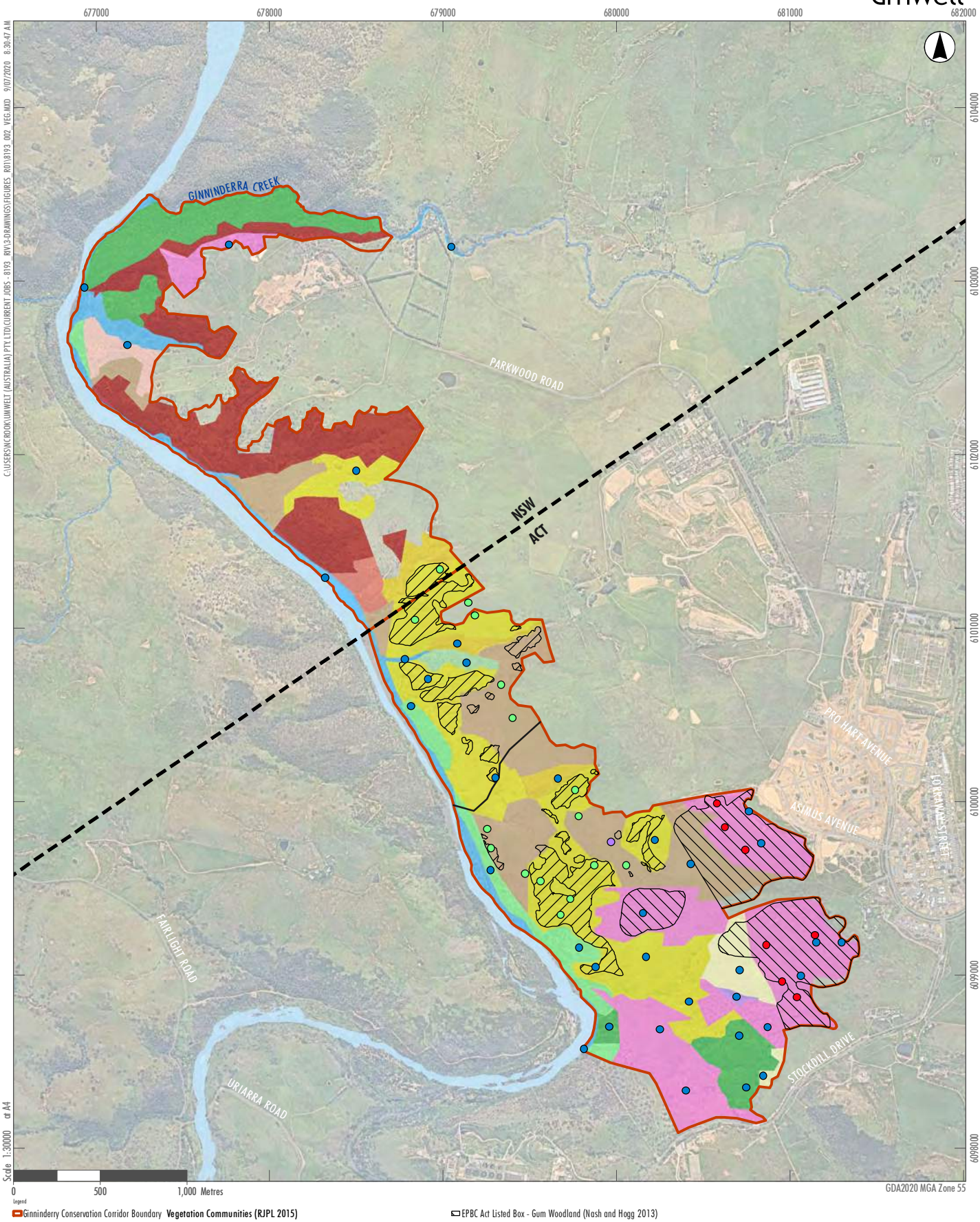
Broad scale mapping completed by RJPL (2015) was completed prior to the release of 2016 update to the EPBC listed critically endangered natural temperate grasslands of the south eastern highlands ecological community (Commonwealth of Australia, 2016). Following release of the updated listing advice, Sharp (2017) reclassified grassland vegetation communities previously identified in RJPL (2015) as "original community uncertain" as "Natural temperate grassland: rocky native grassland" based on revised classification criteria for the 2016 updated listing advice for natural temperate grassland endangered ecological community under the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) (Australian Government, 2016) and recognition of rocky natural grassland by ACT Government. Based on this reclassification, 11 plots completed by RJPL in 2014 were located in potential areas of Rocky Natural Grassland (RJPL, 2017) of which nine are located within the ACT portion of the Conservation Corridor (RJPL, 2017).

Baseline mapping completed in 2020 by Capital Ecology (2020) completed a detailed assessment identifying the distribution of the Commonwealth EPBC Act listed *Natural Temperate Grassland of the South Eastern Highlands* critically endangered ecological community in the Ginninderry Conservation Corridor. A total of 44.47 ha of diverse grasslands within the predicted former extent of natural temperate grasslands met criteria for the critically endangered ecological community. Eight monitoring plots and transects were completed in vegetation zones meeting criteria for the critically endangered ecological community and eight plots were completed in degraded native pasture and exotic pasture derived from natural temperate grassland but not meeting criteria for the critically endangered ecological community. Natural temperate grassland extent and condition data collected by Capital Ecology (2020) represents the best baseline data for natural temperate grassland.

1.6.3 Pink-tailed worm lizard habitat

Initial surveys for pink-tailed worm lizard habitat were completed throughout the Ginninderry Conservation Corridor and adjacent development areas by Wong and Osborne (2012). Pink-tailed worm lizard were confirmed to be widespread within extensive areas of suitable rocky habitat.

Mapping of habitat was updated throughout the Ginninderry Conservation Corridor by Capital Ecology in 2018 and 2019 (**Figure 1.3**). Capital Ecology (2018) confirmed much of the Wong and Osborne (2012) mapping within the ACT portion of the Ginninderry Conservation Corridor, while Capital Ecology (2019) significantly revised PTWL habitat in the NSW portion of the Ginninderry Conservation Corridor, more than doubling the amount originally mapped in 2011/2012 by Wong and Osborne (2013). The extent of pink-tailed worm lizard habitat mapped by Capital Ecology (Capital Ecology, 2018; 2019) represents the most detailed and accurate baseline throughout the corridor.



Legend

- Ginninderry Conservation Corridor Boundary
- Stage 1 Northern Boundary
- ACT/NSW Border
- Murrumbidgee River
- Creeklines
- Roads

Baseline Plots

- Capital Ecology (2020)
- Nash and Hogg (2013)
- RJPL (2015)
- Roberts and Sharp (2019)

Vegetation Communities (RJPL 2015)

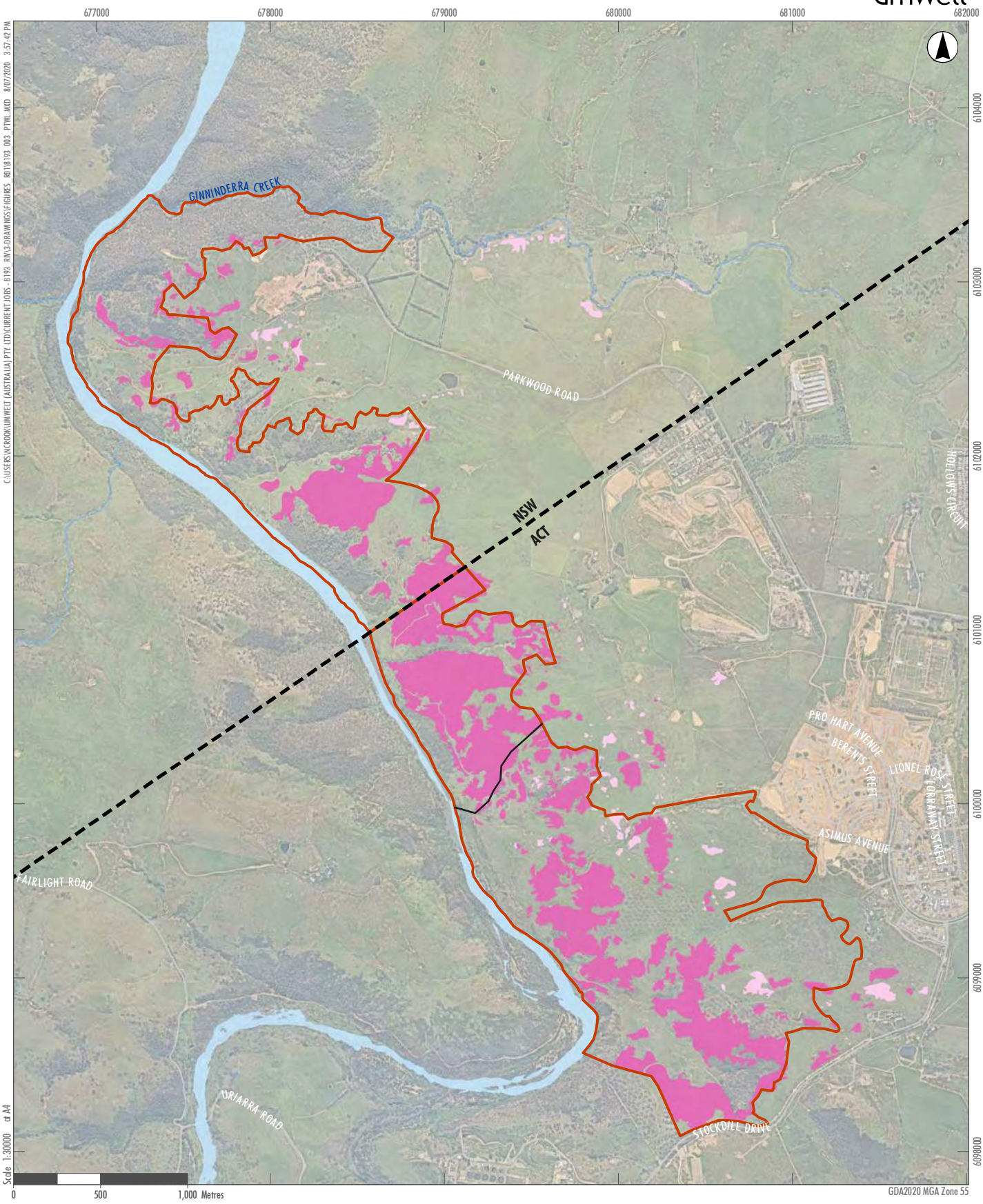
- Black Cypress Pine Tableland Open Forest - riparian and dryland
- Derived shrubland - Black Cypress Pine Tableland Open Forest - riparian and dryland
- Burgan Tableland Shrubland - riparian and dryland
- Red Stringybark - Scribbly Gum Tableland Forest
- Derived shrubland - Red Stringybark - Scribbly Gum Tableland Forest
- Derived grassland - Red Stringybark - Scribbly Gum Tableland Forest
- Depauperate native pasture
- Depauperate native pasture and woody weeds
- Exotic pasture
- River She-oak Tableland Riparian Woodland
- Rocky Natural Grassland
- Tableland Riparian Fringing Wetlands
- Yellow Box - Red Gum Tableland Grassy Woodland

- EPBC Act Listed Box - Gum Woodland (Nash and Hogg 2013)
- EPBC Act Listed Natural Temperate Grassland (Capital Ecology 2020)

FIGURE 1.2

Baseline Vegetation Mapping and Floristic Plot Locations

Image Source: Nearmap (May 2020) Data source: ACTMapi (2020), NSW LPI (2019), Riverview Projects, RJPL (2015); Nash and Hogg (2013)



Legend

- Ginninderry Conservation Corridor Boundary
- Stage 1 Northern Boundary
- ACT/NSW Border
- Murrumbidgee River
- Creeklines
- Roads

Pink-tailed Worm Lizard Habitat Quality

- High Quality
- Low Quality

FIGURE 1.3

Pink-tailed Worm Lizard Habitat

Image Source: Nearmap (May 2020) Data source: ACTMapi (2020), NSW LPI (2019), Riverview (2018), Captial Ecology (2019)

1.6.4 Woodland birds

No systematic woodland bird monitoring has been completed. Results of bird surveys conducted in the conservation area and adjacent development area to assist with development approvals between 2006 and 2013 are summarised in (Kevin Mills & Associates, 2013). This data does not constitute a formal baseline, however provides information on species diversity prior to development.

1.6.5 Non-listed vegetation

Mapping of vegetation zones throughout the Ginninderry Conservation Corridor completed by RJPL in 2014 represents the most detailed baseline mapping of non-listed vegetation (RJPL, 2015) (**Figure 1.2**). Community boundaries are mapped primarily on distinct management differences, and do not represent fine scale delineation of plant community types. As such, this mapping does not reflect original (i.e. pre-clearing) extent of plant communities in the landscape.

Baseline floristic diversity and vegetation structure plots in accordance with the baseline monitoring protocol (Sharp, 2015) were completed by RJPL in all identified vegetation types, providing detailed baseline data on vegetation composition and condition throughout areas of non-listed vegetation. Plot locations are shown in (**Figure 1.2**).

1.6.6 Riparian areas

Baseline floristic diversity and vegetation structure plots in accordance with the baseline monitoring protocol (Sharp, 2015) were completed by RJPL riparian areas, providing detailed baseline data on vegetation composition and condition at two riparian and one wetland site within the ACT portion of the reserve. Plot locations are shown in **Figure 1.2**.

A detailed riparian and aquatic condition assessment were completed in spring 2018 at Stream E (Roberts and Sharp, 2019) and replicated in spring 2019 (Roberts and Sharp, 2020). The assessment of Stream E focussed on physical structure, aquatic character and aquatic vegetation of the stream, however data on riparian vegetation was collated for benches. The detailed monitoring location (E09) is shown in **Figure 1.2**.

1.7 Implementation

1.7.1 Standard Operating Procedures

Monitoring processes in this management plan have been designed to be consistent with monitoring of environmental offset sites completed by the ACT Government Environmental Offset Team. Detailed operating procedures for floristic and vegetation structure monitoring cross reference to Environmental Offset *Ecological Condition Monitoring Methods 2020* (ACT Government, 2020). This is an iterative document and will be updated as methods and/or data collection methods change and evolve. The intent of this monitoring framework is to maintain consistency with ACT Government processes.

The ACT Government Environmental Offset team should be contacted prior to commencement of monitoring each year to obtain the most recent version of the *Ecological Conditions Monitoring Methods*.

1.7.2 Data Collection and Management

Data is to be collected as specified in the Ecological Conditions Monitoring Methods. Based on the Ecological Condition Monitoring Methods 2020, data is best collected using the following ESRI Survey 123 applications prepared by the Environmental Offsets Team:

- woodland Structure
- step Point
- offsets Monitoring
- weeds Monitoring.

Flexibility in the data collection process is permitted. To facilitate data collection, Ginninderry Conservation Trust must maintain appropriate licences with ESRI, to be provided to consultants, contractors or staff collecting the monitoring data. The above apps would be shared by the ACT Government Environmental Offset Team, and data linked with the ACT Government system. Following data collection, finalised data outputs then would be provided by the ACT Government Environmental Offset Team data management to the report authors for processing and interpretation.

This process ensures:

- Data collection is consistent with the latest ACT Government Environmental Offsets Monitoring data collection process
- Data is stored in a centralised database, accessible to the ACT Government in the long term
- Ongoing engagement and collaboration between Ginninderry Conservation Trust and ACT Government Environmental Offsets Team

The ACT Government Environmental Offset team should be contacted prior to commencement of monitoring each year to obtain the most recent version of the data collection apps required to implement the *Ecological Conditions Monitoring Methods*.

1.7.3 Reporting

A monitoring report is to be produced within three months of each monitoring event being completed. For efficiency, monitoring of multiple values may be reported in a single report however data for each monitoring component must be analysed and presented independently to facilitate easy extraction and comparison with other data. At a minimum, reports must contain the following information for each monitoring component:

- Dates of surveys, including documentation and justification of any deviation from recommended survey timing
- Description of any key threats or degradation to monitoring components observed during the surveys
- Summaries of relevant indicators specified for each monitoring component
- Analysis of trends over time for each monitoring component
- Analysis of key indicators against the baseline data and trigger thresholds

- If thresholds are met the report must provide the following information for urgent consideration in the annual works plan and integration in future updates to the management plan:
    - Clearly identify the required response mechanisms
    - Discussion of seasonal conditions potentially influencing degradation
    - Identification of other factors potentially driving degradation
    - Additional information required to develop management recommendations
    - Potential response measures, consistent with those identified for each monitoring component.
- Consideration of the potential role of climate change in driving changes observed, and identification of potential management recommendations to halt degradation and/or increase resilience
- Other management or monitoring recommendations based on results or observations.

1.7.4 Adaptive management

Monitoring results, and specifically consideration of indicators against the baseline and benchmarks, should inform the annual works plans as specified in **Section 2.4**.

Section 2.5 identifies key indicators likely to reflect long term degradation. Where trigger thresholds for these indicators are met, a management review response is triggered to ensure that short and long term management is appropriate to meet the long term objectives. A management review response triggered under **Section 2.5** comprises:

- a review of relevant factors contributing to the observed degradation, including assessment over time with respect to previous monitoring and analysis between correlation in any declines in condition and relevant explanatory factors
- review of feasibility and appropriateness of relevant management measures to address relevant explanatory factors
- identification of potential actions to modify management to prevent further degradation
- identification of remediation actions, if appropriate
- incorporation of management response plan into the next annual works plan within 6 months of finalisation of the monitoring report, or within timeframes specified in the monitoring report, including a schedule for implementation
- implementation of the response must be commenced within 1 year of finalisation of the monitoring report, unless otherwise justified in the response schedule
- inclusion in annual compliance report in accordance with the Program Report (AT Adams Consulting, 2017) prepared in the year following monitoring should include a summary of actions undertaken in response to detected.

Reviews and updates to the Ginninderry Conservation Corridor Management Plan (TRC Tourism, 2018) and the Offset Management Plan (SMEC 2018) must incorporate additional management actions implemented or required on the basis of thresholds being exceeded. Additionally, reviews and updates to the Ginninderry Conservation Corridor Management Plan (TRC Tourism, 2018) and the Offset Management Plan (SMEC 2018) should incorporate any significant new ecological information relating to MNES collated during monitoring.

1.7.5 Review and update of the monitoring framework

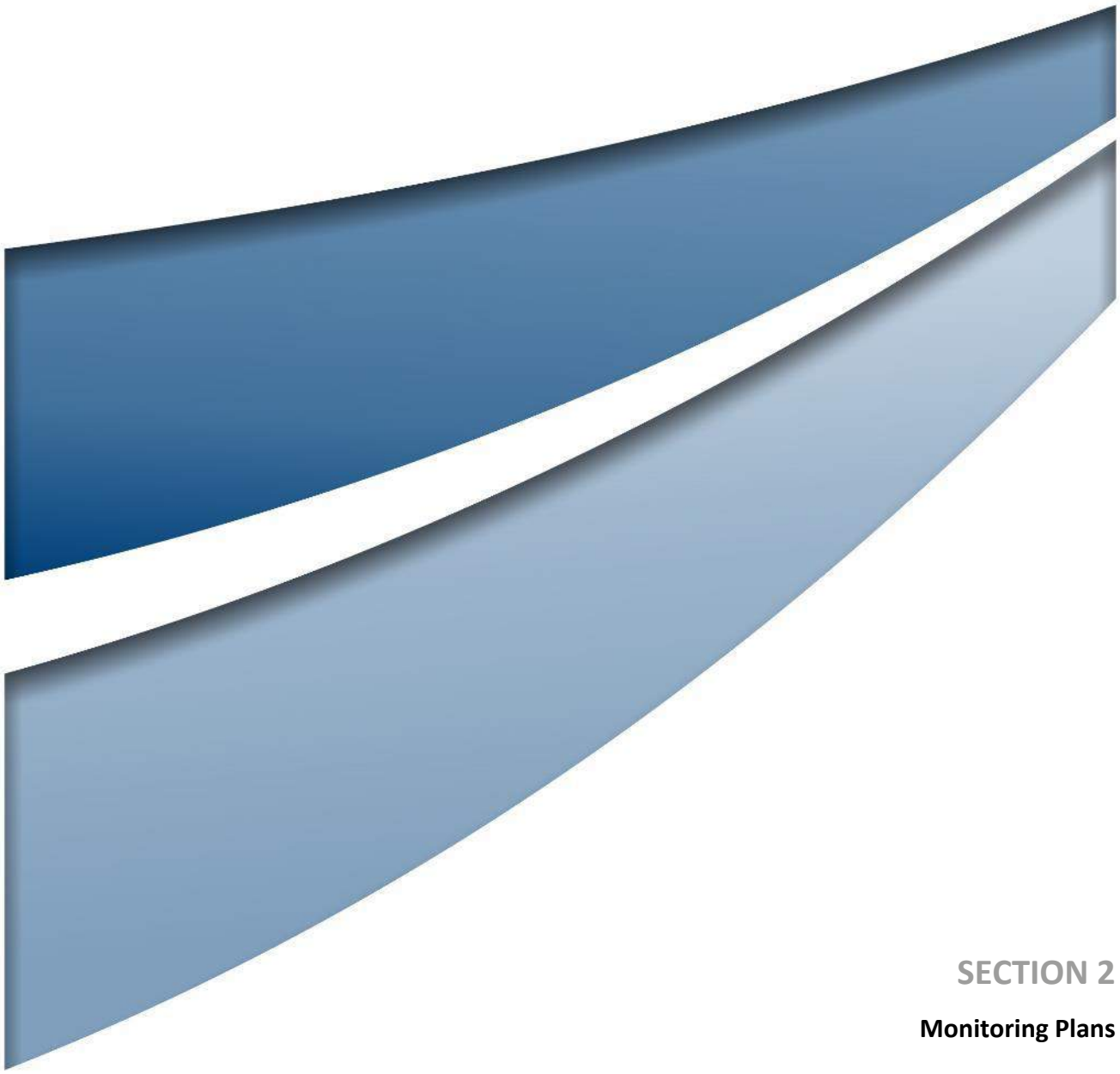
1.7.5.1 Finalisation of monitoring locations

Following completion of the 2020 monitoring of box – gum woodland and the 2021 completion of all remaining floristic plots this report should be updated with **Appendix A** and relevant figures documenting the final monitoring plot locations for each environmental component, including marked co-ordinates, photos and confirmation of the marking system.

1.7.5.2 Detailed review and update

A detailed review of the monitoring framework is required in the following circumstances:

- After 10 years, and every 10 years thereafter
- On agreement between ACT Government and the Ginninderry Conservation Trust:
    - to maintain consistency of monitoring protocols with other ACT Offset monitoring systems, or
    - to incorporate additional monitoring components required to effectively monitor and manage identified threats.



SECTION 2

Monitoring Plans

2.0 Box Gum Woodland Monitoring Plan

2.1 Requirements

The monitoring requirements for the EPBC Act listed box – gum woodland critically endangered ecological community specified in the Program Report are presented in **Table 2.1**. The Ginninderry Conservation Corridor Management Plan (TRC Tourism, 2018) specifies

- Establishment of ongoing monitoring programs to assess the condition of remediation measures (in the next 5 years)
- Ongoing monitoring of the condition and impacts on the habitat
- Require periodic field research to assess changes in the quality and extent of box – gum woodland utilising data recorded by Nash and Hogg (2013) as baseline data.

These requirements specifically apply to box – gum woodland patches identified by Nash and Hogg (2013), however should also be extended to determine the extent of EPBC Act listed box – gum woodland critically endangered ecological community associated with additional areas identified to support 'ACT16 *Eucalyptus melliodora – E. blakelyi* Tableland Grassy Woodland' by RJPL (2015) (**Figure 2.1**).

Table 2.1 Box-gum woodland monitoring requirements (AT Adams Consulting, 2017)

Outcome	Action	Baseline	Frequency
Ongoing monitoring of impact on woodland. Monitoring will be consistent with box-gum woodland monitoring in offset reserves across the ACT.	Field research to be conducted to assess change in the extent and quality of box-gum woodland habitat.	Adopt field data recorded by Nash and Hogg 2013, as baseline data.	Every two years from date of endorsement. Ability to review monitoring period if impacts have stabilised

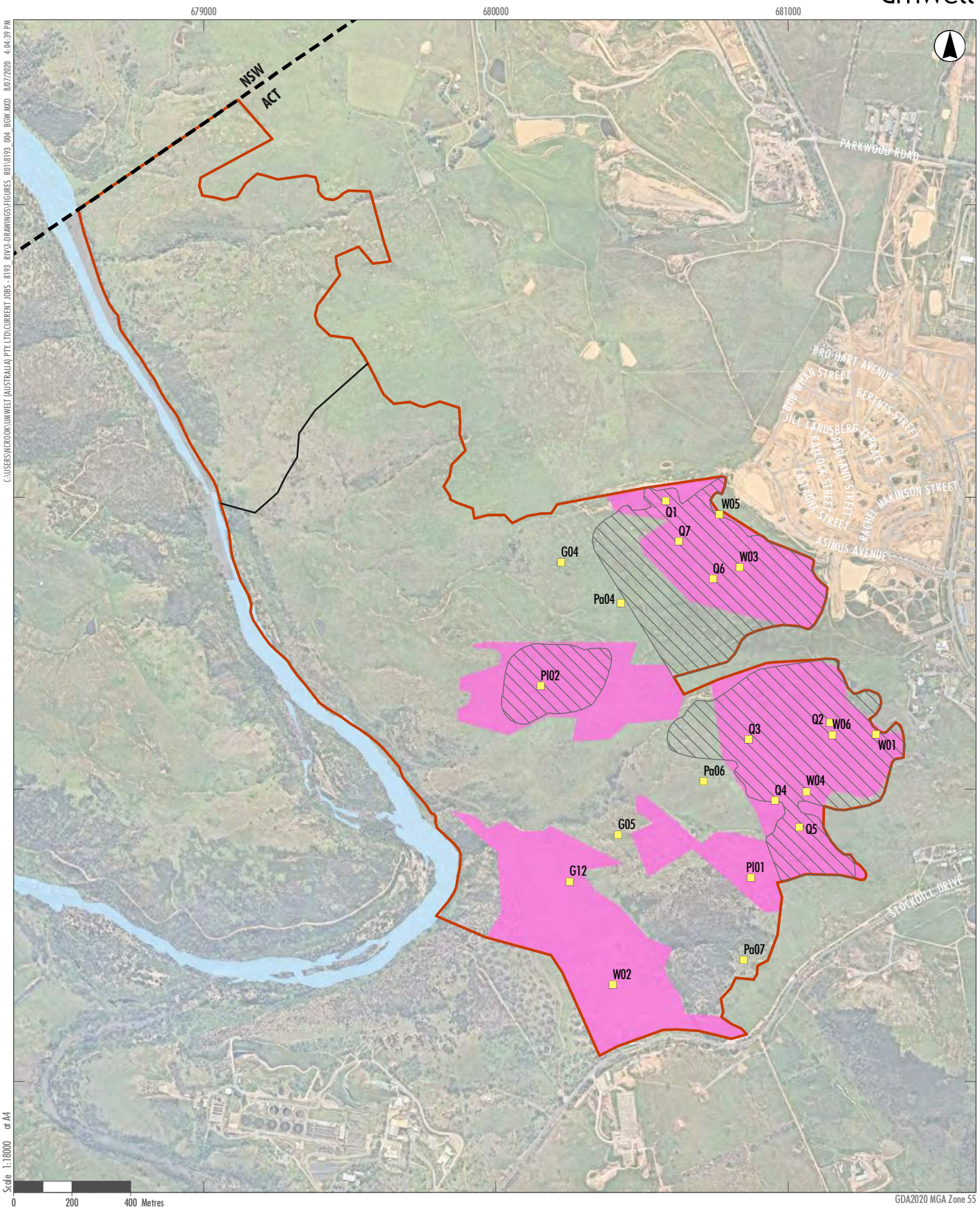
The monitoring program developed in the Offset Management Plan (SMEC, 2018) to meet commitments of the Program Report for box – gum woodland is provided in **Table 2.2**.

Table 2.2 Box-gum woodland monitoring program (SMEC, 2018)

Year	Task	Monitoring approach
In the first year following endorsement and every five years subsequently.	Mapping extent of box-gum woodland, habitat features, and threats.	Mapping consistent with that in other woodland offset reserves in the ACT. Apply Commonwealth criteria to confirm the current extent of box-gum woodland.
First year following endorsement, the third year and every five years subsequently.	Monitoring changes in the floristic condition and structure.	Plot-based monitoring consistent with standard woodland monitoring protocols in the ACT, as outlined in Sharp (2015). Monitoring of at least 18 plots for which baseline data is available.
First year following works, the third year and every five years subsequently. Monitoring duration to consider the features being restored.	Monitoring changes in the condition of specific features in restoration areas.	Plot-based assessment as outlined in work plans.

This section documents the monitoring program for box – gum woodland, including:

- a monitoring schedule, documenting the periodic requirement for monitoring
- the method to monitor the condition of box – gum woodland
- the location of monitoring plots
- key indicators to be used to detect changes in condition
- thresholds of change which will require an adaptive management response.



Legend

- Ginninderry Conservation Corridor Boundary (ACT)
- Stage 1 Northern Boundary
- ACT/NSW Border
- Murrumbidgee River
- Roads
- Yellow Box - Red Gum Tableland Grassy Woodland
- EPBC Act listed Box - gum Woodland (Nash and Hogg 2013)
- Box-gum Woodland Monitoring Plots

FIGURE 2.1

Box - gum Woodland Monitoring Requirements

Image Source: Nearmap (May 2020) Data source: ACTMapi (2020), NSW LPI (2019), Riverview Projects, RJPL (2015); Nash and Hogg (2013)

2.2 Monitoring Method

2.2.1 Extent of woodland and woodland habitat features

A revised baseline for box – gum woodland should be mapped in accordance with the requirements of the ACT Government box – gum woodland monitoring plan (ACT Government 2018a) and surveys undertaken throughout ACT Offset Reserves (Capital Ecology 2018). Areas identified as supporting box – gum woodland and derived grassland in either Nash and Hogg (2013) or RJPL (2015) (**Figure 2.1**), as well as adjacent areas of degraded grasslands, would be assessed to determine the revised baseline.

The revised baseline and subsequent monitoring of box – gum woodland extent should be achieved through implementation of the following steps:

- **Confirmation of Plant Community Type** (as defined by ACT Government 2015c): Areas within and adjacent to previously identified box – gum woodland or restored box gum woodland should be assessed to determine the current extent of 'ACT16 *Eucalyptus melliodora – E. blakelyi* Tableland Grassy Woodland' applied to areas previously identified as supporting box – gum woodland and adjacent vegetation to confirm current extent of the community. Plant Community Type boundaries should be mapped in the field to a high resolution using handheld GPS, mobile data collection device or directly onto high resolution orthorectfied aerial photograph field maps with one metre contours. Where modification has removed or disguised clear elements of the PCT boundaries, the mapping must take into account interpretation of less conspicuous landscape elements, such as:
    - Presence, species, growth form and density of remnant canopy trees and/or stags or stumps
    - Presence and species of midstorey shrubs and trees
    - Floristic composition of the groundstorey
    - Landscape position and other geographic features (elevation, aspect, soils, apparent hydrology etc.).

    The revised baseline monitoring should include an approximate original (i.e. pre-clearing) extent of 'ACT16 *Eucalyptus melliodora – E. blakelyi* Tableland Grassy Woodland' within the Ginninderry Conservation Corridor. Ongoing monitoring of woodland extent would be completed only within the identified area as the original PCT type would not change over time. The focus of ongoing monitoring would be vegetation zone definition and mapping and threat mapping.

- **Vegetation zone definition and mapping:** Areas identified as supporting support 'ACT16 *Eucalyptus melliodora – E. blakelyi* Tableland Grassy Woodland' should be divided into generally homogenous vegetation zones based on the structure, floristic composition and quality of the vegetation as indicated in **Table 2.3**, consistent with those applied by Capital Ecology (2018) throughout the ACT Government offset reserves. The defined zones are consistent with the woodland mapping presented for ACT Government Offset reserves in Capital Ecology (2018), permitting direct comparison with other sites in the ACT and assists in determining the type and prioritisation of management activities.

    Zone classification will take into account plot based floristic diversity and structure data (**Section 2.2.2**) Vegetation zone boundaries should be accurately mapped in the field to a high resolution using handheld GPS, mobile data collection device or directly onto high resolution ortho-rectfied aerial photograph field maps with one metre contours. Vegetation zones should be confirmed with reference to floristic diversity and structure data. For operational reasons, the minimum size of a vegetation zone is 0.25 ha. In many cases low condition vegetation includes isolated trees within modified landscapes.

- **Critically Endangered Ecological Community Determination:** Following zone definition and floristic condition monitoring, each vegetation zone is to be compared against the criteria identified in the relevant Commonwealth guidelines (Commonwealth of Australia, 2006; **Table 2.4**) to determine whether zones meet criteria for inclusion in the critically endangered ecological community.

- **Threat mapping**: The location and extent of any key threats or degradation within areas of box – gum woodland should be recorded, including erosion, weed infestation, dieback or significant grazing by native or invasive animals with the potential to degrade groundcover.

Ongoing monitoring would be completed in and adjacent to the confirmed revised baseline box – gum woodland area. The focus of ongoing monitoring would be vegetation zone definition and mapping and threat mapping as the original PCT type would not change over time.

Table 2.3 Vegetation zones for ACT16 *Eucalyptus melliodora - E. blakelyi* Tableland Grassy Woodland (Capital Ecology 2018)

Goundstorey dominance	Mature characteristic canopy sp. spp.	Regeneration of characteristic canopy sp./spp.	Native Forb Diversity[#] (Low, Mod-High)	Vegetation Zone ID
Native	Present	Present	Mod-High	16.1 (EPBC BGW)
			Low	16.2 (EPBC BGW)
	Absent	Present	Mod-High	16.3 (EPBC BGW)
		Absent	Mod-High	16.4 (EPBC BGW)
		Absent	Low	16.5
Exotic	Present	Present	Low	16.6
		Absent	Low	16.7
	Absent	Absent	Low	16.8

[#]Low = <12 sp. (disturbance tolerant spp. only); Mod – High = ≥12 sp.; incl. ≥1 important sp.; including disturbance sensitive spp.

Table 2.4 Criteria for the EPBC Act listed White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland Critically Endangered Ecological Community

Criteria	
Is, or was previously, at least one of the most common overstorey species white box, yellow box, or Blakely's red gum? ***and***	
Does the patch have a predominantly native understorey? ***and either***	
If the patch is 0.1 ha or greater in size:	Are there 12 or more native non-grass understorey species present? Is there at least one important species?
If the patch is 2 ha or greater in size:	Does the patch have an average of 20 or more mature trees per hectare, or is there regeneration of the dominant over storey eucalypts

[#]Important species as defined in the Listing Advice (Commonwealth of Australia, 2006).

2.2.2 Floristic diversity and structure

2.2.2.1 Monitoring locations

Previously completed baseline plot locations within areas identified as box – gum woodland are identified in **Figure 2.1**. Co-ordinates of all baseline monitoring locations are presented in **Appendix A**. In the first year following endorsement, survey should be completed in the ACT part of the conservation corridor for all identified plots for which baseline data is available (**Appendix A**), plus additional plots to ensure sampling of vegetation zones identified in **Section 2.2.1** meets minimum sampling requirements identified in the ACT Government environmental offsets calculator (ACT Government 2015b).

A total of 19 candidate plots for monitoring of box – gum woodland have been identified in the ACT, and one candidate plot also identified in NSW. Baseline surveys for all candidate were completed by by RJPL (2015) or Nash and Hogg (2013).

The first monitoring report should review and confirm the number and location of plots requiring ongoing monitoring, taking into account vegetation zones mapped as specified in **Section 2.2.1**. Where possible, monitoring of baseline plots should be preferentially selected however where not required, or effort is duplicated, baseline plot locations may be rationalised. This ecological monitoring framework, including **Appendix A** and relevant figures should be updated with the locations of ongoing monitoring plots following the initial monitoring report in accordance with **Section 1.7.5**.

2.2.2.2 Monitoring approach

Permanently marked plot are to be established at each monitoring location. The plot size to be used is a 0.04 0.1 ha (usually 20 m x 50 m) plot for vegetation and habitat structure with an associated transect for groundcover monitoring. The indicative layout is shown in **Appendix B**. Surveys must be undertaken according to the Environmental Offsets Ecological Condition Monitoring Methods (ACT Government, 2020). Grassland plots must be monitored using the following methods, preferably using the applicable Survey 123 apps provided by the ACT Government:

- SOP #1 Vegetation Surveys – Floristic Surveys
- SOP #2 Vegetation Surveys – Understorey Structure Surveys (using the *step point* transect survey option)
- SOP #3 Vegetation Surveys – Weeds Monitoring
- SOP #4 Vegetation Surveys – Woodland Attribute Surveys
- SOP #6 Soil Core Sampling.

Data is to be collected in Survey 123 using the relevant applications prepared and to be supplied by the ACT Government or collected using equivalent protocols to ensure the same indicators are captured. Data collected in accordance with the Environmental Offsets Ecological Condition Monitoring Methods (ACT Government, 2020) is comparable with West Belconnen Baseline Monitoring Procedure (Sharp, 2015) and compliant with the ACT Government environmental offsets calculator (ACT Government 2015b)

Floristic diversity data from 20 m x 20 m plots must be entered into the floristic value score calculator (Rehwinkel, 2015) to calculate a floristic value score as a key indicator of woodland groundcover condition. ACT Government data output systems include automatic calculation of floristic value scores and associated indicators.

2.2.3 Restoration monitoring

Restoration works should be subject to additional monitoring requirements outlined in the relevant work plan. Work plans would require monitoring of restoration sites to be completed in accordance with the monitoring guidance for woodland floristic diversity, structure and extent provided in **Sections 2.2.1** to **2.2.2**, but may include additional monitoring targeted at measuring the woodland components being actively restored.

Restoration works involving installation of vertical structures and habitat resources for hollow dependent species in box – gum woodland must include a plan for monitoring of the utilisation of habitat features by invasive bird species to comply with the OMP (SMEC, 2018). The recommended monitoring approach would be a single annual stag watch (20 minutes per site) at each installed vertical structure, completed in spring, documenting the number and type of both native and exotic species utilising the feature.

2.3 Survey Timing and Schedule

2.3.1 Survey timing

Monitoring surveys should be completed between October and December to correspond with maximum emergence of native forbs in box – gum woodland in the ACT, permitting assessment of native diversity in favourable conditions. However, exact survey timing may be adjusted to allow for seasonal variation in conditions. Late surveys should be avoided in hot and dry conditions. Any deviations from the recommended survey timing should be documented in the monitoring reports.

2.3.2 Monitoring schedule

The monitoring schedule for assessing box-gum woodland is presented in **Table 2.5**, and is in accordance with the program of monitoring proposed in the Offset Management Plan (SMEC 2018). Monitoring would be undertaken in the first year, third year and every five years unless otherwise determined by a review of monitoring requirements.

In the first year following endorsement, all plots at which baseline assessments have been undertaken (Nash and Hogg 2013; RJPL 2015), identified in **Appendix A**. The initial monitoring event must include a review of the 18 existing plots and assessment of whether these plots can be rationalised, or whether additional plots are required to gain a representative and informative sample across the box – gum woodland patch.

Table 2.5 Box - gum woodland monitoring schedule

Year	Season	Task
2020	Spring	• Mapping extent of box-gum woodland, habitat features, and threats; determination of the revised baseline. • Complete floristic condition and structure monitoring at baseline plots, and additional locations as required. • Field verification of plot locations for ongoing monitoring. • Park permanent plot locations.
2022	Spring	• Monitoring changes in the floristic condition and structure, 2nd year of baseline data.

Year	Season	Task
2024	Spring	• Mapping extent of box-gum woodland, habitat features, and threats. • Monitoring changes in the floristic condition and structure, 1st year of monitoring data. • Assessment of change against thresholds
2029 Ongoing every 5 years subject to review every 10 years commencing at 10 years.	Spring	• Mapping extent of box-gum woodland, habitat features, and threats. • Monitoring changes in the floristic condition and structure, ongoing. • Assessment of change against and thresholds
2030, 2040	n/a	• Review of monitoring framework and monitoring methods. • Ongoing monitoring every 5 years unless otherwise scheduled • Consultation with stakeholders regarding ongoing monitoring requirements.

2.4 Indicators

Monitoring metrics for box – gum woodland have been selected to be consistent with the Environmental Offsets Ecological Monitoring Program Report 2018-2019 (Howland, B, Carlson, E and O'Loughlin, T 2020) and represent a subset of indicators identified in the CEMP (ACT Government, 2017). Benchmark values represent the long term management target in most cases, however also represent short term targets for thatch density, grass height and weed density (plants per ha).

Each metric listed in **Table 2.6** must be summarised in each monitoring report and compared against benchmark value, the monitoring event results and baseline data, comprising the average of the first three years of monitoring following commencement. The purpose of this process is to track indicators that can be used to inform annual work plans and for short and long term tracking of ecological condition. Monitoring reports must include discussion of any substantial degradation relative to the baseline data (i.e. first three years of monitoring), with respect to potential causational factors. Indicators should be reviewed for each plot individually and for an average of each vegetation unit. If the following indicators exceed or are outside the benchmark ranges, then consideration of whether corrective management is required in the management response plan in accordance with **Section 1.7.4**:

- Thatch density
- Grass height
- Weed density (CNG, ALG, ST, STh, SJW) (plants per ha).

Additional threats and observed degradation not otherwise recorded by indicators, such as development of informal trails or invasive herbivore grazing, and potential management implications should also be noted.

In the event that conditions of any indicators are determined to be declining, consideration in accordance with **Section 1.7.4** is required to determine if there is a potential or confirmed threat, and whether a short or long term management response is warranted. Reporting should consider whether any management response required is localised, in response to change or degradation at specific locations, or general, in response to change or degradation across a broader area.

Table 2.6 Vegetation condition metrics for box – gum woodland (ACT16) (Howland, B, Carlson, E and O'Loughlin, T 2020).

Metric	Benchmark Values (ACT16)	Sampling unit	Standard Operating Procedures for Monitoring	ACT Government Survey123 App
Native overstorey cover (%)	11-32	20 x 50 m (0.1 ha), 10 random points	Ecological Offsets Monitoring Guidelines SOP #4 Vegetation Surveys – Woodland Attribute Surveys	Woodland Structure
Native mid-storey cover (%)	0-12.5	20 x 50 m (0.1 ha), 10 random points	Ecological Offsets Monitoring Guidelines SOP #4 Vegetation Surveys – Woodland Attribute Surveys	Woodland Structure
Proportion native cover (<1 m height) (%)	≥50	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Native ground cover (grasses)	23-63%	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Native grass cover (*Rytidosperma* sp.)		Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Native grass cover (C4 grasses)		Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Native ground cover (shrubs <1m height)	0-4.5%	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Native ground cover (other)	8-16.5%	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Exotic cover (perennial grasses)	≤5%	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Exotic cover (annual grasses)	≤5%	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Exotic cover (broadleaf)	≤5%	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Exotic cover (clover)	≤5%	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point

Metric	Benchmark Values (ACT16)	Sampling unit	Standard Operating Procedures for Monitoring	ACT Government Survey123 App
Rock cover		Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Bare ground cover (%)	10-20	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Cryptogam cover	1.6%	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Thatch cover (%)	15-30	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Leaf litter cover	68%	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Soil phosphorus (Colwell) (ppm 5 cm depth)	<20	20 x 20 m (0.04 ha), One amalgamated sample from 10 points in plot.	Ecological Offsets Monitoring Guidelines SOP #6 Soil Core Sampling	N/A
Floristic Value Score (FVS)	>37	20 x 20 m (0.04 ha)	Ecological Offsets Monitoring Guidelines SOP #1 Vegetation Surveys – Floristic Surveys	Offsets Monitoring
Native plant species richness	>35	20 x 20 m (0.04 ha)	Ecological Offsets Monitoring Guidelines SOP #1 Vegetation Surveys – Floristic Surveys	Offsets Monitoring
Important species richness		20 x 20 m (0.04 ha)	Ecological Offsets Monitoring Guidelines SOP #1 Vegetation Surveys – Floristic Surveys	Offsets Monitoring
Non-grass species richness		20 x 20 m (0.04 ha)	Ecological Offsets Monitoring Guidelines SOP #1 Vegetation Surveys – Floristic Surveys	Offsets Monitoring
Native vs exotic woodland understorey		Site extent	**Section 2.2.1**	
Extent of BGW		Site extent	**Section 2.2.1**	
Thatch depth (cm)		1 x 1 m	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point

Metric	Benchmark Values (ACT16)	Sampling unit	Standard Operating Procedures for Monitoring	ACT Government Survey123 App
Thatch density (thatch cover x thatch depth)	<0.25	1 x 1 m	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Average grass height (cm)	5-12	1 x 1 m	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
% large trees healthy (>75% canopy)		20 x 50 m (0.1 ha)	Ecological Offsets Monitoring Guidelines SOP #4 Vegetation Surveys – Woodland Attribute Surveys	Woodland Structure
% large trees dying (<25% canopy)		20 x 50 m (0.1 ha)	Ecological Offsets Monitoring Guidelines SOP #4 Vegetation Surveys – Woodland Attribute Surveys	Woodland Structure
Number of mature trees^	2	20 x 50 m (0.1 ha)	Ecological Offsets Monitoring Guidelines SOP #4 Vegetation Surveys – Woodland Attribute Surveys	Woodland Structure
Total length of coarse woody debris (m)	>35	20 x 50 m (0.1 ha)	Ecological Offsets Monitoring Guidelines SOP #4 Vegetation Surveys – Woodland Attribute Surveys	Woodland Structure
Overstorey regeneration (between 0 and 1)	1	Site extent	Ecological Offsets Monitoring Guidelines SOP #4 Vegetation Surveys – Woodland Attribute Surveys	
Abundance of eucalypt regeneration (stems ≤ 5cm)	100	20 x 50 m (0.1 ha)	Ecological Offsets Monitoring Guidelines SOP #4 Vegetation Surveys – Woodland Attribute Surveys	Woodland Structure
Invasive weeds density (plants per ha) [*Chilean needlegrass, African lovegrass, serrated tussock, saffron thistle, St John's wort*]	<1% or 50 plants perha	15 m radius from centre point of 20 x 20 m plot	Ecological Offsets Monitoring Guidelines SOP #3 Vegetation Surveys – Weeds Survey	Weeds Monitoring
Weed Value Score (WVS)	N/A	15 m radius from centre point of 20 x 20 m plot	Ecological Offsets Monitoring Guidelines SOP #3 Vegetation Surveys – Weeds Survey	Weeds Monitoring

Data Source: *Howland, B, Carlson, E and O'Loughlin, T 2020. Environmental Offsets Ecological Monitoring Program Report 2018 – 2019. Technical Report. Environment, Planning and Sustainable Development Directorate, ACT Government, Canberra and Environmental Offsets,* and *ACT Government 2020. Ecological Condition Monitoring Methods 2020. Technical Report. Environment, Environment, Planning and Sustainable Development Directorate, ACT Government, Canberra*

2.5 Triggers and Corrective Actions

Table 2.7 identifies the indicators, targets and thresholds and appropriate corrective actions to be implemented as specified in the Offset Management Plan (SMEC, 2018). The purpose is to enable identification of long term degradation, opportunities to improve long term management practices and development of a remedial action plan.

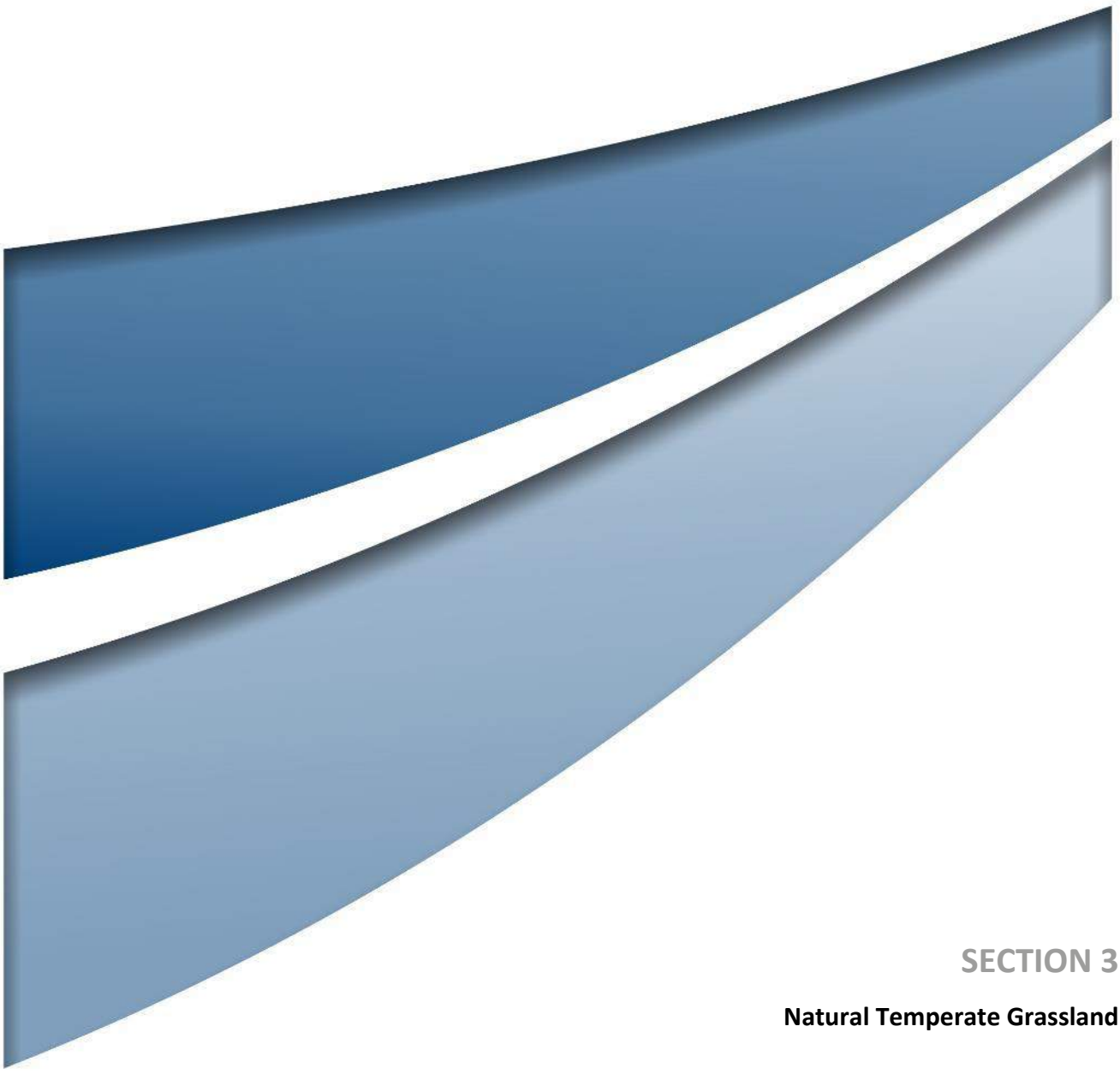
If thresholds are met, monitoring reports should address potential causes, and a review of causal factors and management options is triggered in accordance with **Section 1.7.4**.Where there is a measured decline in the quality of the box-gum woodland or associated habitat features, that is not likely to be caused by stochastic factors such as seasonal conditions, corrective actions – both with respect to short term response in the annual work plan and updating the overall management approach – are to be considered.

Review of overall management approach may also be recommended in monitoring reports based on observed and substantial changes to other indicators identified in **Section 2.3** where there are identified and justified.

Table 2.7 Box-gum woodland condition compliance (triggers and responses)

Habitat parameter	Sampling unit	Baseline	Target	Trigger	Response/Action
Extent of vegetation meeting criteria for Commonwealth listed box-gum woodland	The box – gum woodland management zone.	Extent of box – gum woodland meeting criteria for Commonwealth listed box-gum woodland (**Table 2.3**) mapped in the first year following endorsement.	15% increase in combined extent of Zones 16.1 to 16.4 in sampled areas over 20 years	Two or more season of monitoring showing a reduction relative to the baseline in extent of box-gum woodland habitat in the management zone.	• Review in monitoring report reasons for reduction in extent (i.e. management activities, disturbance, degradation or seasonal conditions) • Review of management measures specified in the GCCMP (TRC Tourism, 2018). • Consult with ACT PCS
Invasive weeds density (plants per ha) [Chilean needlegrass, African lovegrass, serrated tussock, saffron thistle, St John's wort]	Average **weed density** values in each vegetation unit in the box – gum woodland management zone	Average of the first three years of monitoring.	Benchmark values	Increase of 10% relative to the baseline *or* Benchmark (<50) exceeded after 10 years of management.	• Review of annual management response to weeds to ensure response is appropriate in scale and nature. • Review of management measures specified in the GCCMP (TRC Tourism, 2018), including consideration of need for update of long term weed management strategy. • Consideration or review of targeted weed control measures for box – gum woodland areas.

Habitat parameter	Sampling unit	Baseline	Target	Trigger	Response/Action
Average floristic condition of box-gum woodland independent of restoration sites. Floristic Value Score based calculated according to Rehwinkel (2015).	Average **Floristic Value Score** in each of Zones 16.1, 16.2, 16.3, 16.4 and 16.5	Average of first three years of monitoring data, plus consideration of variance from data from RJPL 2014 where plots coincide.	Benchmark values	Decrease of more than 20% in floristic condition of sampled areas relative to the baseline for two or more consecutive sampling years. *and* Zones 16.1, 16.3 and 16.4: After 10 years of management, do not meet benchmark. Zones 16.2 and 16.5: After 10 years of management have no positive trend towards benchmark.	• Review in monitoring report reason for reduction in condition (i.e. management activities, disturbance, degradation or seasonal conditions) • Review of management measures specified in the GCCMP (TRC Tourism, 2018). • Review of box-gum woodland restoration measures in consultation with ACT Government Parks and Conservation Service.
Presence of additional habitat features.	Average **length of fallen timber** in plots within each vegetation zone	Values recorded in the recorded in the initial monitoring	Benchmark values	No increase in the cover of woody debris in sampled areas of box-gum woodland relative to the baseline after 5 years.	• Review of box-gum woodland restoration measures in consultation with ACT Government Parks and Conservation Service.
Invasive bird species.	Installed vertical structures (**Section 2.2.3**)	N/A	No use of installed vertical structures by invasive native or exotic bird species	More than 30% installed vertical structures occupied by invasive native or exotic bird species.	• Review of management measures specified in the GCCMP (TRC Tourism, 2018). • Review of pest animal management strategy relating to invasive bird species.
Biomass management.	Average **Thatch Density** in each of Zones 16.1, 16.2, 16.3, 16.4 and 16.5	N/A Apply benchmark values.	Benchmark values	Thatch cover consistently outside benchmark values for 3 or more sequential monitoring periods	• Review of management measures specified in the GCCMP (TRC Tourism, 2018). • Review of annual biomass management response measures.



SECTION 3

Natural Temperate Grassland

3.0 Natural Temperate Grassland Monitoring Plan

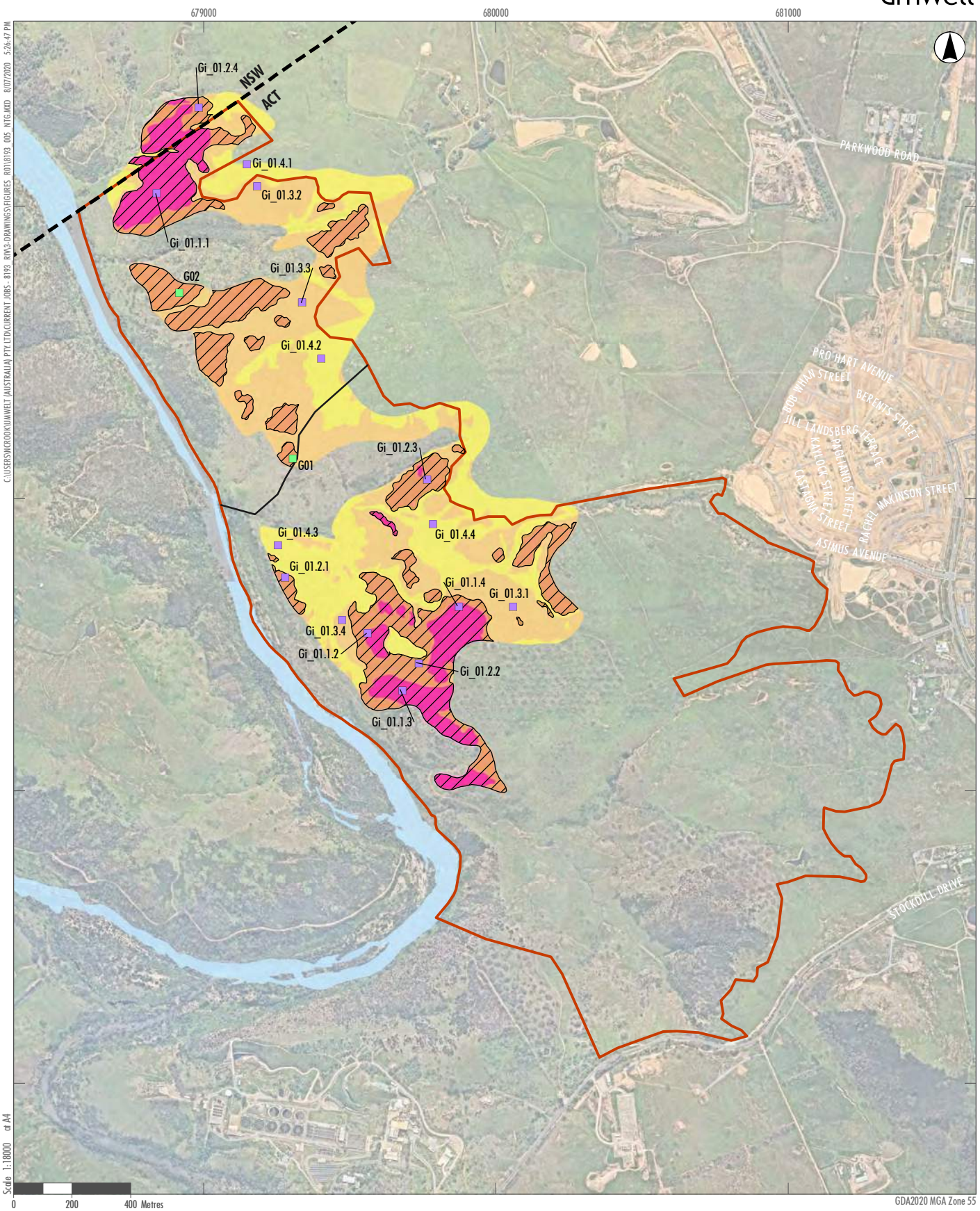
3.1 Requirements

No monitoring requirements are detailed in the Program Report (AT Adams Consulting, 2017). Natural temperate grassland was first identified in the Ginninderry Conservation Corridor in 2017 (Sharp, 2017) following approval of the Program Report. The Ginninderry Conservation Corridor Management Plan specifies the following monitoring requirements with respect to natural temperate grassland:

- Establishment of ongoing monitoring programs to assess the condition of the grasslands, in reference to the baseline condition previously surveyed (in the next 5 years)
- Ongoing monitoring of the condition and impacts on the natural temperate grassland
- Periodic monitoring of the condition of natural temperate grassland areas utilising the baseline data established by Sharp (2017)

This section documents the monitoring program for natural temperate grassland, including:

- a monitoring schedule, documenting the periodic requirement for monitoring
- the method to monitor the condition of natural temperate grassland
- the location of monitoring plots
- key indicators to be used to detect changes in condition
- thresholds of change which will require an adaptive management response.



Legend

- Ginninderry Conservation Corridor Boundary (ACT)
- Stage 1 Northern Boundary
- ACT/NSW Border
- Murrumbidgee River
- Roads

Grassland Monitoring Plots

- RJPL (2015)
- Capital Ecology (2020)

- ACT01 Zone 1 - NativeDom - High-VeryHighDiversity (Captial Ecology 2020)
- ACT01 Zone 2 - NativeDom - Mod-HighDiversity (Captial Ecology 2020)
- ACT01 Zone3 - NativeDom - LowDiversity (Captial Ecology 2020)
- ACT01 Zone4 - ExoticDom (Captial Ecology 2020)

- EPBC Act Listed Natural Temperate Grassland (Capital Ecology 2020)

FIGURE 3.1

Natural Temperate Grassland Monitoring Requirements

Image Source: Nearmap (May 2020) Data source: ACTMapi (2020), Captial Ecology (2020); NSW LPI (2019), Riverview Projects, RJPL (2015)

3.2 Monitoring Method

3.2.1 Extent of natural temperate grassland

Natural temperate grassland throughout the Ginninderry Conservation Corridor was mapped by Capital Ecology in Autumn 2020 (Capital Ecology, 2020) (**Figure 3.1**) comprising the first detailed mapping of grassland extent in accordance with the Commonwealth listing guidelines for the natural temperate grasslands critically endangered ecological community (Commonwealth of Australia, 2016), ACT Government natural temperate grasslands monitoring guidelines (ACT Government, 2018cd and associated baseline mapping and monitoring surveys undertaken throughout ACT Offset Reserves (Capital Ecology, 2018b).

Future monitoring of the extent of natural temperate grassland should be completed in accordance with the requirements of the ACT Government natural temperate grasslands monitoring guidelines (ACT Government 2018d) and associated baseline mapping and monitoring surveys undertaken throughout ACT Offset Reserves (Capital Ecology, 2018b). The estimated pre 1750 extent of natural temperate grassland in the Ginninderry Conservation Corridor estimated in Capital Ecology (2020) should be the maximum extent of natural temperate grassland assessment.

Monitoring of natural temperate grassland extent should be conducted through the following steps:

- **Confirmation of Plant Community Type** (as defined by ACT Government, 2015c): The pre 1750 extent of natural temperate grassland in the Ginninderry Conservation Corridor estimated in Capital Ecology (2020) should be used to inform the maximum extent of natural temperate grassland assessment. Ongoing monitoring would be completed only within this area as the original PCT type would not change over time. The focus of ongoing monitoring would be vegetation zone definition and mapping and threat mapping.

- **Vegetation zone definition and mapping:** Areas identified as supporting support 'ACT01 – Tablelands Dry Tussock Grassland' should be divided into generally homogenous vegetation zones based on the structure, floristic composition and quality of the vegetation as indicated in **Table 3.1**, consistent with those applied by Capital Ecology (2020). The defined zones are consistent with the grassland mapping presented for ACT Government managed offset reserves in Capital Ecology (2018b), permitting direct comparison with other sites in the ACT and assists in determining the type and prioritisation of management activities.

  Zone classification will take into account plot based floristic diversity and structure data (**Section 3.2.2**) Vegetation zone boundaries should be accurately mapped in the field to a high resolution using handheld GPS, mobile data collection device or directly onto high resolution orthorectified aerial photograph field maps with one metre contours. Vegetation zones should be confirmed with reference to floristic diversity and structure data. For operational reasons, the minimum size of a vegetation zone is 0.25 ha. In many cases low condition vegetation includes isolated trees within modified landscapes.

- **Critically Endangered Ecological Community Determination:** Following zone definition and floristic condition monitoring, each vegetation zone is to be compared against the condition thresholds identified in the Commonwealth guidelines (Commonwealth of Australia, 2016a; 2016b; **Table** 3.2) to determine whether zones meet criteria for inclusion in the critically endangered ecological community.

- **Threat mapping**: The location and extent of any key threats or degradation should be recorded, including erosion, weed infestation, excessive biomass, or significant grazing by native or invasive animals with the potential to degrade groundcover.

Table 3.1 Vegetation zones for ACT01 Tablelands Dry Tussock Grassland (Capital Ecology 2018b)

Goundstorey dominance	Native Forb Diversity (Floristic Value Score)	Vegetation Zone ID	Reason for Exotic Dominance
Native	High: FVS ≥ 6.5	01.1 (EPBC NTG-SEH)	N/A
	Mod: FVS ≥5 but ≤ 6.5; and/or >50% foliage cover of *Carex bichenoviana*, *Themeda triandra* or *Poa labillardieri*	01.2 (EPBC NTG-SEH)	N/A
	Low: FVS <5	01.3	N/A
Exotic	N/A	01.4	PA: Pasture and Agricultural Weed Species (cultivation or pasture improvement)
			S: Stock camp (soil nutrification, annual weed dominance)
			N: Noxious weed species (e.g. dense serrated tussock, Chilean needlegrass or African lovegrass)

Table 3.2 NTG condition thresholds (for favourable sampling time) as sampled at 0.04 ha plots, where the cover of native plants is greater than the cover of perennial exotic plants (Commonwealth of Australia, 2016a)

High-Very High Condition Threshold	Moderate – High Condition Threshold	Native Pasture
Favourable sampling times: • At least 12 non-grass native species **OR** • At least 3 indicator species **OR** • A floristic value score (FVS) of at least 6.5	Favourable sampling times: • At least 8 non-grass native species **OR** • At least 2 indicator species **OR** • A floristic value score (FVS) of at least 5 Characterised by at least 50% foliage cover of the ground of: • Themeda triandra (kangaroo grass) **OR** • *Poa labillardierei* (river tussock grass), (generally in flats and drainage lines where this vegetation type naturally occurs). **OR** • *Carex bichenoviana* (a native sedge) (or at least 50 tussocks for every 100 m^2)	The patch lacks the minimum native understorey for classification as Natural Temperate Grassland

3.2.2 Floristic diversity and structure

3.2.2.1 Monitoring locations

Previously completed baseline plot locations within areas identified as natural temperate grassland are identified in **Figure 3.1**. Co-ordinates of all baseline monitoring locations are presented in **Appendix A**. Ongoing monitoring is required in all areas within the former extent of natural temperate grassland which support native pasture. A total of 17 plots would be monitored in ACT, comprising of the four plots in each of Zones 01.1, 01.3 and 01.4 and three plots in Zone 01.2 established by Capital Ecology in 2020 (Capital Ecology, 2020) and two plots established by RJPL (2015) (**Figure 3.1**), three plots in Zone 01.2. Two candidate plots for natural temperate grassland monitoring have also been proposed in NSW, including one plot in Zone 01.2 stablished by Capital Ecology in 2020 (Capital Ecology, 2020) and one plot established by RJPL (2015). Nine plots are co-located with pink-tailed worm lizard monitoring plots and hence floristic data relating to habitat quality would be collected at the same time.

3.2.2.2 Monitoring approach

Permanently marked plot are to be established at each monitoring location. The plot size to be used is a 0.04 0.1 ha (usually 20 m x 50 m) plot for vegetation and habitat structure with an associated transect for groundcover monitoring. The indicative layout is shown in **Appendix B**. Surveys must be undertaken according to the Environmental Offsets Ecological Condition Monitoring Methods (ACT Government, 2020). Grassland plots must be monitored using the following methods, preferably using the applicable Survey 123 apps provided by the ACT Government:

- SOP #1 Vegetation Surveys – Floristic Surveys
- SOP #2 Vegetation Surveys – Understorey Structure Surveys (using the *step point* transect survey option)
- SOP #3 Vegetation Surveys – Weeds Monitoring
- SOP #4 Vegetation Surveys – Woodland Attribute Surveys
- SOP #6 Soil Core Sampling.

Data is to be collected in Survey 123 using the relevant applications prepared and to be supplied by the ACT Government or collected using equivalent protocols to ensure the same indicators are captured. Data collected in accordance with the Environmental Offsets Ecological Condition Monitoring Methods (ACT Government, 2020) is comparable with West Belconnen Baseline Monitoring Procedure (Sharp, 2015) and compliant with the ACT Government environmental offsets calculator (ACT Government 2015b). SOP #4 is applied in order to detect changes in canopy condition that may impact the ecological function of natural temperate grassland communities.

Floristic diversity data from 20 m x 20 m plots must be entered into the floristic value score calculator (Rehwinkel, 2015) to calculate a floristic value score as a key indicator of condition and to inform assessment against the criteria for the EPBC Act listed natural temperate grasslands critically endangered ecological community. For comparison with the floristic value score calculated by Capital Ecology (2020) the species significance ratings in the floristic value score calculator are to be adjusted to take into account typical condition of grasslands in the ACT as presented in **Table 3.3**.

Table 3.3 Species Significance Ratings adjustments for ACT as per Capital Ecology (2020)

Species Significance Rating	Species
Adjusted from *'Level A'* to *'Level B'*	*Chrysocephalum apiculatum* *Desmodium varians* *Glycine tabacina* *Lomandra filiformis-coriacea* *Poa sieberiana* *Themeda triandra* *Tricoryne elatior*
Adjusted from *'Level B'* to *'Level C'*	*Cymbonotus lawsonianus* *Wahlenbergia communis*

3.3 Survey Timing and Schedule

3.3.1 Survey timing

Monitoring surveys should be completed between October and December to correspond with maximum emergence of native forbs in natural temperate grassland in the ACT, permitting assessment of native diversity in favourable conditions. However, exact survey timing may be adjusted to allow for seasonal variation in conditions. Late surveys should be avoided in hot and dry conditions. Any deviations from the recommended survey timing should be documented in the monitoring reports.

3.3.2 Monitoring schedule

The monitoring schedule for assessing natural temperate grassland is presented in **Table 3.4**, and is in accordance with the program of monitoring proposed in the Offset Management Plan (SMEC 2018). Monitoring would be undertaken in the 1st year, 3rd year, 5th year and every five years unless otherwise determined by a review of monitoring requirements. Floristic monitoring of natural temperate grassland should be completed concurrently with habitat quality assessments for pink-tailed worm lizard habitat (**Section 4.3.2**) to maximise efficiency of the monitoring program.

Table 3.4 Natural temperate grassland monitoring schedule

Year	Season	Task
–2020 (completed)	Autumn	• Extent of natural temperate grassland, habitat features, and threats mapped. • Floristic condition and structure monitoring completed at new baseline plots, and additional locations as required. • Capital Ecology (2020) baseline plots marked
2021	Spring	• Monitoring changes in the floristic condition and structure. • Mark additional plots.
2023	Spring	• Mapping extent of natural temperate grassland, habitat features, and threats. • Monitoring changes in the condition of specific features in restoration areas. • Assessment of change against and thresholds

Year	Season	Task
2025	Spring	• Mapping extent of natural temperate grassland, habitat features, and threats. • Monitoring changes in the condition of specific features in restoration areas. • Monitoring changes in the floristic condition and structure. • Assessment of change against and thresholds
2030 Ongoing every five years subject to review every 10 years commencing at 10 years.	Spring	• Mapping extent of natural temperate grassland, habitat features, and threats. • Monitoring changes in the condition of specific features in restoration areas. • Monitoring changes in the floristic condition and structure. • Assessment of change against and thresholds
2030, 2040	n/a	• Review of monitoring framework and monitoring methods. • Consultation with stakeholders regarding ongoing monitoring requirements.

3.4 Indicators

Key monitoring indicators for natural temperate grassland have been selected to be consistent with the Environmental Offsets Ecological Monitoring Program (Howland, B, Carlson, E and O'Loughlin, T 2020) for natural temperate grassland and represent a subset of indicators identified in the CEMP (ACT Government, 2017). Benchmark values represent the long term management target in most cases, however also represent short term targets for thatch density, grass height and weed density (plants per ha).

Each metric in **Table 3.5** must be summarised in each monitoring report and compared against benchmark value, the monitoring event results and baseline data, comprising the average of the first three years of monitoring following commencement. The purpose of this process is to track indicators that can be used to inform annual work plans and for short and long term tracking of ecological condition. Monitoring reports must include discussion of any substantial degradation relative to the baseline data (i.e. first three years of monitoring), with respect to potential causational factors. Indicators should be reviewed for each plot individually and for an average of each vegetation unit. If the following indicators exceed or are outside the benchmark ranges, then consideration of whether corrective management is required in the management response plan in accordance with **Section 1.7.4**:

- Thatch density
- Grass height
- Weed density (CNG, ALG, ST, STh, SJW) (plants per ha).

Additional threats and observed degradation not otherwise recorded by indicators, such as development of informal trails or invasive herbivore grazing, and potential management implications should also be noted.

In the event that conditions of any indicators are determined to be declining, consideration in accordance with **Section 1.7.4** is required to determine if there is a potential or confirmed threat, and whether a short or long term management response is warranted. Reporting should consider whether any management response required is localised, in response to change or degradation at specific locations, or general, in response to change or degradation across a broader area.

Table 3.5 Vegetation condition metrics for natural temperate grassland (ACT01) (Howland, B, Carlson, E and O'Loughlin, T 2020)

Metric	Benchmark Values (ACT01)	Sampling unit	Standard Operating Procedures for Monitoring	ACT Government Survey123 App
Native overstorey cover (%)	≤10	20 x 50 m (0.1 ha), 10 random points	Ecological Offsets Monitoring Guidelines SOP #4 Vegetation Surveys – Woodland Attribute Surveys	Woodland Structure
Native mid-storey cover (%)	≤10	20 x 50 m (0.1 ha), 10 random points	Ecological Offsets Monitoring Guidelines SOP #4 Vegetation Surveys – Woodland Attribute Surveys	Woodland Structure
Proportion native cover (<1 m height) (%)	≥50	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Native ground cover (grasses)	34-63%	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Native grass cover (Rytidosperma sp.)		Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Native grass cover (C4 grasses)		Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Native ground cover		Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
(shrubs <1m height)	4-17%	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Native ground cover (other)	0-29.9%	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Exotic cover (perennial grasses)	0-28.5%	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Exotic cover (annual grasses)	0-27.8%	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Exotic cover (broadleaf)		Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Exotic cover (clover)	0-2.8%	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Bare ground cover (%)	10-20%	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Cryptogam cover	0-3.2%	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Thatch cover (%)	10-20 %	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point

Metric	Benchmark Values (ACT01)	Sampling unit	Standard Operating Procedures for Monitoring	ACT Government Survey123 App
Soil phosphorus (Colwell) (ppm 5 cm depth)	<20	20 x 20 m (0.04 ha), One amalgamated sample from 10 points in plot.	Ecological Offsets Monitoring Guidelines SOP #6 Soil Core Sampling	N/A
Floristic Value Score (FVS)	≥5	20 x 20 m (0.04 ha)	Ecological Offsets Monitoring Guidelines SOP #1 Vegetation Surveys – Floristic Surveys	Offsets Monitoring
Native plant species richness	>24	20 x 20 m (0.04 ha)	Ecological Offsets Monitoring Guidelines SOP #1 Vegetation Surveys – Floristic Surveys	Offsets Monitoring
Non-grass native species richness	>8	20 x 20 m (0.04 ha)	Ecological Offsets Monitoring Guidelines SOP #1 Vegetation Surveys – Floristic Surveys	Offsets Monitoring
Indicator species richness	>8	20 x 20 m (0.04 ha)	Ecological Offsets Monitoring Guidelines SOP #1 Vegetation Surveys – Floristic Surveys	Offsets Monitoring
Native vs exotic grassland		Pre 1780s grassland extent in site	**Section 3.2.1**	
Extent of NTG		Pre 1780s grassland extent in site	**Section 3.2.1**	
Thatch depth (cm)	<1	1 x 1 m	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Thatch density (thatch cover x thatch depth)	<0.25	1 x 1 m	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Average grass height (cm)	5-12	1 x 1 m	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Invasive weeds density (plants per ha) [*Chilean needlegrass, African lovegrass, serrated tussock, saffron thistle, St John's wort*]	<50	15 m radius from centre point of 20 x 20 m plot	Ecological Offsets Monitoring Guidelines SOP #3 Vegetation Surveys – Weeds Survey	Weeds Monitoring
Weed Value Score (WVS)	N/A	15 m radius from centre point of 20 x 20 m plot	Ecological Offsets Monitoring Guidelines SOP #3 Vegetation Surveys – Weeds Survey	Weeds Monitoring

Data Source: *Howland, B, Carlson, E and O'Loughlin, T 2020. Environmental Offsets Ecological Monitoring Program Report 2018 – 2019. Technical Report. Environment, Planning and Sustainable Development Directorate, ACT Government, Canberra and Environmental Offsets,* and *ACT Government 2020. Ecological Condition Monitoring Methods 2020. Technical Report. Environment, Environment, Planning and Sustainable Development Directorate, ACT Government, Canberra*

3.5 Triggers and Corrective Actions

Each monitoring report would include an assessment of key indicators against aspirational targets and thresholds for additional management actions. **Table 3.6** identifies the indicators, targets and thresholds and appropriate corrective actions to be implemented. As natural temperate grassland was not included in the Offset Management Plan (SMEC, 2018), where appropriate management responses have been proposed consistent with those identified for box – gum woodland in the Offset Management Plan. The purpose of identified thresholds is to enable identification of long term degradation, opportunities to improve long term management practices and development of a remedial action plan.

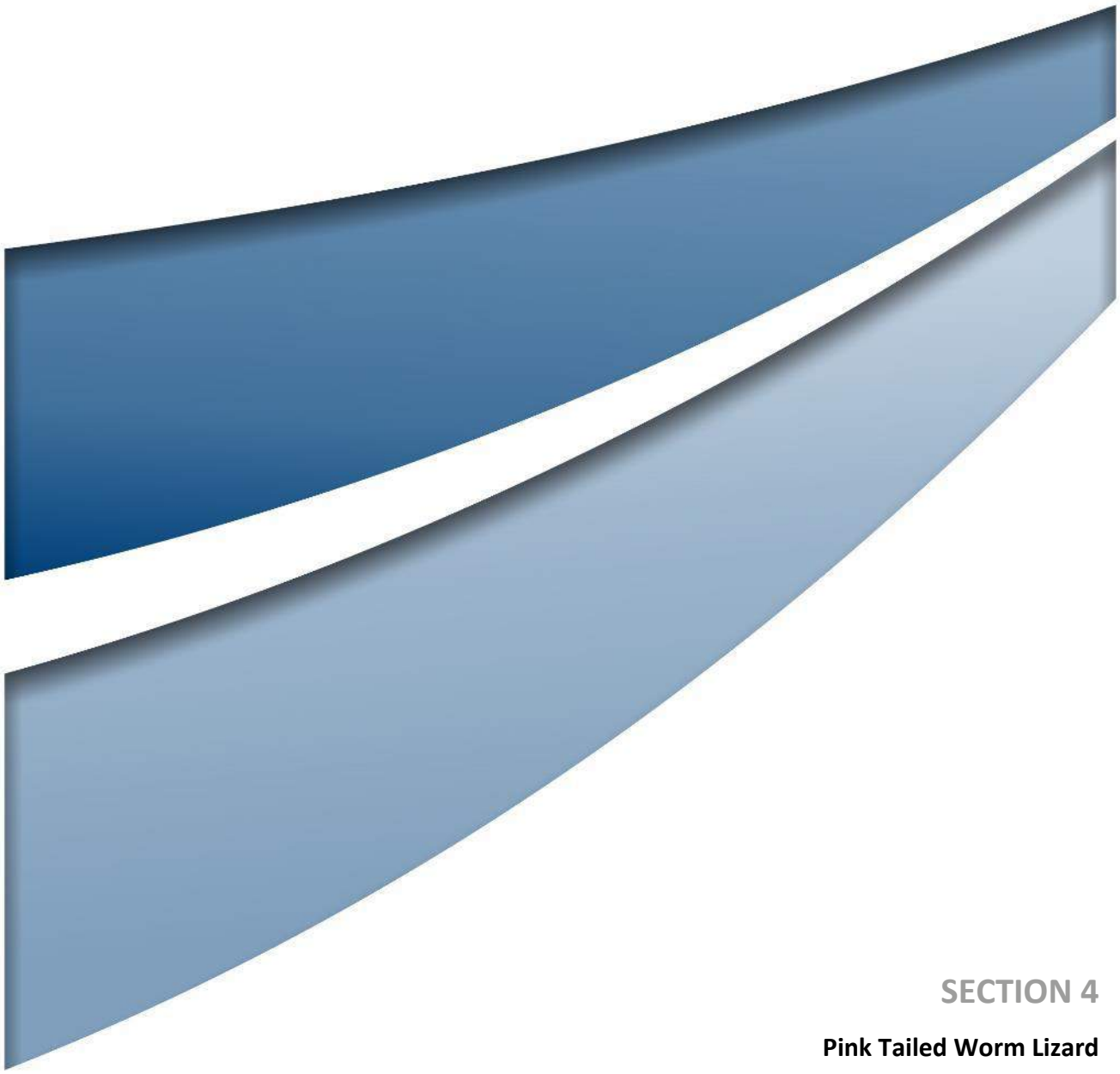
If thresholds are met, monitoring reports should address potential causes, and a review of causal factors and management options is triggered in accordance with **Section 1.7.4**.Where there is a measured decline in the quality of the natural temperate grassland or associated habitat features, that is not likely to be caused by stochastic factors such as seasonal conditions, corrective actions – both with respect to short term response in the annual work plan and updating the overall management approach – are to be considered.

Review of management measures may also be recommended in monitoring reports based on observed and substantial changes to other indicators identified in **Section 3.3** where these are identified and justified.

Table 3.6 Natural temperate grassland condition compliance (triggers and responses)

Habitat parameter	Sampling unit	Baseline	Target	Trigger	Response/Action
Extent of vegetation meeting criteria for Commonwealth listed natural temperate grassland in the Ginninderry Conservation Corridor.	Identified likely pre-1750 extent of natural temperate grassland (Capital Ecology, 2020)	Extent of natural temperate grassland in Zones 01.1 and 01.2 mapped by Capital Ecology in 2020 (Capital Ecology, 2020; **Figure 3.1**). Given the unusual seasonal conditions and the timing of survey appropriateness of using data from Capital Ecology (2020) as baseline should be reviewed following the second year of monitoring.	15% increase in combined extent of Zones 01.1 and 01.2 in sampled areas over 20 years	10% reduction in combined extent of Zones 01.1 and 01.2	• Review in monitoring report reasons for reduction in extent (i.e. management activities, disturbance, degradation or seasonal conditions) • Review of management measures specified in the GCCMP (TRC Tourism, 2018). • Consult with ACT PCS
Invasive weeds density (plants per ha) [Chilean needlegrass, African lovegrass, serrated tussock, saffron thistle, St John's wort]	Average **weed density** values (plants per ha) n Zones 01.1, 01.2 and 01.3 mapped by Capital Ecology in 2020 (Capital Ecology, 2020)	Average of the first three years of monitoring.	Benchmark value	Increase of 10% relative to the baseline *or* Benchmark (<50) exceeded after 10 years of management.	• Review of annual management response to weeds to ensure response is appropriate in scale and nature. • Review of weed management measures specified in the GCCMP (TRC Tourism, 2018). • Development of targeted weed control measures for natural temperate grassland areas.

Habitat parameter	Sampling unit	Baseline	Target	Trigger	Response/Action
Proportion native groundcover	Average **Proportion native cover (<1 m height) (%)** in Zones 01.1, 01.2 and 01.3 mapped by Capital Ecology in 2020 (Capital Ecology, 2020)	Average of first 3 years of monitoring data, including data from Capital Ecology (2020). Given the unusual seasonal conditions and the timing of survey appropriateness of using data from Capital Ecology (2020) as baseline should be reviewed following the first year of monitoring.	15% reduction in annual and exotic grass cover in sampled areas over 20 years	>30% increase in cover of either annual or perennial exotic grasses relative to baseline plots.	• Review of annual management response to weeds to ensure response is appropriate in scale and nature. • Review of management measures specified in the GCCMP (TRC Tourism, 2018), including consideration of need for update of long term weed management strategy. • Consideration or review of targeted weed control measures for natural temperate grassland areas.
Average floristic condition of natural temperate grassland independent of restoration areas. Floristic Value Score based calculated according to Rehwinkel (2015).	Average **Floristic Value Score** in each of Zones 01.1, 01.2 and 01.3 mapped by Capital Ecology in 2020 (Capital Ecology, 2020)	Average of first three years of monitoring data, including data from Capital Ecology (2020). Given the unusual seasonal conditions and the timing of survey appropriateness of using data from Capital Ecology (2020) as baseline should be reviewed following the first year of monitoring.	Benchmark values	Zones 01.1 and 01.2 are less than benchmark for more than two years running, unless explained by seasonal conditions.. Zones 01.3: After 10 years of management have no positive trend towards benchmark.	• Review in monitoring report reason for reduction in condition (i.e. management activities, disturbance, degradation or seasonal conditions) • Review of management measures specified in the GCCMP (TRC Tourism, 2018).
Biomass.	Average **Thatch Density** in each of Zones 01.1, 01.2 and 01.3 mapped by Capital Ecology in 2020 (Capital Ecology, 2020)	N/A Apply benchmark values.	Benchmark values	Thatch cover consistently outside benchmark values for three or more sequential monitoring periods.	• Review of management measures specified in the GCCMP (TRC Tourism, 2018). • Review of annual biomass management response measures.



SECTION 4

Pink Tailed Worm Lizard

4.0 Pink-Tailed Worm Lizard Habitat Monitoring Plan

4.1 Requirements

The monitoring requirements for pink-tailed worm lizard habitat specified in the Program Report are presented in **Table 4.1**. The Ginninderry Conservation Corridor Management Plan specifies:

- Periodic monitoring of the condition of PTWL habitat using the baseline data established by Osborne and Wong (2013)
- Monitoring of the condition of the PTWL population.

Table 4.1 PTWL monitoring requirements (AT Adams Consulting, 2017)

Outcome	Action	Baseline	Frequency
Ongoing monitoring of impact on habitat. Monitoring will be consistent with PTWL monitoring across the ACT.	Conduct field research to assess change in the extent and quality of PTWL habitat.	Adopt field data recorded by Osborne and Wong 2013 as baseline data.	Every two years from date of endorsement. Ability to review monitoring period if impacts have stabilised

Additional monitoring requirements, including minimum monitoring effort is specified in the Offset Management Plan (SMEC, 2018). The survey requirements specified by the Offset Management Plan throughout the Ginninderry Conservation Corridor (both ACT and NSW) comprises:

- **Habitat extent**: targeted mapping of pink-tailed worm lizard habitat extent at 30 1.0 ha plots
- **Habitat quality**: assessment of habitat floristic condition and rock cover at 15 0.04 ha (i.e. 20 m x 20 m) plots
- **PTWL distribution**: monitoring of PTWL presence or absence by rock rolling or artificial shelter surveys at thirty 0.04 ha (i.e. 20 m x 20 m) plots

Over 75% of PTWL habitat within the Conservation Corridor is within the ACT, and consequently at least 75% of the survey effort specified in the Offset Management Plan should be located within the ACT portion of the Conservation Corridor. The monitoring program specified in the Offset Management Plan (SMEC, 2018) is presented in **Table 4.2**. The detailed monitoring approach outlined in this document is consistent with the requirements of the Offset Management Plan (SMEC, 2018).

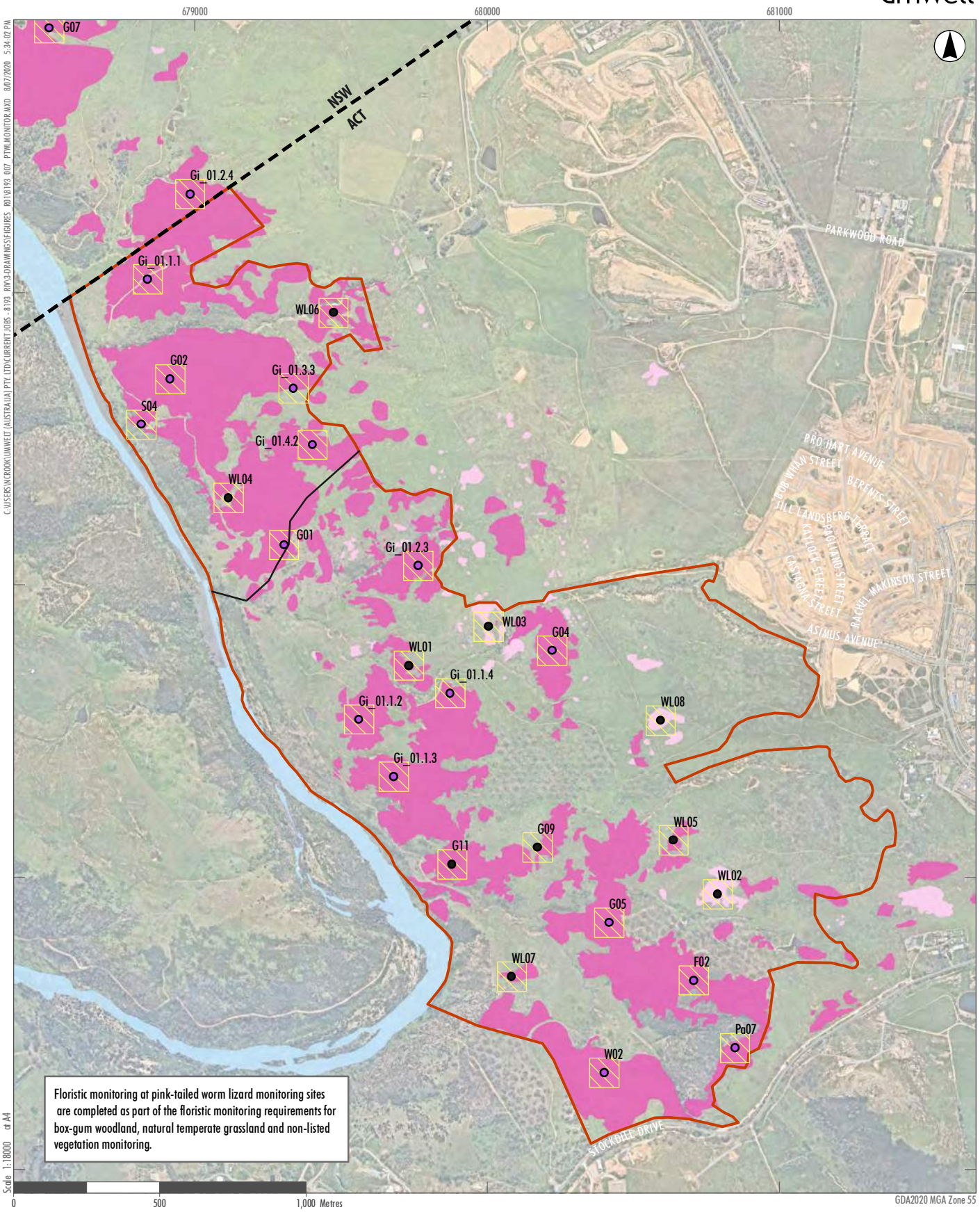
Table 4.2 PTWL monitoring program (SMEC, 2018)

Year	Task	Monitoring approach
First year following endorsement, the third year and every five years subsequently.	Monitoring changes in the extent of PTWL habitat.	Mapping of habitat extent and category, as specified in **Section 4.2.2**, at 30 1 ha plots in the PTWL habitat area.

Year	Task	Monitoring approach
First year following endorsement, the third year and every five years subsequently.	Monitoring changes in the condition of PTWL habitat.	Plot-based assessment of floristic condition and rock cover at 15 plots within the PTWL habitat area according to methods specified in Sharp (2015).
First year following endorsement, the third year and every five years subsequently.	Monitoring PTWL presence or absence throughout the habitat area.	Rock rolling in 30 20 m x 20 m plots distributed randomly within medium – high quality habitat *Or* Permanent brick-based monitoring plots if approved by ACT Parks and Conservation Service.
First year following works, the third year and every five years subsequently.	Monitoring changes in the extent of PTWL habitat and habitat categories in habitat creation or improvement areas.	Mapping of habitat extent and category, as specified in **Section 4.2.2**. Details to be confirmed in the work plans.
First year following works, the third year and every five years subsequently.	Monitoring changes in the condition of PTWL habitat and habitat categories in habitat creation or improvement areas.	Plot-based assessment of floristic condition and rock cover according to methods specified in Sharp (2015) Details to be confirmed in work plans.
First year following works, the third year and every five years subsequently, or until PTWL use of created rocky habitat is confirmed.	Monitoring PTWL presence or absence in habitat creation or improvement areas.	Plot-based rock-rolling sampling approach. Details to be confirmed in the work plans.

This section documents the monitoring program for pink-tailed worm lizard habitat, including:

- a monitoring schedule, documenting the periodic requirement for monitoring
- the method to monitor the condition of pink-tailed worm lizard habitat
- the location of monitoring plots
- key indicators to be used to detect changes in condition
- thresholds of change which will require an adaptive management response.



Legend

- Ginninderry Conservation Corridor Boundary (ACT)
- Stage 1 Northern Boundary
- ACT/NSW Border
- Murrumbidgee River
- Roads

Pink-tailed Worm Lizard Habitat Quality

- High Quality
- Low Quality

Pink-tailed Worm Lizard Monitoring Plots

- Artifical Shelters
- Artifical Shelters and Floristic Plots
- Habitat Monitoring Plots

FIGURE 4.1

Pink-tailed Worm Lizard Monitoring Requirements

Image Source: Nearmap (May 2020) Data source: ACTMapi (2020), NSW LPI (2019), Riverview Projects, RJPL (2015)

4.2 Monitoring Method

4.2.1 Monitoring locations

Locations of monitoring plots for habitat extent, habitat quality and pink-tailed worm lizard distribution are shown in **Figure 4.2**. Co-ordinates of all baseline monitoring locations are presented in **Appendix A**. In the first year following endorsement, survey should be completed in the ACT part of the conservation corridor for which baseline data is available (**Appendix A**), plus additional plots to ensure sampling of vegetation zones identified in **Section 2.2.1** meets minimum sampling requirements identified in the ACT Government environmental offsets calculator (ACT Government 2015b).

Two monitoring plots requiring habitat quality assessment are co-located with identified candidate plots for monitoring box – gum woodland (**Section 2.2.2.1**) and nine monitoring plots requiring habitat quality assessment are co-located with identified monitoring plots for natural temperate grassland (**Section 3.2.2.1**). Monitoring methods for natural temperate grassland floristic condition and pink-tailed worm lizard habitat quality are equivalent, and the same monitoring event meets requirements for these components.

4.2.2 Habitat extent

Habitat extent monitoring would be undertaken on a sampling basis at each of the 30 one hectare plots identified in **Figure 4.1**. Within each plot, habitat would be categorised in accordance with Osborne and Wong (2013), with reference to revised baseline habitat extent mapping completed by Capital Ecology (2019).

Table 4.3 PTWL potential habitat categories (Osbourne and Wong, 2013)

PTWL Potential Habitat Category*	Description
High quality	Suitable rocky areas dominated by, or with a large component of, kangaroo grass (*Themeda triandra*) - and often containing *Aristida ramosa*, *Cymbopogon refractus*, *Poa sieberiana* and *Lomandra* spp. - and often a high diversity of disturbance-sensitive native forbs. Exotic annual species, such as haresfoot clover (*Trifolium arvense*) and *Vulpia* spp., may also be present.
Moderate quality	Suitable rocky areas usually dominated by spear grasses (*Austrostipa* spp.) and wallaby grasses (*Rytidosperma* spp.). Native forb species and exotic annual species, such as haresfoot clover (*Trifolium arvense*), wild oats (*Avena* sp.), and saffron thistle (*Carthamus lanatus*), may also be present.
Low quality	Suitable rocky areas that have been subject to high levels of disturbance in the recent past (e.g. areas previously under mature pine plantation) displaying high levels of disturbance to the soil layer or dominated by sown pasture grasses, other agronomic species and weeds; includes former sheep camps that no longer support native ground cover.
Absent	No suitable rocky areas present.

4.2.3 Habitat quality

Habitat quality, including floristic condition and rock cover, would be assessed throughout the PTWL habitat area using plots and transects at 15 locations in accordance with the survey method outlined for natural temperate grassland and box gum woodland in **Sections 2.2.2.2** and **3.2.2.2**. The 15 plots would be co-located with 15 of the habitat extent plots (**Section 4.2.1**) according to the plot layout shown in **Figure 4.2**.

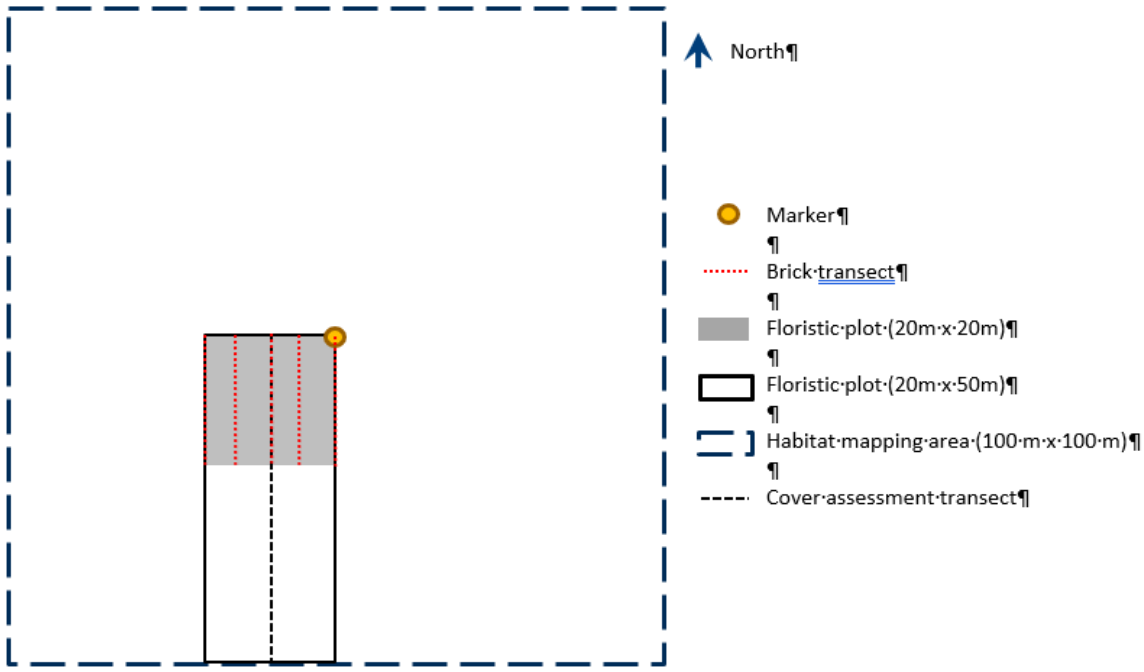


Figure 4.2 PTWL habitat extent, habitat quality, and artificial shelter plot layout

4.2.4 Pink-tailed worm lizard distribution

Pink-tailed worm lizard distribution is to be monitored at plots through a combination of rock rolling surveys and artificial shelter surveys. Rock rolling surveys are to be minimised due to their destructive nature and the potential for adverse impacts on pink-tailed worm lizard habitat quality, but are included to support artificial shelter surveys.

4.2.4.1 Rock rolling

Rock rolling surveys are to be conducted only where alternatives are not available to minimise adverse impacts on pink tailed worm lizard habitat (**Table 4.4**). Rock rolling surveys involves rolling all suitable loose surface rock within the 20 x 20 m plot. All easily movable surface rocks between 10 and 30 cm across within the 20 x 20 m plot are to be inspected. Pink-tailed worm lizard individuals and skins should be recorded separately. The total number of rocks rolled and the total number of individuals detected recorded for each plot. Skins should be recorded as presence.

Following survey, all rocks are to be carefully returned to their original position, minimising disturbance to associated microhabitats.

4.2.4.2 Artificial shelter surveys

Artificial shelter survey plots would be established 30 locations, co-located with the habitat extent survey areas and habitat quality plots (where applicable) as indicated in **Figure 4.2**. Each plot would comprise of 100 bricks spaced in a 20 m x 20 m area in five transects 5 m apart with twenty bricks 1 m apart as indicated in **Figure 4.2.** Pink-tailed worm lizard individuals and skins should be recorded separately at each artificial shelter, along with the total number of individuals detected recorded for each plot.

Following survey, all artificial shelters are to be carefully returned to their original position, minimising disturbance to associated microhabitats.

4.3 Survey Timing and Schedule

4.3.1 Survey timing

Pink-tailed worm lizard population monitoring surveys should be completed between October and December to correspond with peak detection levels in the ACT. Exact survey timing should be adjusted to allow for seasonal variation in conditions. Late surveys should be avoided in hot and dry conditions. Population monitoring surveys should be completed:

- on warm but not hot days, after a period of rainfall extending over several days where possible
- in late November/December restricted to mornings or on cloudy days when soil temperatures beneath the rocks are not too high.

Any deviations from the recommended survey timing and conditions should be documented in the monitoring reports.

4.3.2 Monitoring schedule

The monitoring schedule for pink-tailed worm lizard surveys is presented in **Table 2.5**, and is in accordance with the program of monitoring proposed in the Offset Management Plan (SMEC 2018). Monitoring would be undertaken in the 1st year, 3rd year and every five years unless otherwise determined by a review of monitoring requirements. In the long term, habitat quality assessments for pink-tailed worm lizard habitat should be completed concurrently with floristic monitoring of natural temperate grassland (**Section 3.3.2**) to maximise efficiency of the monitoring program.

Table 4.4 Pink-tailed worm lizard monitoring schedule

Year	Season	Task
2019	Spring	• Baseline mapping of habitat extent and category (completed)
2021	Spring/Early Summer	• Plot based mapping of habitat extent and category • Plot based floristic condition monitoring, baseline data collection • Plot based baseline rock rolling surveys • Establishment of artificial shelter monitoring plots. • Mark permanent monitoring plots.

Year	Season	Task
2023	Spring/Early Summer	• Plot based mapping of habitat extent and category • Plot based floristic condition monitoring, baseline data collection • Monitoring of artificial shelter plots.
2025	Spring/Early Summer	• Plot based mapping of habitat extent and category • Plot based floristic condition monitoring • Monitoring of artificial shelter plots • Assessment of change against and thresholds.
2030 Ongoing every 5 years subject to review every 10 years commencing at 10 years.	Spring/Early Summer	• Plot based mapping of habitat extent and category • Plot based floristic condition monitoring • Plot based baseline rock rolling surveys • Monitoring artificial shelter plots • Assessment of change against and thresholds.
2030, 2040	n/a	• Review of monitoring framework and monitoring methods. • Consultation with stakeholders regarding ongoing monitoring requirements.
n/a Following 3 surveys without detection of PTWL under artificial shelters.	Spring/Early Summer	• Plot based baseline rock rolling surveys • Monitoring artificial shelter plots

4.4 Indicators

Key monitoring indicators for pink-tailed worm lizard have been selected based on those for natural temperate grassland in accordance with the Environmental Offsets Ecological Monitoring Program (Howland, B, Carlson, E and O'Loughlin, T 2020). These represent a subset of indicators identified in the CEMP (ACT Government, 2017). Specific indicators correlating to the condition of pink-tailed worm lizard habitat have been selected. Benchmark values represent the long term management target in most cases, however also represent short term targets for thatch cover, grass height and weed density (plants per ha).

Key monitoring indicators identified for pink tailed worm lizard are presented in **Table 4.5.** These represent a subset of indicators for natural temperate grassland (**Table 3.5**) that are likely to be most informative with respect to the condition of habitat for pink-tailed worm lizard. The monitoring results should include a summary of results for pink-tailed worm lizard habitat and review against baseline data, comprising the average of the first three years of monitoring following commencement. The purpose of this process is to track indicators that can be used to inform annual work plans and for short and long term tracking of ecological condition. Monitoring reports must include discussion of any substantial degradation relative to the baseline data (i.e. first three years of monitoring), with respect to potential causational factors. Indicators should be reviewed for each plot individually and for an average of each vegetation unit. Additional threats and observed degradation not otherwise recorded by indicators, such as development of informal trails or invasive herbivore grazing, and potential management implications should also be noted.

In the event that conditions of any indicators are determined to be declining, consideration in accordance with **Section 1.7.4** is required to determine if there is a potential or confirmed threat, and whether a short or long term management response is warranted. Reporting should consider whether any management response required is localised, in response to change or degradation at specific locations, or general, in response to change or degradation across a broader area.

Table 4.5 Key variables for pink-tailed worm lizard habitat, based on Environmental Monitoring Program (Howland, B, Carlson, E and O'Loughlin, T 2020)

Metric	Benchmark Values (ACT01)	Sampling unit	Standard Operating Procedures for Monitoring	ACT Government Survey123 App
Extent of moderate – high quality habitat	N/A	PTWL Management Zone	N/A	N/A
Presence / absence of individuals or signs by plot	N/A	20 m x 20 m artificial shelter plot	N/A	N/A
Average number of individuals detected per plot	N/A	20 m x 20 m artificial shelter plot	N/A	N/A
Native overstorey cover (%)	≤10	20 x 50 m (0.1 ha), 10 random points	Ecological Offsets Monitoring Guidelines SOP #4 Vegetation Surveys – Woodland Attribute Surveys	Woodland Structure
Native mid-storey cover (%)	≤10	20 x 50 m (0.1 ha), 10 random points	Ecological Offsets Monitoring Guidelines SOP #4 Vegetation Surveys – Woodland Attribute Surveys	Woodland Structure
Proportion native cover (<1 m height) (%)	≥50	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Native ground cover (grasses)	34-64%	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Rock cover	0-28%	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Bare ground cover (%)	10-20	Step point transect (50 points)	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Floristic Value Score (FVS)	≥5	20 x 20 m (0.04 ha)	Ecological Offsets Monitoring Guidelines SOP #1 Vegetation Surveys – Floristic Surveys	Offsets Monitoring
Thatch density (thatch cover x thatch depth)	<0.25	1 x 1 m	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point
Average grass height (cm)	5-12	1 x 1 m	Ecological Offsets Monitoring Guidelines SOP #2 Vegetation Surveys – Understorey Structure Surveys	Step Point

Metric	Benchmark Values (ACT01)	Sampling unit	Standard Operating Procedures for Monitoring	ACT Government Survey123 App
Invasive weeds density (plants per ha) [*Chilean needlegrass, African lovegrass, serrated tussock, saffron thistle, St John's wort*]	<1% or 50 plants perha	15 m radius from centre point of 20 x 20 m plot	Ecological Offsets Monitoring Guidelines SOP #3 Vegetation Surveys – Weeds Survey	Weeds Monitoring

Invasive weed density abbreviations: ALG = African Lovegrass; CNG = Chilean Needle Grass; SJW = St John's Wort; ST = Serrated Tussock; STh = Saffron Thistle

Data Source: *Howland, B, Carlson, E and O'Loughlin, T 2020. Environmental Offsets Ecological Monitoring Program Report 2018 – 2019. Technical Report. Environment, Planning and Sustainable Development Directorate, ACT Government, Canberra and Environmental Offsets,* and *ACT Government 2020. Ecological Condition Monitoring Methods 2020. Technical Report. Environment, Environment, Planning and Sustainable Development Directorate, ACT Government, Canberra*

4.5 Triggers and Corrective Actions

Each monitoring report would include an assessment of key indicators against aspirational targets and thresholds for additional management actions. **Table 4.6** identifies the indicators, targets and thresholds and appropriate corrective actions to be implemented, consistent with thresholds identified in the Offset Management Plan (SMEC, 2018). Corrective actions must be implemented if, as determined by the monitoring program, offset requirements are not met or there is a measured decline in PTWL populations or the extent or quality of PTWL habitat.

If thresholds are met, monitoring reports should address potential causes, and a review of causal factors and management options is triggered in accordance with **Section 1.7.4**.Where there is a measured decline in the population or habitat quality of pink-tailed worm lizard that is unlikely to be caused by stochastic factors such as seasonal conditions, corrective actions – both with respect to short term response in the annual work plan and updating the overall management approach – are to be considered.

Review of management measures may also be recommended in monitoring reports based on observed and substantial changes to other indicators identified in **Section 4.3** where there are identified and justified.

Table 4.6 PTWL habitat and population offset compliance (triggers/responses)

Habitat parameter	Sampling unit	Baseline	Target	Trigger	Response/Action
Extent of medium – high quality habitat	Average across 30 one hectare habitat extent plots	Extent mapped in plots by Capital Ecology (2019)	Maintain or expand (increase by at least 5% consistently over 2 sampling periods) the extent of medium – high quality habitat.	20% reduction in extent of medium – high quality habitat in sampled areas.	• Review of management measures specified in the GCCMP (TRC Tourism, 2018) • Remedial actions will be determined in consultation with ACT Government Parks and Conservation Service (ACT GPCS)
Invasive weeds density (plants per ha) [Chilean needlegrass, African lovegrass, serrated tussock, saffron thistle, St John's wort]	Average **weed density** values (plants per ha) in moderate and high condition habitat	Average of the first 3 years of monitoring.	Benchmark value for respective vegetation communities	Increase of 10% relative to the baseline *or* Benchmark (<50) exceeded after 10 years of management.	• Review of annual management response to weeds to ensure response is appropriate in scale and nature. • Review of management measures specified in the GCCMP (TRC Tourism, 2018). Development of specific weed control measures for PTWL habitat zone. • Remedial actions will be determined in consultation with ACT GPCS
Floristic condition of habitat	Average **FVS** floristic plots in medium – high quality habitat	An average of the floristic condition (**Scenario 2**) recorded by Capital Ecology (2020) or RJPL (2015) (depending on date of plot establishment) and the initial year of monitoring. Given the unusual seasonal conditions and the timing of survey appropriateness of using data from Capital Ecology (2020) as baseline should be reviewed following the first year of monitoring.	n/a	20% reduction in average floristic condition in sampled areas of medium – high quality habitat.	• Review of PTWL habitat management and drivers of degradation in consultation with ACT GPCS • Remedial actions will be determined in consultation with ACT GPCS

Habitat parameter	Sampling unit	Baseline	Target	Trigger	Response/Action
Native grass cover	Average **Native ground cover (grasses)** at floristic plots in medium – high quality habitat	Average of first three years of monitoring data, including data from Capital Ecology (2020). Given the unusual seasonal conditions and the timing of survey appropriateness of using data from Capital Ecology (2020) as baseline should be reviewed following the first year of monitoring.	Benchmark values	>20% decrease in native ground cover (grasses) relative to baseline.	• Review of PTWL habitat management and drivers of degradation in consultation with ACT GPCS • Remedial actions will be determined in consultation with ACT GPCS
Rock cover	Average **Rock cover** at floristic plots in medium – high quality habitat	First year of monitoring.	No reduction in rock cover	Any real decrease in rock cover relative to baseline not driven by changes in vegetation cover.	• Review of PTWL habitat management and drivers of degradation (including bush rock collection) in consultation with ACT GPCS • Remedial actions will be determined in consultation with ACT GPCS
Biomass management.	Average **Thatch Density** in floristic plots in medium – high quality habitat	N/A Apply benchmark values.	Benchmark values	Thatch cover consistently outside benchmark values for three or more sequential monitoring periods.	• Review of management measures specified in the GCCMP (TRC Tourism, 2018). • Review of annual biomass management response measures.
Population condition	Average number of individuals per plot in each habitat condition class	The average of the first three years of monitoring.	No decline.	Consistent decline of >30% in PTWL detection in sampled areas of the PTWL habitat with continued declining trend recorded over at least two sampling periods.	• Review of management measures specified in the GCCMP (TRC Tourism, 2018) • Review of proposed habitat improvement measures

SECTION 5

Non-Listed Vegetation

5.0 Non-Listed Native Vegetation Monitoring Plan

5.1 Requirements

The Ginninderry Conservation Corridor Management Plan (TRC Tourism, 2018) specifies that the polygon-based baseline monitoring protocol (Sharp, 2017) would be adopted to assess trends in vegetation condition across the Corridor through time. This section documents the monitoring requirements for non-listed vegetation, including:

- a monitoring schedule, documenting the periodic requirement for monitoring
- the method to monitor the condition of native vegetation
- the location of monitoring plots
- key indicators to be used to detect changes in condition
- thresholds of change which will require an adaptive management response.

Monitoring is restricted to areas dominated by moderate to high quality native vegetation only. Depauperate native pastures and exotic dominated vegetation communities would not be monitored.

5.2 Monitoring Method

5.2.1 Floristic diversity and structure

5.2.1.1 Monitoring locations

The required number of plots for monitoring of each vegetation zone in accordance with the ACT Government environmental offsets calculator (ACT Government 2015b) is shown in **Table 5.1**. Previously completed baseline plot locations within non-listed native vegetation types are identified in **Figure 5.1**. Co-ordinates of monitoring locations are presented in **Appendix A**.

5.2.1.2 Monitoring approach

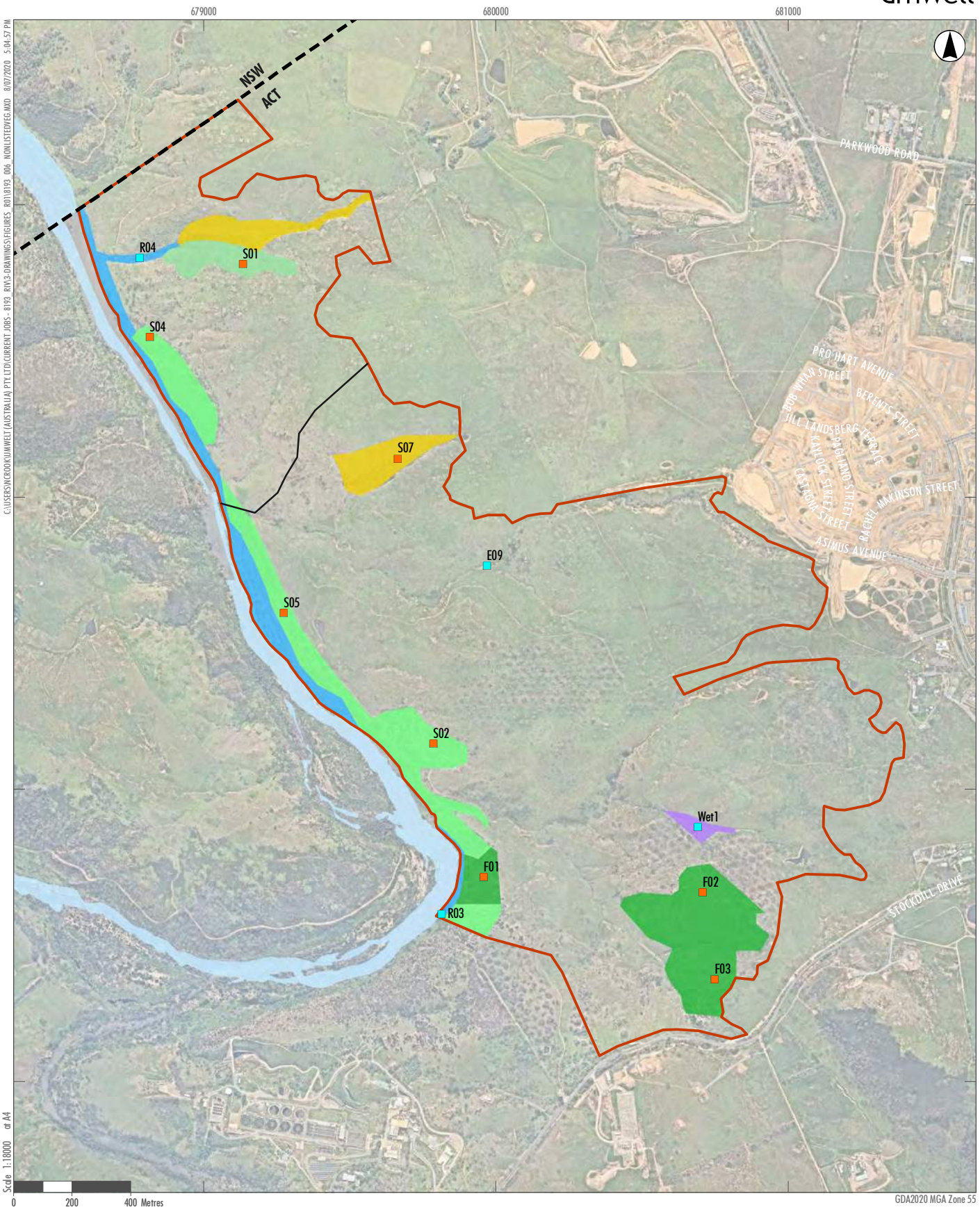
Permanently marked plot are to be established at each monitoring location. The plot size to be used is a 0.04 0.1 ha (usually 20 m x 50 m) plot for vegetation and habitat structure with an associated transect for groundcover monitoring. The indicative layout is shown in **Appendix B**. Surveys must be undertaken according to the Environmental Offsets Ecological Condition Monitoring Methods (ACT Government, 2020). Grassland plots must be monitored using the following methods, preferably using the applicable Survey 123 apps provided by the ACT Government:

- SOP #1 Vegetation Surveys – Floristic Surveys
- SOP #2 Vegetation Surveys – Understorey Structure Surveys (using the *step point* transect survey option)
- SOP #3 Vegetation Surveys – Weeds Monitoring
- SOP #4 Vegetation Surveys – Woodland Attribute Surveys

- SOP #6 Soil Core Sampling.

Data is to be collected in Survey 123 using the relevant applications prepared and to be supplied by the ACT Government or collected using equivalent protocols to ensure the same indicators are captured. Data collected in accordance with the Environmental Offsets Ecological Condition Monitoring Methods (ACT Government, 2020) is comparable with West Belconnen Baseline Monitoring Procedure (Sharp, 2015) and compliant with the ACT Government environmental offsets calculator (ACT Government 2015b). SOP #4 is applied in order to detect changes in canopy condition that may impact the ecological function of natural temperate grassland communities.

Floristic diversity data from 20 m x 20 m plots must be entered into the floristic value score calculator (Rehwinkel, 2015) to calculate a floristic value score as a key indicator of condition.



Legend

- Ginninderry Conservation Corridor Boundary (ACT)
- Stage 1 Northern Boundary
- ACT/NSW Border
- Murrumbidgee River
- Creeklines
- Roads

Non-listed Vegetation Monitoring Plots

- Non-listed Vegetation
- Riparian

Vegetation Communities

- Black Cypress Pine Tableland Open Forest - riparian and dryland
- Derived shrubland - Black Cypress Pine Tableland Open Forest - riparian and dryland
- Burgan Tableland Shrubland - riparian and dryland
- Depauperate native pasture and woody weeds
- River She-oak Tableland Riparian Woodland
- Tableland Riparian Fringing Wetlands

FIGURE 5.1

Non-listed Vegetation and Riparian Monitoring Requirements

Image Source: Nearmap (May 2020) Data source: ACTMapi (2020), NSW LPI (2019), Riverview Projects, RJPL (2015)

Table 5.1 Number of plots required in non-listed native vegetation in the ACT

Category	Vegetation association	Area in ACT (ha)	Plots required	Plot numbers
Non-listed vegetation	Black Cypress Pine Tableland Open Forest - riparian and dryland	16.1	3	F01, F03, F02
Non-listed vegetation	Burgan Tableland Shrubland - riparian and dryland	3.7	2	S01, additional plot required
Non-listed vegetation	Derived shrubland - Black Cypress Pine Tableland Open Forest - riparian and dryland	18.5	3	S02, S04, S05
Non-listed vegetation	Depauperate native pasture and woody weeds	7.9	3	S07, S08, additional plot required
Riparian area, non-listed vegetation	River She-oak Tableland Riparian Woodland	9.0	3	R03, R04, additional plot required
Riparian area, non-listed vegetation	Tableland Riparian Fringing Wetlands	0.9	1	Wet1

5.2.2 Threat mapping

The location and extent of any key threats or degradation within non-listed vegetation zones surrounding the monitoring plot locations should be recorded, including erosion, weed infestation, dieback or significant grazing by native or invasive animals with the potential to degrade groundcover.

5.3 Survey timing and Schedule

5.3.1 Survey timing

Monitoring surveys should be completed between October and December to correspond with maximum emergence of native forbs in the ACT, permitting assessment of native diversity in favourable conditions. However, exact survey timing may be adjusted to allow for seasonal variation in conditions. Late surveys should be avoided in hot and dry conditions. Any deviations from the recommended survey timing should be documented in the monitoring reports.

5.3.2 Monitoring schedule

The monitoring schedule for assessing non-listed vegetation is presented in **Table 5.2**, and is in accordance with the program of monitoring proposed in the Offset Management Plan (SMEC 2018). Monitoring would be undertaken in every five years unless otherwise determined by a review of monitoring requirements.

Table 5.2 Non-listed vegetation monitoring schedule

Year	Season	Task
2020	Spring	• Complete floristic condition and structure monitoring at baseline plots, and establish additional plots as required. • Marking of plot locations for ongoing monitoring.
2024 Ongoing every 5 years subject to review every 10 years commencing at 10 years.	Spring/early summer	• Complete floristic condition and structure monitoring at baseline plots, and establish additional plots as required. • Complete threat assessment • Assessment of change against and thresholds
2030, 2040	n/a	• Review of monitoring framework and monitoring methods. • Consultation with stakeholders regarding ongoing monitoring requirements.

5.4 Indicators

Key monitoring indicators for non-listed vegetation are consistent with those for box – gum woodland as listed in **Table 2.6**, based on the Environmental Offsets Ecological Monitoring Program (Howland, B, Carlson, E and O'Loughlin, T 2020)**.** Benchmarks identified in **Table 2.6** apply only to box gum woodland and are not applicable to non-listed vegetation communities for the purposes of this monitoring. These indicators must be summarised in each monitoring report, with comparison against baseline data and previous monitoring results to be completed for individual plots do detect localised changes and as an average across each plant community type to identify broader trends. Where degradation relative to the baseline is identified independent of the threshold values identified in **Section 5.5** additional management recommendations may be provided.

The purpose of this process is to track indicators that can be used to inform annual work plans and for short and long term tracking of ecological condition. Monitoring reports must include discussion of any substantial degradation relative to the baseline data (i.e. first three years of monitoring), with respect to potential causational factors. Indicators should be reviewed for each plot individually and for an average of each vegetation unit. Additional threats and observed degradation not otherwise recorded by indicators, such as development of informal trails or invasive herbivore grazing, and potential management implications should also be noted.

In the event that conditions of any indicators are determined to be declining, consideration in accordance with **Section 1.7.4** is required to determine if there is a potential or confirmed threat, and whether a short or long term management response is warranted. Reporting should consider whether any management response required is localised, in response to change or degradation at specific locations, or general, in response to change or degradation across a broader area.

5.5 Triggers and Corrective Actions

Each monitoring report would include an assessment of key indicators against aspirational targets and thresholds for additional management actions. **Table 5.3** identifies the indicators, targets and thresholds and appropriate corrective actions to be implemented as specified in the Offset Management Plan (SMEC, 2018).

If thresholds are met, monitoring reports should address potential causes, and identify recommendations for remedial action for inclusion into the annual works plan as an immediate action or integration in an amended management plan. Where there is a measured decline in the quality of the vegetation zone or associated habitat features, that is not likely to be caused by stochastic factors such as seasonal conditions, the need for corrective actions must be specified. Additional threats and observed degradation not otherwise recorded by indicators, such as development of informal trails or invasive herbivore grazing, and potential management implications should also be noted.

Review of management measures may also be recommended in monitoring reports on the basis of significant changes to other indicators identified in **Section 5.4** where there are identified and justified concerns relating degradation not detected by the threshold values identified below.

Table 5.3 Non-listed vegetation communities condition compliance (triggers and responses)

Habitat parameter	Sampling unit	Baseline	Target	Trigger	Response / Action
Invasive weeds density (plants per ha) [Chilean needlegrass, African lovegrass, serrated tussock, saffron thistle, St John's wort]	Average **weed density** values in each vegetation unit	Average of the first 3 years of monitoring.	<50 plants per ha for all species.	Increase of 10% relative to the baseline *or* Benchmark (<50) exceeded after 20 years of management.	• Review of management measures specified in the GCCMP (TRC Tourism, 2018). • Development of specific weed control measures for the relevant vegetation zones.
Average floristic condition Floristic condition based calculated according to Rehwinkel (2015).	Average **Floristic Value Score** of plots within each Management Unit as determined in the initial year of monitoring.	Average of first 3 years of monitoring data, plus consideration of variance from data from RJPL 2014 where plots coincide.	n/a	Decrease of more than 20% in floristic condition of sampled areas relative to the baseline for two or more consecutive sampling years	• Review management and potential drivers of degradation in consultation with ACT GPCS • Review of management measures specified in the GCCMP (TRC Tourism, 2018), and update management plan or annual management responses as required.

SECTION 6

Riparian Areas

6.0 Riparian Areas Monitoring Plan

6.1 Requirements

The Ginninderry Conservation Corridor Management Plan (TRC Tourism, 2018) commits to monitoring of the condition of the riparian zone and recreation impacts, with further details to be provided in the Murrumbidgee Riparian Zone Plan (not yet prepared). Monitoring approaches for the condition of aquatic habitat and fish populations is yet to be developed in conjunction with ACT and NSW Agencies and is not included in this plan.

The monitoring approach provided is designed to collect data consistent with metrics C3 of the riparian and aquatic CEMP (ACT Government, in prep), hence the monitoring proposed is consistent with the biometric plot method. Other metrics identified in the riparian and aquatic CEMP relate to physical stream characteristics and aquatic habitats and are not addressed.

While this plan does not include aquatic monitoring, for completeness, monitoring of the riparian and aquatic downstream impacts of development at Stream E consistent with Roberts and Sharp (2019) and Roberts and Sharp (2020) has been included in this plan.

This section documents interim monitoring requirements for the riparian zone, pending completion of the Murrumbidgee Riparian Zone Plan, including:

- a monitoring schedule, documenting the periodic requirement for monitoring
- the method to monitor the condition of native vegetation
- the location of monitoring plots
- key indicators to be used to detect changes in condition
- thresholds of change which will require an adaptive management response.

This plan is intended to be implemented in conjunction with the non-listed vegetation monitoring plan (**Section 5.0**). Plot details and plot locations are presented in association with non-listed vegetation in **Section 5.2**.

6.2 Monitoring Method

6.2.1 Floristic diversity and structure

6.2.1.1 Monitoring locations

A total of four biometric monitoring plots are required in riparian areas. The required number of plots for monitoring in riparian zones in accordance with the ACT Government environmental offsets calculator (ACT Government 2015b) are shown in **Table 5.1**. Two plots are already established and one additional plot would need to be established in River She-oak Tableland Riparian Woodland and one plot is established in Tableland Riparian Fringing Wetlands. Locations of baseline plots in riparian zones are presented in **Figure 5.1**. Co-ordinates of baseline monitoring locations are presented in **Appendix A**.

6.2.1.2 Monitoring Approach

Permanently marked plot and transects have been established at each monitoring location, and monitoring must be undertaken as specified in **Appendix B**, consistent with other no-listed vegetation areas. Data collected is consistent and comparable with West Belconnen Baseline Monitoring Procedure (Sharp, 2015) and compliant with the ACT Government environmental offsets calculator (ACT Government 2015b). Plot surveys are used to collect quantitative data for comparing sites and vegetation communities.

The plot size to be used is a 0.04 0.1 ha (usually 20 m x 50 m) plot for vegetation and habitat structure consistent with ACT Government (2015a) and Sharp (2015). During the plot survey, additional details relating to the condition of the riparian vegetation zone should be noted as specified in **Appendix B**. Vegetation cover in the over-storey, mid-storey and ground stratum are measured by the use of a 50 metre transect consistent with ACT Government (2015a) and Sharp (2015). Floristic diversity data from 20 m x 20 m plots must be entered into the floristic value score calculator (Rehwinkel, 2015) to calculate a floristic value score as a key indicator of condition.

6.2.2 Threat mapping

The location and extent of any key threats or degradation within non-listed vegetation zones surrounding the monitoring plot locations should be recorded, including erosion, weed infestation, dieback or significant grazing by native or invasive animals with the potential to degrade groundcover.

6.2.3 Optional monitoring (Stream E)

Detailed baseline aquatic and riparian monitoring was completed along Stream E in Spring 2018 to allow monitoring of the long term impacts of upstream development (Roberts and Sharp, 2019). Monitoring of pools and benches is to be completed along the full extent of Stream E, and repeated every five years to allow monitoring of construction and development impacts. Repeatable methods and field sheets are provided in Section 5 and associated appendices of Roberts and Sharp (2019) (**Appendix C**).

6.3 Survey Timing and Schedule

6.3.1 Survey timing

Monitoring surveys for biometric plots should be completed between October and December to correspond with maximum emergence of native forbs in the ACT, permitting assessment of native diversity in favourable conditions. However, exact survey timing may be adjusted to allow for seasonal variation in conditions. Late surveys should be avoided in hot and dry conditions. Any deviations from the recommended survey timing should be documented in the monitoring reports.

6.3.2 Monitoring schedule

The monitoring schedule for assessing non-listed vegetation is presented in **Table 6.1**, and is in accordance with the program of monitoring proposed in the Offset Management Plan (SMEC 2018). Monitoring would be undertaken in every five years unless otherwise determined by a review of monitoring requirements.

Table 6.1 Riparian zone monitoring schedule

Year	Season	Task
2020	Spring	• Complete floristic condition and structure monitoring at baseline plots, and establish one additional plots as required. • Permanent marking of plot locations for ongoing monitoring.
2022 Ongoing every 5 years subject to review commencing at 10 years.	Spring	• Stream E Monitoring in accordance with Roberts and Sharp (2019)
2024 Ongoing every 5 years subject to review commencing at 10 years.	Spring / early summer	• Complete floristic condition and structure monitoring at baseline plots, and establish additional plots as required. • Complete threat assessment • Assessment of change against and thresholds
10 (2030) 20 (2040)	n/a	• Review of monitoring framework and monitoring methods. • Consultation with stakeholders regarding ongoing monitoring requirements.

6.4 Indicators

Key monitoring indicators specified for non-listed vegetation (**Table 2.6**) must be summarised in each monitoring report and compared against baseline data (where available) and previous monitoring results. Additional monitoring indicators specifically for Stream E (**Section 6.2.3**) are presented in **Table 6.2**. Where degradation relative to the baseline is identified independent of the threshold values identified in **Section 6.5** additional management recommendations may be provided.

Table 6.2 Riparian and aquatic monitoring indicators for Stream E only (Roberts and Sharp, 2019)

Indicator	Plot or transect
Tall emergent macrophytes (area)	Per Roberts and Sharp (2019)
Submerged macrophytes (area)	Per Roberts and Sharp (2019)
Sediment Depth	Per Roberts and Sharp (2019)
Bare ground: Amount of bare unvegetated ground (as % of quadrat)	1 m x 5 m quadrat; per Roberts and Sharp (2019)
Annual cover: Cover of annual (short-lived) species (as % of quadrat)	1 m x 5 m quadrat; per Roberts and Sharp (2019)
Nativeness (species richness): Nativeness (excluding grasses but including shrubs) by dividing the number of non-grass native species by the number of non-grass exotic species	1 m x 5 m quadrat; per Roberts and Sharp (2019)
Nativeness (cover): Nativeness (excluding grasses but including shrubs) for cover by dividing the no-grass native cover by the non-grass perennial cover	1 m x 5 m quadrat; per Roberts and Sharp (2019)
Grasses: Cover that is grasses (as % quadrat)	1 m x 5 m quadrat; per Roberts and Sharp (2019)

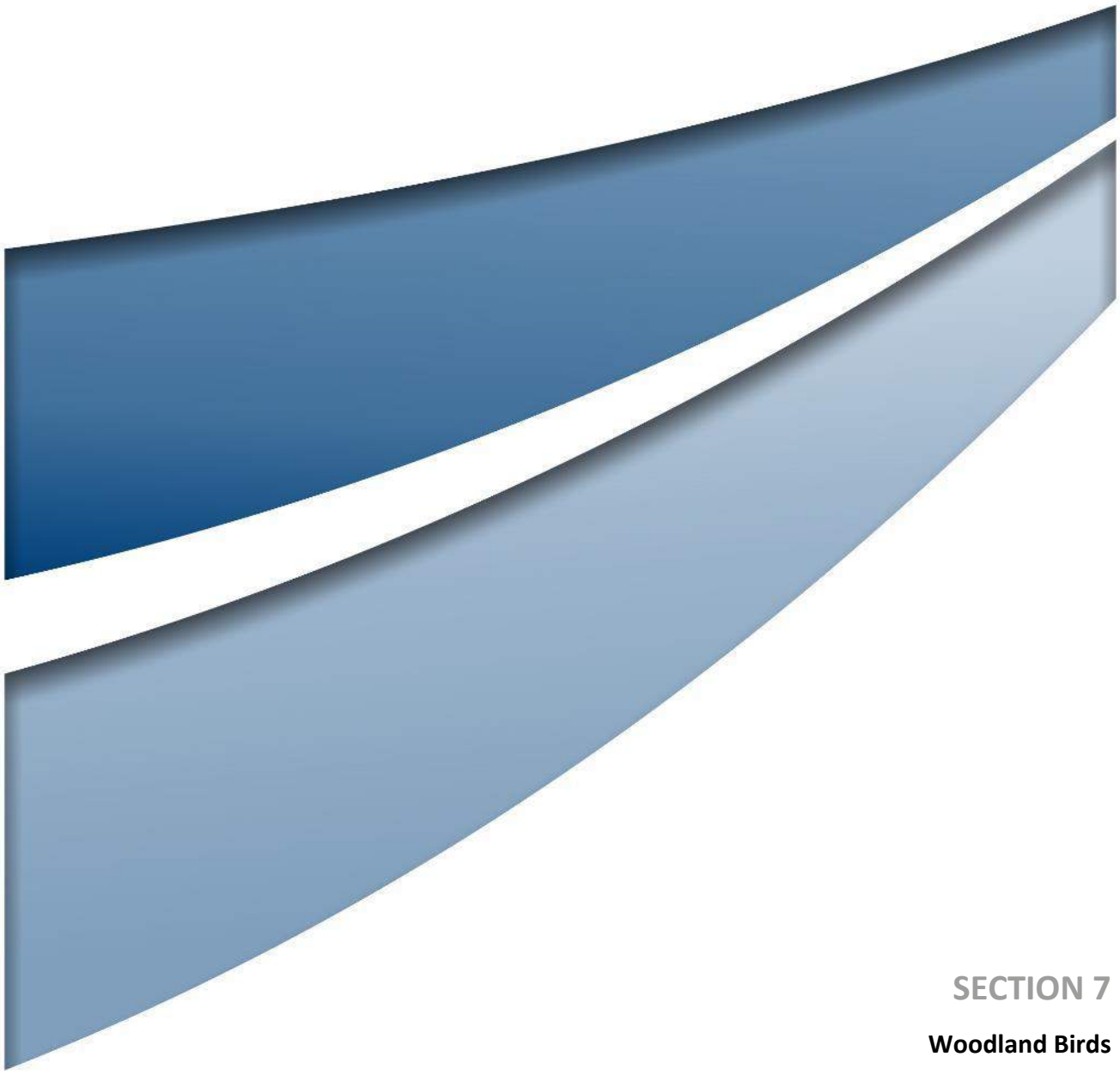
6.5 Triggers and Corrective Actions

Each monitoring report would include an assessment of key indicators against aspirational targets and thresholds for additional management actions. Floristic and vegetation structure thresholds and appropriate corrective actions for riparian areas are to be implemented as specified for non-listed vegetation types in **Section 5.5** (**Table 5.3**).

Specific trigger thresholds relating to the condition of riparian zones Stream E recommended by the baseline survey of Stream E (Roberts and Sharp 2019) are presented in **Table 6.3**. Indicative management responses are provided.

Table 6.3 Trigger thresholds for management review for Stream E (Roberts and Sharp, 2019)

Habitat parameter	Trigger	Response/Action
Sedimentation levels in pools	Sediment depth in BS pools exceeding 5%.	• Review of upstream construction environmental management controls (during construction phase) and stormwater management (during residential phase)
Sedimentation levels in pools	Sediment depth in DSC and UNC pools exceeding 80%	• Review of upstream construction environmental management controls (during construction phase) and stormwater management (during residential phase)
Extent of macrophytes in individual pools	Expansion of macrophyte extent throughout entire pool.	• To be determined in the Aquatic and Riparian Management Plan
Level of occupancy of submerged macrophytes	Less than seven pools occupied by macrophytes.	• To be determined in the Aquatic and Riparian Management Plan
Perennial cover on benches	Perennial cover on benches below 70%.	• Assess stormwater flow volumes and review stormwater retention and management.
Grass cover on benches	Grass cover on benches below 60%.	• Assess stormwater flow volumes and review stormwater retention and management.
Shrub cover on benches	Shrub cover on benches exceeding 5%.	• Assess stormwater flow volumes and review stormwater retention and management.



SECTION 7

Woodland Birds

7.0 Woodland Birds

7.1 Requirements

There is no specific requirement to monitor woodland birds under the Commonwealth approval. Diversity of native bird species is an effective indicator of ecological health, as it is driven by a range of factors including connectivity, diversity of habitats, quality of habitats and levels of disturbance. Monitoring of woodland bird populations, and the presence of invasive bird species, in box – gum woodland is required as a key indicator of woodland health and is therefore considered an essential component. Though there are no specific requirements monitoring of woodland birds enable examination of the impact of management of the Ginninderry Conservation Corridor. Such surveys are currently undertaken in the Molonglo River Corridor to monitor changes in bird abundance in response to plantings within the Reserve and urban development in surrounding areas. This section provides an monitoring method consistent with monitoring of woodland bird populations within the Molonglo River Corridor. Implementation of the woodland bird monitoring procedure is required for areas of box – gum woodland, and optional for remaining areas.

7.2 Monitoring Method

7.2.1 Monitoring plot locations

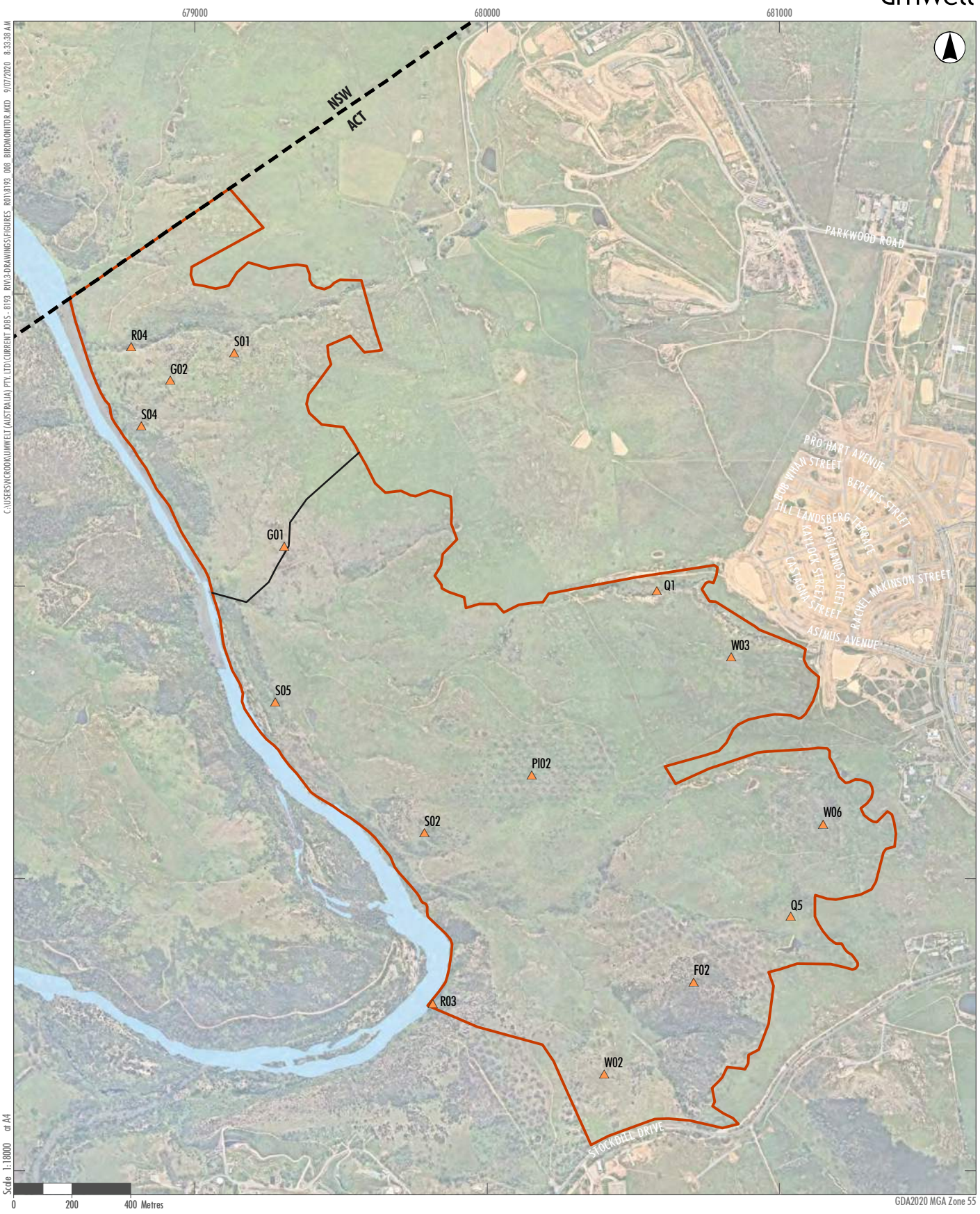
Fifteen (15) proposed monitoring locations are nominated throughout the ACT portion of the Ginninderry Conservation Corridor **(Appendix A, Section 5; Figure 7.1**). Six monitoring locations are within identified box – gum woodland. Monitoring locations are co-located with floristic plot monitoring locations to be sampled as part of **Sections 2.0, 5.0** and **6.0** allowing interpretation of bird survey results with information on habitat characteristics and quality.

7.2.2 Bird diversity survey approach

Bird diversity are to be surveyed using seasonal morning timed area-based survey approach, consistent with Bounds *et al.* (2010). Data is to be collected using the Environmental Offsets Bird Monitoring App in Survey 123 and consistent with the point count method documented in *Environmental Offsets SOP # 9 Woodland Bird Surveys – Transects and Point Counts* (Environmental Offsets, 2020). Ten minute observation periods are to be implemented in circular plots measuring 50m in radius (approximately 0.8ha), with provided co-ordinates representing the centre point. For each monitoring point the following information must be recorded:

- number of each bird species seen or heard within the 50m radius monitoring site
- number of each bird species seen outside the monitoring site (from 50 - 100m).

Birds flying overhead would not be recorded unless hawking (e.g. feeding swallows). Any sightings of threatened or declining birds observed outside of the survey area or period would be recorded (incl. GPS location) and any breeding activity of threatened or declining birds are to be noted (incl. GPS location of nests). Observations of invasive or overabundant bird species breeding or excluding other native birds from habitat patches are to be recorded.



Legend

- Ginninderry Conservation Corridor Boundary (ACT)
- Stage 1 Northern Boundary
- ACT/NSW Border
- Murrumbidgee River
- Roads
- Bird Monitoring Locations

FIGURE 7.1

Woodland Bird Monitoring Plot Locations

Image Source: Nearmap (May 2020) Data source: ACTMapi (2020), NSW LPI (2019), Riverview (2018), RJPL (2015)

7.2.3 Survey Conditions

Surveys are to be undertaken between 15 minutes after sunrise and 10:30 am in appropriate conditions, and specifically surveys should not be undertaken on days with any one of the following weather conditions:

- wind speed exceeds approximately 20 km (grass, leaves, twigs constantly moving)
- rainfall intensity is above drizzle
- conditions are misty or foggy
- temperatures are either well below or above the seasonal average.

7.3 Survey Timing and Schedule

7.3.1 Survey timing

Seasonal monitoring surveys should be completed each monitoring year in the same two week windows, i.e. the last two weeks of January (summer), the last two weeks of April (Autumn), the last two weeks of June (winter) and the last two weeks of September (Spring). Any deviations from the recommended survey timing and conditions should be documented in the monitoring reports.

7.3.2 Monitoring schedule

As there is no specific requirement for woodland bird monitoring under the relevant approvals, there is no specified schedule for monitoring. The proposed schedule (**Table 7.1**) assumes that baseline data would be collected in Year 1 and Year 3, and that monitoring would be undertaken every 5 years from Year 5 onwards.

Table 7.1 Indicative and optional woodland bird monitoring schedule

Year	Month	Task
2021	January, April, June, September	• Baseline seasonal monitoring of bird communities
2023	January, April, June, September	• Baseline seasonal monitoring of bird communities
2025	January, April, June, September	• Seasonal bird monitoring
2030 Ongoing every 5 years subject to review every 10 years commencing at 10 years.	January, April, June, September	• Seasonal bird monitoring

7.4 Indicators

Key monitoring indicators for woodland birds have been determined based on the Environmental Offsets Ecological Monitoring Program (Howland, B, Carlson, E and O'Loughlin, T 2020). The indicators listed below would be summarised in each monitoring report and compared against baseline data (where available) and previous monitoring results:

- Native bird species richness
- % small native birds
- Density of noisy miners per ha
- % exotic invasive bird species
- Number of vulnerable bird species.

Indicators should be compared with baseline data individually and averaged across vegetation units.

Data from areas supporting box – gum woodland must be analysed independently as specified in **Section 2.0**.

7.5 Triggers and Corrective Actions

As there are no specific monitoring or reporting requirements, no formal thresholds or corrective actions are defined. However, a review of potential management actions is recommended in the event that:

- the ratio of invasive (native and exotic) bird species to native bird abundance increases by 20% or more relative to the average of the first two years of monitoring
- the number of rare or threatened bird species detected is 20% or more lower for two years in a row relative to the baseline.

SECTION 8

Monitoring Summary

8.0 Monitoring Summary

8.1 Monitoring Schedule

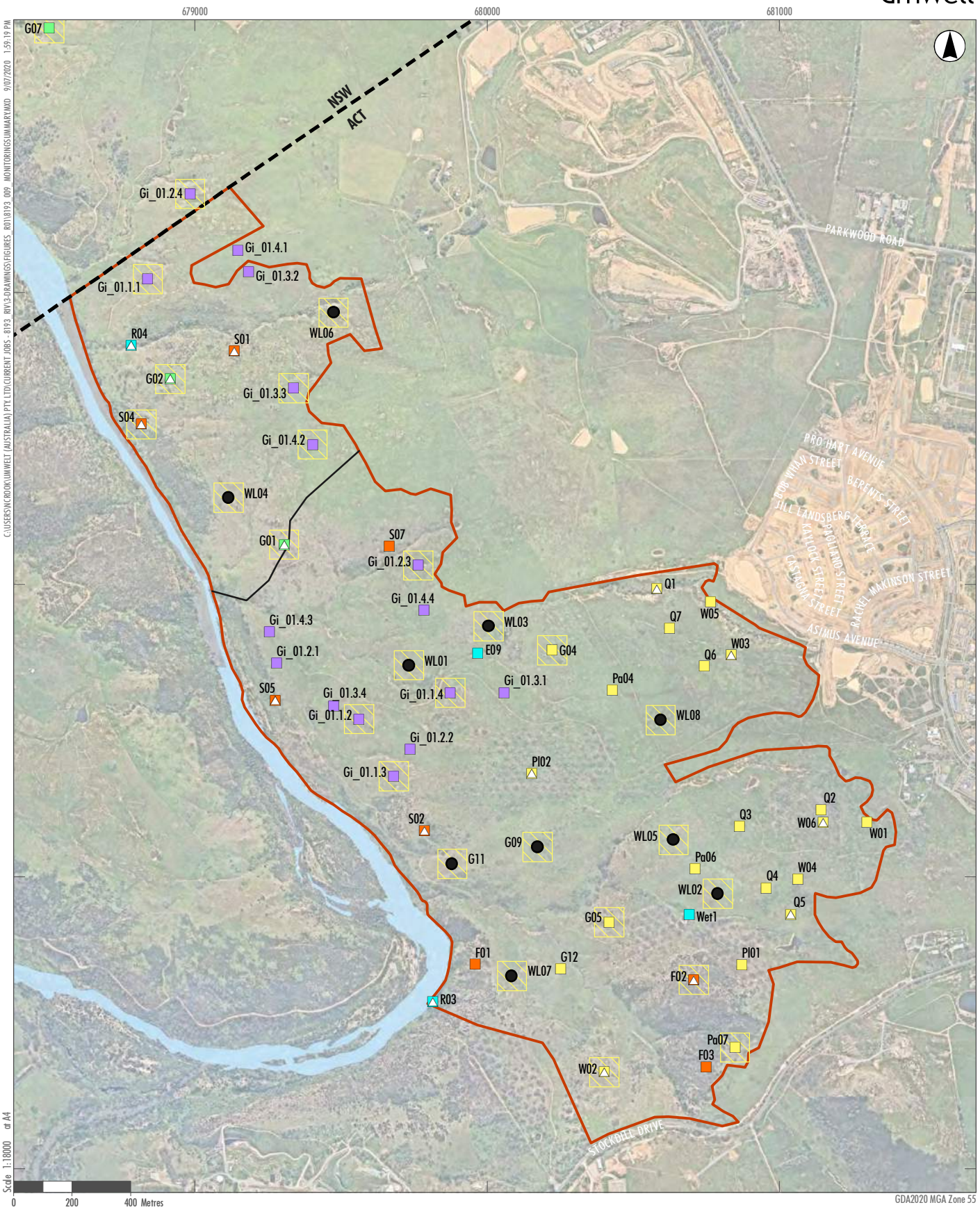
A summarised monitoring schedule is presented in **Table 8.1**.

8.2 Monitoring Locations

Collated monitoring locations are shown in **Figure 8.1** and presented in **Table 8.2**. Monitoring locations for box – gum woodland are candidate locations only, and the final monitoring locations would be determined during the initial season of monitoring. Locations of additional plots required in non-listed and riparian vegetation would be determined during the initial season of monitoring.

Table 8.1 Monitoring schedule

Year	Season	Task
2020	Spring	• Box – gum woodland monitoring • Non-listed vegetation monitoring • Riparian vegetation monitoring
2021	Spring	• Natural temperate grassland monitoring • Pink-tailed worm lizard habitat monitoring • Woodland bird monitoring
2022	Spring	• Box – gum woodland monitoring • Non-listed vegetation monitoring • Riparian vegetation monitoring
2023	Spring	• Natural temperate grassland monitoring • Pink-tailed worm lizard habitat monitoring • Woodland bird monitoring
2024	Spring	• Box – gum woodland monitoring • Non-listed vegetation monitoring • Riparian vegetation monitoring
2025	Spring	• Natural temperate grassland monitoring • Pink-tailed worm lizard habitat monitoring • Woodland bird monitoring
2029- Ongoing every 5 years subject to review every 10 years	Spring	• Box – gum woodland monitoring • Non-listed vegetation monitoring • Riparian vegetation monitoring
2030 - Ongoing every 5 years subject to review every 10 years	Spring	• Natural temperate grassland monitoring • Pink-tailed worm lizard habitat monitoring • Woodland bird monitoring
2030, 2040	n/a	• Review of monitoring framework and monitoring methods. • Consultation with stakeholders regarding ongoing monitoring requirements.



Legend

- Ginninderry Conservation Corridor Boundary (ACT)
- Stage 1 Northern Boundary
- ACT/NSW Border
- Murrumbidgee River
- Roads
- Pink-tailed Worm Lizard Habitat Monitoring Plots
- Pink-tailed Worm Lizard Artifical Shelters
- Bird Monitoring Locations
- Box-gum Woodland Monitoring Plots

Grassland Monitoring Plots

- RJPL (2015)
- Capital Ecology (2020)

Non-listed Vegetation Monitoring Plots

- Non-listed Vegetation
- Riparian

FIGURE 8.1

Ginninderry Conservation Corridor Monitoring Requirement Summary

Image Source: Nearmap (May 2020) Data source: ACTMapi (2020), NSW LPI (2019), Riverview Projects, RJPL (2015)

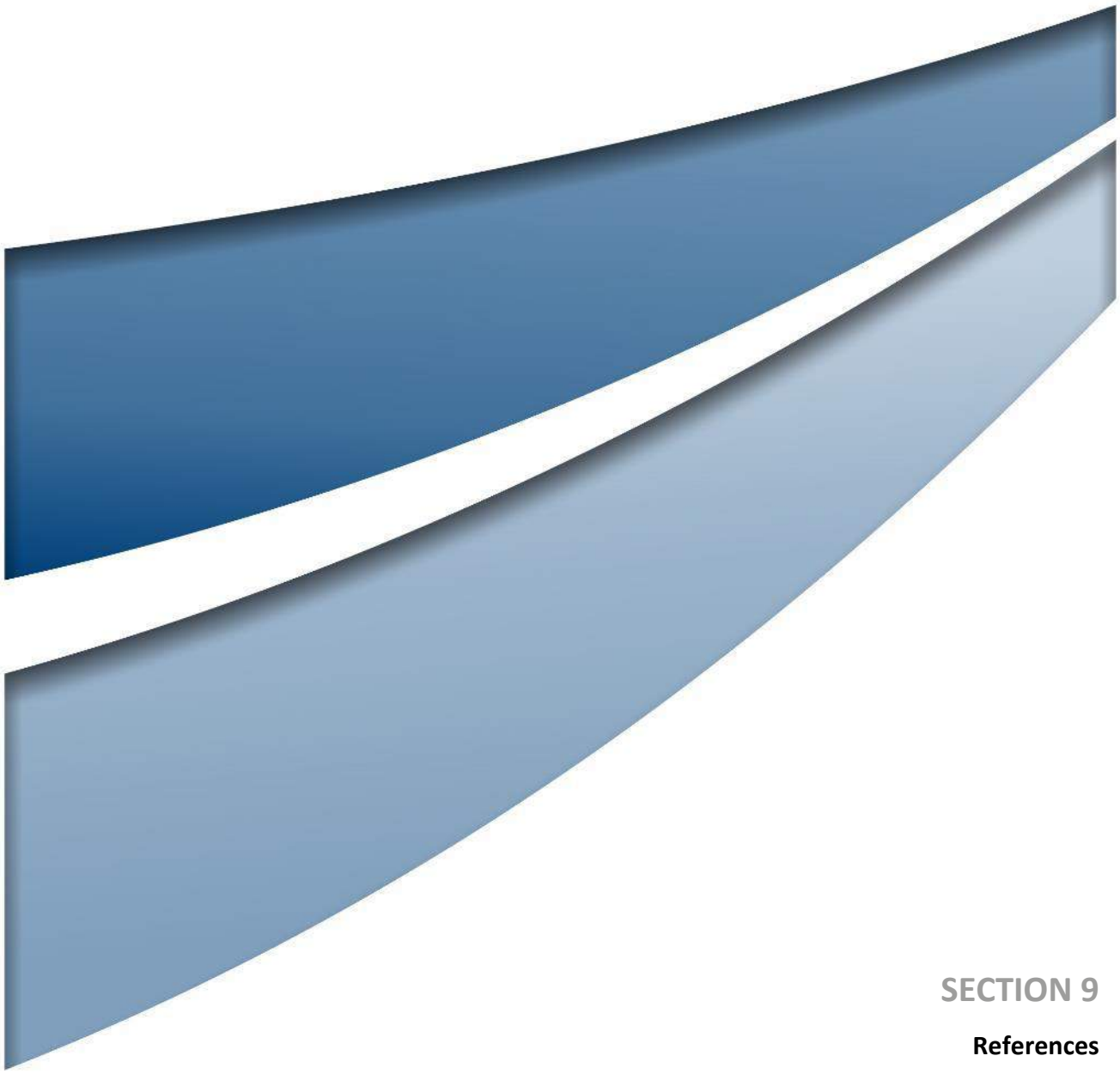
Table 8.2 Summary of plot locations

Plot Name	Floristic Baseline	Floristic Monitoring	PTWL Monitoring	Bird Monitoring	Projection	X	Y
E09	Roberts & Sharp (2019)	Stream E			GDA2020 Zone 55	679969	6099765
F01	RJPL(2015)	Non-listed vegetation			GDA2020 Zone 55	679959	6098699
F02	RJPL(2015)	Non-listed vegetation	Floristics, Brick Array and Habitat	Yes	GDA2020 Zone 55	680708	6098647
F03	RJPL(2015)	Non-listed vegetation			GDA2020 Zone 55	680750	6098348
G01	RJPL(2015)	Natural grassland	Floristics, Brick Array and Habitat	Yes	GDA2020 Zone 55	679305	6100137
G02	RJPL(2015)	Natural grassland	Floristics, Brick Array and Habitat	Yes	GDA2020 Zone 55	678916	6100704
G04	RJPL(2015)	Box - gum woodland	Floristics, Brick Array and Habitat		GDA2020 Zone 55	680223	6099775
G05	RJPL(2015)	Box - gum woodland	Floristics, Brick Array and Habitat		GDA2020 Zone 55	680418	6098844
G07	RJPL(2015)	NTG Candidate (NSW)	NSW - Complete		GDA2020 Zone 55	678501	6101905
G08	RJPL(2015)		NSW - Complete		GDA2020 Zone 55	677181	6102629
G09	RJPL(2015)	None	Brick Array and Habitat		GDA2020 Zone 55	680173	6099102
G11	RJPL(2015)	None	Brick Array and Habitat		GDA2020 Zone 55	679881	6099044
G12	RJPL(2015)	Box - gum woodland			GDA2020 Zone 55	680252	6098684
Gi_01.1.1	Capital Ecology, 2020	Natural grassland	Floristics, Brick Array and Habitat		GDA2020 Zone 55	678839	6101045
Gi_01.1.2	Capital Ecology, 2020	Natural grassland	Floristics, Brick Array and Habitat		GDA2020 Zone 55	679562	6099539
Gi_01.1.3	Capital Ecology, 2020	Natural grassland	Floristics, Brick Array and Habitat		GDA2020 Zone 55	679681	6099343

Plot Name	Floristic Baseline	Floristic Monitoring	PTWL Monitoring	Bird Monitoring	Projection	X	Y
Gi_01.1.4	Capital Ecology, 2020	Natural grassland	Floristics, Brick Array and Habitat		GDA2020 Zone 55	679874	6099629
Gi_01.2.1	Capital Ecology, 2020	Natural grassland			GDA2020 Zone 55	679280	6099730
Gi_01.2.2	Capital Ecology, 2020	Natural grassland			GDA2020 Zone 55	679737	6099435
Gi_01.2.3	Capital Ecology, 2020	Natural grassland	Floristics, Brick Array and Habitat		GDA2020 Zone 55	679765	6100065
Gi_01.2.4	Capital Ecology, 2020	NTG Candidate (NSW)	NSW - Complete		GDA2020 Zone 55	678984	6101337
Gi_01.3.1	Capital Ecology, 2020	Natural grassland			GDA2020 Zone 55	680059	6099629
Gi_01.3.2	Capital Ecology, 2020	Natural grassland			GDA2020 Zone 55	679184	6101069
Gi_01.3.3	Capital Ecology, 2020	Natural grassland	Floristics, Brick Array and Habitat		GDA2020 Zone 55	679338	6100672
Gi_01.3.4	Capital Ecology, 2020	Natural grassland			GDA2020 Zone 55	679475	6099583
Gi_01.4.1	Capital Ecology, 2020	Natural grassland			GDA2020 Zone 55	679148	6101143
Gi_01.4.2	Capital Ecology, 2020	Natural grassland	Floristics, Brick Array and Habitat		GDA2020 Zone 55	679403	6100479
Gi_01.4.3	Capital Ecology, 2020	Natural grassland			GDA2020 Zone 55	679256	6099839
Gi_01.4.4	Capital Ecology, 2020	Natural grassland			GDA2020 Zone 55	679785	6099912
Pa04	RJPL(2015)	Box - gum woodland			GDA2020 Zone 55	680428	6099638
Pa06	RJPL(2015)	Box - gum woodland			GDA2020 Zone 55	680711	6099027

Plot Name	Floristic Baseline	Floristic Monitoring	PTWL Monitoring	Bird Monitoring	Projection	X	Y
Pa07	RJPL(2015)	Box - gum woodland	Floristics, Brick Array and Habitat		GDA2020 Zone 55	680848	6098415
Pl01	RJPL(2015)	Box - gum woodland			GDA2020 Zone 55	680873	6098697
Pl02	RJPL(2015)	Box - gum woodland		Yes	GDA2020 Zone 55	680153	6099353
Q1	Nash & Hogg 2013	Box - gum woodland		Yes	GDA2020 Zone 55	680582	6099985
Q2	Nash & Hogg 2013	Box - gum woodland			GDA2020 Zone 55	681144	6099227
Q3	Nash & Hogg 2013	Box - gum woodland			GDA2020 Zone 55	680865	6099171
Q4	Nash & Hogg 2013	Box - gum woodland			GDA2020 Zone 55	680956	6098960
Q5	Nash & Hogg 2013	Box - gum woodland		Yes	GDA2020 Zone 55	681040	6098869
Q6	Nash & Hogg 2013	Box - gum woodland			GDA2020 Zone 55	680744	6099719
Q7	Nash & Hogg 2013	Box - gum woodland			GDA2020 Zone 55	680626	6099849
R01	RJPL(2015)	Riparian candidate (NSW)			GDA2020 Zone 55	676935	6102963
R02	RJPL(2015)	Riparian candidate (NSW)			GDA2020 Zone 55	678321	6101290
R03	RJPL(2015)	Riparian		Yes	GDA2020 Zone 55	679815	6098572
R04	RJPL(2015)	Riparian		Yes	GDA2020 Zone 55	678781	6100819
R05	RJPL(2015)	Riparian candidate (NSW)			GDA2020 Zone 55	679049	6103196
S01	RJPL(2015)	Non-listed vegetation		Yes	GDA2020 Zone 55	679135	6100798
S02	RJPL(2015)	Non-listed vegetation		Yes	GDA2020 Zone 55	679786	6099156
S04	RJPL(2015)	Non-listed vegetation	Floristics, Brick Array and Habitat	Yes	GDA2020 Zone 55	678817	6100548
S05	RJPL(2015)	Non-listed vegetation		Yes	GDA2020 Zone 55	679275	6099604

Plot Name	Floristic Baseline	Floristic Monitoring	PTWL Monitoring	Bird Monitoring	Projection	X	Y
S07	RJPL(2015)	Non-listed vegetation			GDA2020 Zone 55	679665	6100132
S08	RJPL(2015)	Non-listed vegetation			GDA2020 Zone 55	679083	6100907
W01	RJPL(2015)	Box - gum woodland			GDA2020 Zone 55	681300	6099187
W02	RJPL(2015)	Box - gum woodland	Floristics, Brick Array and Habitat	Yes	GDA2020 Zone 55	680401	6098330
W03	RJPL(2015)	Box - gum woodland		Yes	GDA2020 Zone 55	680835	6099759
W04	RJPL(2015)	Box - gum woodland			GDA2020 Zone 55	681063	6098992
W05	RJPL(2015)	Box - gum woodland			GDA2020 Zone 55	680765	6099941
W06	RJPL(2015)	Box - gum woodland		Yes	GDA2020 Zone 55	681151	6099185
W08	RJPL(2015)	Box - gum candidate (NSW)			GDA2020 Zone 55	677769	6103208
Wet1	RJPL(2015)	Riparian			GDA2020 Zone 55	680692	6098871
WL01	None	None	Brick Array and Habitat		GDA2020 Zone 55	679732	6099724
WL02	None	None	Brick Array and Habitat		GDA2020 Zone 55	680790	6098942
WL03	None	None	Brick Array and Habitat		GDA2020 Zone 55	680005	6099857
WL04	None	None	Brick Array and Habitat		GDA2020 Zone 55	679115	6100297
WL05		None	Brick Array and Habitat		GDA2020 Zone 55	680638	6099126
WL06	None	None	Brick Array and Habitat		GDA2020 Zone 55	679474	6100931
WL07	None	None	Brick Array and Habitat		GDA2020 Zone 55	680085	6098659
WL08	None	None	Brick Array and Habitat		GDA2020 Zone 55	680594	6099536
WL10		None	NSW - Brick		GDA2020 Zone 55	677541	6103052
WL9		None	NSW - Brick		GDA2020 Zone 55	678093	6101705



SECTION 9

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APPENDIX A

Plot Locations

Table A1 Box – gum woodland baseline plot locations (note – final monitoring locations to be determined following initial season of monitoring)

Monitoring	Plot name	Source	Plot type	Vegetation community	Coordinate location	Projection	X	Y	Transect Orientation	Baseline Survey date
Candidate	G12	RJPL, 2015	Sharp, 2015	Yellow Box - Red Gum Tableland Grassy Woodland	NE corner	GDA2020 55	680252	6098682	320	29/10/2014
Candidate	Pa04	RJPL, 2015	Sharp, 2015	Exotic pasture	NE corner	GDA2020 55	680428	6099636	270	13/11/2014
Candidate	Pa06	RJPL, 2015	Sharp, 2015	Depauperate native pasture	NE corner	GDA2020 55	680711	6099025	270	11/11/2014
Candidate	Pa07	RJPL, 2015	Sharp, 2015	Depauperate native pasture	NE corner	GDA2020 55	680848	6098414	56	28/10/2014
Candidate	Pl01	RJPL, 2015	Sharp, 2015	Yellow Box - Red Gum Tableland Grassy Woodland	NE corner	GDA2020 55	680872	6098696	337	28/10/2014
Candidate	Pl02	RJPL, 2015	Sharp, 2015	Yellow Box - Red Gum Tableland Grassy Woodland	NE corner	GDA2020 55	680153	6099352	270	11/11/2014
Candidate	Q1	Nash and Hogg, 2013	20 x 20 m floristic quadrat Transects not co-located	Yellow Box - Red Gum Tableland Grassy Woodland	NE corner	GDA2020 55	680581	6099984	n/a	October 2012
Candidate	Q2	Nash and Hogg, 2013	20 x 20 m floristic quadrat Transects not co-located	Yellow Box - Red Gum Tableland Grassy Woodland	NE corner	GDA2020 55	681143	6099226	n/	October 2012
Candidate	Q3	Nash and Hogg, 2013	20 x 20 m floristic quadrat Transects not co-located	Yellow Box - Red Gum Tableland Grassy Woodland	NE corner	GDA2020 55	680864	6099170	n/	October 2012
Candidate	Q4	Nash and Hogg, 2013	20 x 20 m floristic quadrat Transects not co-located	Yellow Box - Red Gum Tableland Grassy Woodland	NE corner	GDA2020 55	680955	6098959	n/	October 2012
Candidate	Q5	Nash and Hogg, 2013	20 x 20 m floristic quadrat Transects not co-located	Yellow Box - Red Gum Tableland Grassy Woodland	NE corner	GDA2020 55	681039	6098868	n/	October 2012
Candidate	Q6	Nash and Hogg, 2013	20 x 20 m floristic quadrat Transects not co-located	Yellow Box - Red Gum Tableland Grassy Woodland	NE corner	GDA2020 55	680743	6099718	n/	October 2012
Candidate	Q7	Nash and Hogg, 2013	20 x 20 m floristic quadrat Transects not co-located	Yellow Box - Red Gum Tableland Grassy Woodland	NE corner	GDA2020 55	680625	6099848	n/	October 2012

Monitoring	Plot name	Source	Plot type	Vegetation community	Coordinate location	Projection	X	Y	Transect Orientation	Baseline Survey date
Candidate	W01	RJPL, 2015	Sharp, 2015	Yellow Box - Red Gum Tableland Grassy Woodland	NE corner	GDA2020 55	681300	6099186	270	11/11/2014
Candidate	W02	RJPL, 2015	Sharp, 2015	Yellow Box - Red Gum Tableland Grassy Woodland	NE corner	GDA2020 55	680400	6098329	75	29/10/2014
Candidate	W03	RJPL, 2015	Sharp, 2015	Yellow Box - Red Gum Tableland Grassy Woodland	NE corner	GDA2020 55	680835	6099757	270	13/11/2014
Candidate	W04	RJPL, 2015	Sharp, 2015	Yellow Box - Red Gum Tableland Grassy Woodland	NE corner	GDA2020 55	681063	6098990	270	11/11/2014
Candidate	W05	RJPL, 2015	Sharp, 2015	Yellow Box - Red Gum Tableland Grassy Woodland	NE corner	GDA2020 55	680764	6099940	270	13/11/2014
Candidate	W06	RJPL, 2015	Sharp, 2015	Yellow Box - Red Gum Tableland Grassy Woodland	NE corner	GDA2020 55	681151	6099184	270	11/11/2014
Candidate (NSW)	W08	RJPL, 2015	Sharp, 2015	Yellow Box - Red Gum Tableland Grassy Woodland	NE corner	GDA2020 55	677769	6103208	270	11/11/2014

Table A2.1 Natural temperate grassland baseline plot locations

Monitoring	Plot name	Source	Plot type	Vegetation Community	Coordinate location	Projection	X	Y	Transect Orientation	Baseline Survey Date
Yes	G01	RJPL, 2015	Sharp, 2015	Natural Temperate Grassland: Rocky Natural Grassland	NE corner	GDA2020 55	679304	6100135	200	13/11/2014
Yes	G02	RJPL, 2015	Sharp, 2015	Natural Temperate Grassland: Rocky Natural Grassland	NE corner	GDA2020 55	678915	6100702	270	14/11/2014
Candidate (NSW)	G07	RJPL, 2015	Sharp, 2015	Natural Temperate Grassland: Rocky Natural Grassland in a mosaic with Red Stringybark - Scribbly Gum Tableland Forest: secondary grassland	NE corner	GDA2020 55	678501	6101905	270	28/11/2014
Yes	Gi_01.1.1	Capital Ecology 2020	ACT Government (2015d) Transects not co-located	Natural Temperate Grassland of the South Eastern Highlands	NW Corner	GDA2020 55	678838	6101044	n/a	March 2020
Yes	Gi_01.1.2	Capital Ecology 2020	ACT Government (2015d) Transects not co-located	Natural Temperate Grassland of the South Eastern Highlands	NW Corner	GDA2020 55	679561	6099538	n/a	March 2020
Yes	Gi_01.1.3	Capital Ecology 2020	ACT Government (2015d) Transects not co-located	Natural Temperate Grassland of the South Eastern Highlands	NW Corner	GDA2020 55	679680	6099342	n/a	March 2020
Yes	Gi_01.1.4	Capital Ecology 2020	ACT Government (2015d) Transects not co-located	Natural Temperate Grassland of the South Eastern Highlands	NW Corner	GDA2020 55	679873	6099628	n/a	March 2020
Yes	Gi_01.2.1	Capital Ecology 2020	ACT Government (2015d) Transects not co-located	Natural Temperate Grassland of the South Eastern Highlands	NW Corner	GDA2020 55	679279	6099729	n/a	March 2020
Yes	Gi_01.2.2	Capital Ecology 2020	ACT Government (2015d) Transects not co-located	Natural Temperate Grassland of the South Eastern Highlands	NW Corner	GDA2020 55	679736	6099434	n/a	March 2020
Yes	Gi_01.2.3	Capital Ecology 2020	ACT Government (2015d) Transects not co-located	Natural Temperate Grassland of the South Eastern Highlands	NW Corner	GDA2020 55	679764	6100064	n/a	March 2020
Yes	Gi_01.2.4	Capital Ecology 2020	ACT Government (2015d) Transects not co-located	Natural Temperate Grassland of the South Eastern Highlands	NW Corner	GDA2020 55	678983	6101336	n/a	March 2020
Candidate (NSW)	Gi_01.2.4	Capital Ecology 2020	ACT Government (2015d) Transects not co-located	Natural Temperate Grassland of the South Eastern Highlands	NW Corner	GDA2020 55	678983	6101336	n/a	March 2020
Yes	Gi_01.3.1	Capital Ecology 2020	ACT Government (2015d) Transects not co-located	Natural Temperate Grassland of the South Eastern Highlands	NW Corner	GDA2020 55	680058	6099628	n/a	March 2020
Yes	Gi_01.3.2	Capital Ecology 2020	ACT Government (2015d) Transects not co-located	Natural Temperate Grassland of the South Eastern Highlands	NW Corner	GDA2020 55	679183	6101068	n/a	March 2020
Yes	Gi_01.3.3	Capital Ecology 2020	ACT Government (2015d) Transects not co-located	Natural Temperate Grassland of the South Eastern Highlands	NW Corner	GDA2020 55	679337	6100671	n/a	March 2020

Monitoring	Plot name	Source	Plot type	Vegetation Community	Coordinate location	Projection	X	Y	Transect Orientation	Baseline Survey Date
Yes	Gi_01.3.4	Capital Ecology 2020	ACT Government (2015d) Transects not co-located	Natural Temperate Grassland of the South Eastern Highlands	NW Corner	GDA2020 55	679474	6099582	n/a	March 2020
Yes	Gi_01.4.1	Capital Ecology 2020	ACT Government (2015d) Transects not co-located	Natural Temperate Grassland of the South Eastern Highlands	NW Corner	GDA2020 55	679147	6101142	n/a	March 2020
Yes	Gi_01.4.2	Capital Ecology 2020	ACT Government (2015d) Transects not co-located	Natural Temperate Grassland of the South Eastern Highlands	NW Corner	GDA2020 55	679402	6100478	n/a	March 2020
Yes	Gi_01.4.3	Capital Ecology 2020	ACT Government (2015d) Transects not co-located	Natural Temperate Grassland of the South Eastern Highlands	NW Corner	GDA2020 55	679255	6099838	n/a	March 2020
Yes	Gi_01.4.4	Capital Ecology 2020	ACT Government (2015d) Transects not co-located	Natural Temperate Grassland of the South Eastern Highlands	NW Corner	GDA2020 55	679784	6099911	n/a	March 2020

Table A2.2 Natural temperate grassland baseline independent transect locations (Capital Ecology, 2020)

Monitoring	PCT	Zone	Transect ID	Datum and Zone	Start Easting	Start Northing	Length (m)	Orientation
Yes	1	1	Gi_01.1.1	GDA2020 Zone 55	678838	6101044	50	TBC
Yes	1	2	Gi_01.2.1	GDA2020 Zone 55	679279	6099729	50	TBC
Yes	1	3	Gi_01.3.1	GDA2020 Zone 55	680058	6099628	50	TBC
Yes	1	4	Gi_01.4.1	GDA2020 Zone 55	679147	6101142	50	TBC
Yes	1	1	Gi_01.1.2	GDA2020 Zone 55	679561	6099538	50	TBC
Yes	1	2	Gi_01.2.2	GDA2020 Zone 55	679736	6099434	50	TBC
Yes	1	3	Gi_01.3.2	GDA2020 Zone 55	679183	6101068	50	TBC
Yes	1	4	Gi_01.4.2	GDA2020 Zone 55	679402	6100478	50	TBC
Yes	1	1	Gi_01.1.3	GDA2020 Zone 55	679680	6099342	50	TBC
Yes	1	2	Gi_01.2.3	GDA2020 Zone 55	679764	6100064	50	TBC
Yes	1	3	Gi_01.3.3	GDA2020 Zone 55	679337	6100671	50	TBC
Yes	1	4	Gi_01.4.3	GDA2020 Zone 55	679255	6099838	50	TBC
Yes	1	1	Gi_01.1.4	GDA2020 Zone 55	679873	6099628	50	TBC
Candidate (NSW)	1	2	Gi_01.2.4	GDA2020 Zone 55	678983	6101336	50	TBC
Yes	1	3	Gi_01.3.4	GDA2020 Zone 55	679474	6099582	50	TBC
Yes	1	4	Gi_01.4.4	GDA2020 Zone 55	678838	6101044	50	TBC

Table A3 Non-listed vegetation monitoring plot locations

Monitoring	Plot name	Source	Plot type	Vegetation community	Coordinate location	Projection	X	Y	Transect Orientation	Baseline Survey date
Non-listed	F01	RJPL, 2015	Sharp, 2015	Black Cypress Pine Tall Dry Open Forest	NE corner	GDA2020 55	679959	6098700	290	30/10/2014
Non-listed	F02	RJPL, 2015	Sharp, 2015	Black Cypress Pine Tall Dry Open Forest	NE corner	GDA2020 55	680708	6098647	340	29/10/2014
Non-listed	F03	RJPL, 2015	Sharp, 2015	Black Cypress Pine Tall Dry Open Forest	NE corner	GDA2020 55	680750	6098350	295	28/10/2014
Non-listed	S01	RJPL, 2015	Sharp, 2015	River Bottlebrush - Burgan Tableland Shrubland	NE corner	GDA2020 55	679135	6100798	270	14/11/2014
Non-listed	Additional plot required, to be determined during initial monitoring			River Bottlebrush - Burgan Tableland Shrubland						
Non-listed	S02	RJPL, 2015	Sharp, 2015	Black Cypress Pine Tall Dry Open Forest: derived shrubland	NE corner	GDA2020 55	679786	6099156	270	10/11/2019
Non-listed	S04	RJPL, 2015	Sharp, 2015	Black Cypress Pine Tall Dry Open Forest: derived shrubland	NE corner	GDA2020 55	678817	6100548	180	17/11/2014
Non-listed	S05	RJPL, 2015	Sharp, 2015	Black Cypress Pine Tall Dry Open Forest: derived shrubland	NE corner	GDA2020 55	679275	6099605	320	10/11/2014
Non-listed	S07	RJPL, 2015	Sharp, 2015	Depauperate native pasture and woody weeds	NE corner	GDA2020 55	679666	6100133	240	13/11/2014
Non-listed	S08	RJPL, 2015	Sharp, 2015	Depauperate native pasture and woody weeds	NE corner	GDA2020 55	679083	6100907	270	14/11/2014
Non-listed	Additional plot required, to be determined during initial monitoring			Depauperate native pasture and woody weeds						
Riparian	R04	RJPL, 2015	Sharp, 2015	River She-oak Tableland Riparian Woodland	NE corner	GDA2020 55	678781	6100819	260	17/11/2014
Riparian	R03	RJPL, 2015	Sharp, 2015	River She-oak Tableland Riparian Woodland	NE corner	GDA2020 55	679815	6098572	320	5/12/2014
Riparian	Additional plot required, to be determined during initial monitoring			River She-oak Tableland Riparian Woodland						
Riparian	Wet1	RJPL, 2015	Sharp, 2015	Tableland Riparian Fringing Wetlands	NE corner	GDA2020 55	680692	6098869	290	11/11/2014
Stream E	E09	Roberts and Sharp, 2019	Detailed riparian	Exotic pasture, riparian	n/a	GDA2020 55	679969	6099765	n/a	Spring 2018; Spring 2019
Candidate (NSW)	R01	RJPL, 2015	Sharp, 2015	River She-oak Tableland Riparian Woodland	NE corner	GDA2020 55	676935	6102963	0	27/11/2014
Candidate (NSW)	R02	RJPL, 2015	Sharp, 2015	River She-oak Tableland Riparian Woodland	NE corner	GDA2020 55	678321	6101290	110	28/11/2014
Candidate (NSW)	R03	RJPL, 2015	Sharp, 2015	River She-oak Tableland Riparian Woodland	NE corner	GDA2020 55	679049	6103196	180	5/12/2014

Table A4 Draft pink-tailed worm lizard monitoring plot locations

Plot name	PTWL habitat quality	Plot type	Projection	X	Y
F02	High	Floristics, brick array and habitat	GDA2020 55	680708	6098647
G01	High	Floristics, brick array and habitat	GDA2020 55	679305	6100137
G02	High	Floristics, brick array and habitat	GDA2020 55	678916	6100704
G04	High	Floristics, brick array and habitat	GDA2020 55	680223	6099775
G05	High	Floristics, brick array and habitat	GDA2020 55	680418	6098844
G07	High	NSW Candidate Floristics, brick array and habitat	GDA2020 55	678501	6101905
G08	High	NSW Candidate Floristics, brick array and habitat	GDA2020 55	677181	6102629
G09	High	Brick array and habitat	GDA2020 55	680173	6099102
G11	High	Brick array and habitat	GDA2020 55	679881	6099044
Gi_01.1.1	High	Floristics, brick array and habitat	GDA2020 55	678838	6101044
Gi_01.1.2	High	Floristics, brick array and habitat	GDA2020 55	679561	6099538
Gi_01.1.3	High	Floristics, brick array and habitat	GDA2020 55	679680	6099342
Gi_01.1.4	High	Floristics, brick array and habitat	GDA2020 55	679873	6099628
Gi_01.2.3	High	Floristics, brick array and habitat	GDA2020 55	679764	6100064
Gi_01.2.4	High	NSW Candidate Floristics, brick array and habitat	GDA2020 55	678984	6101337
Gi_01.3.3	High	Floristics, brick array and habitat	GDA2020 55	679337	6100671
Gi_01.4.2	High	Floristics, brick array and habitat	GDA2020 55	679402	6100478
Pa07	High	Floristics, brick array and habitat	GDA2020 55	680848	6098415
S04	High	Floristics, brick array and habitat	GDA2020 55	678817	6100548
W02	High	Floristics, brick array and habitat	GDA2020 55	680401	6098330
WL01	High	Brick array and habitat	GDA2020 55	679732	6099724
WL02	Low	Brick array and habitat	GDA2020 55	680790	6098942
WL03	Low	Brick array and habitat	GDA2020 55	680005	6099857
WL04	High	Brick array and habitat	GDA2020 55	679115	6100297
WL05	High	Brick array and habitat	GDA2020 55	680638	6099126
WL06	High	Brick array and habitat	GDA2020 55	679474	6100931
WL07	High	Brick array and habitat	GDA2020 55	680085	6098659
WL08	Low	Brick array and habitat	GDA2020 55	680594	6099536
WL09	High	NSW Candidate Brick array and habitat	GDA2020 55	677541	6103052
WL10	High	NSW Candidate Brick array and habitat	GDA2020 55	678093	6101705

Table A5 Woodland Bird Monitoring Locations

Plot Name	Vegetation community	Datum	X	Y
F02	Black Cypress Pine Tall Dry Open Forest	GDA2020 55	680708	6098647
S01	River Bottlebrush - Burgan Tableland Shrubland	GDA2020 55	679135	6100798
S04	Black Cypress Pine Tall Dry Open Forest: derived shrubland	GDA2020 55	678817	6100548
S02	Black Cypress Pine Tall Dry Open Forest: derived shrubland	GDA2020 55	679786	6099156
S05	Black Cypress Pine Tall Dry Open Forest: derived shrubland	GDA2020 55	679275	6099604
R03	River She-oak Dry Riparian Forest	GDA2020 55	679815	6098572
W02	Yellow Box - Blakely's Red Gum Grassy Woodland	GDA2020 55	680401	6098330
W06	Yellow Box - Blakely's Red Gum Grassy Woodland	GDA2020 55	681151	6099185
Pl02	Yellow Box - Blakely's Red Gum Grassy Woodland; remainder depauperate native pasture	GDA2020 55	680153	6099353
W03	Yellow Box - Blakely's Red Gum Grassy Woodland	GDA2020 55	680835	6099759
G01	Natural Temperate Grassland: Rocky Natural Grassland	GDA2020 55	679305	6100137
G02	Natural Temperate Grassland: Rocky Natural Grassland	GDA2020 55	678916	6100704
R04	River She-oak Dry Riparian Forest	GDA2020 55	678781	6100819
Q1	Yellow Box - Blakely's Red Gum Grassy Woodland	GDA2020 55	680582	6099985
Q5	Yellow Box - Blakely's Red Gum Grassy Woodland	GDA2020 55	681040	6098869

APPENDIX B

Indicative monitoring layout

Floristic monitoring is to be completed in line with the Environmental Offsets Ecological Condition Monitoring Methods (ACT Government, 2020). Plots are to be monitored using the following Statement of Procedures from the Environmental Offsets Ecological Condition Monitoring Methods, preferably using the applicable Survey 123 apps provided by the ACT Government:

- SOP #1 Vegetation Surveys – Floristic Surveys
- SOP #2 Vegetation Surveys – Understorey Structure Surveys (using the *step point* transect survey option)
- SOP #3 Vegetation Surveys – Weeds Monitoring
- SOP #4 Vegetation Surveys – Woodland Attribute Surveys
- SOP #6 Soil Core Sampling.

Where possible, each plot and transect monitoring location is to be laid out as indicated shown in **Figure B1** below. During the first monitoring survey, north-west corner point of each plot should be marked with a permanent marking device, such as a low peg with an orange cattle tag or a high visibility plastic square surveyors peg (minimum top diameter of 30 mm x 30 mm standing 0 - 5 cm above the ground. Plots should be placed so that the 50 m length is running north - south independent of slope, with the floristic diversity plot at the northern end and the transect running north – south down the middle of the plot. however this may be dependent on the size and dimensions of the vegetation zone being assessed. If a vegetation zone does not permit this layout, the plot shape may be modified but not the size (e.g. a 40 m x 10 m floristic diversity plot nested within a 100 m x 10 m vegetation and habitat structure plot may be more practical). Full details of any modification to the plot layout must be documented to allow future monitoring to replicate the process. Where an alternative plot orientation is provided, the Y-axis runs along the alternative orientation.

Transects may be completed as the centreline of the 20 m x 50 m plot as illustrated, or as an independent transect. If transects are independent, this should be noted, and coordinates recorded.

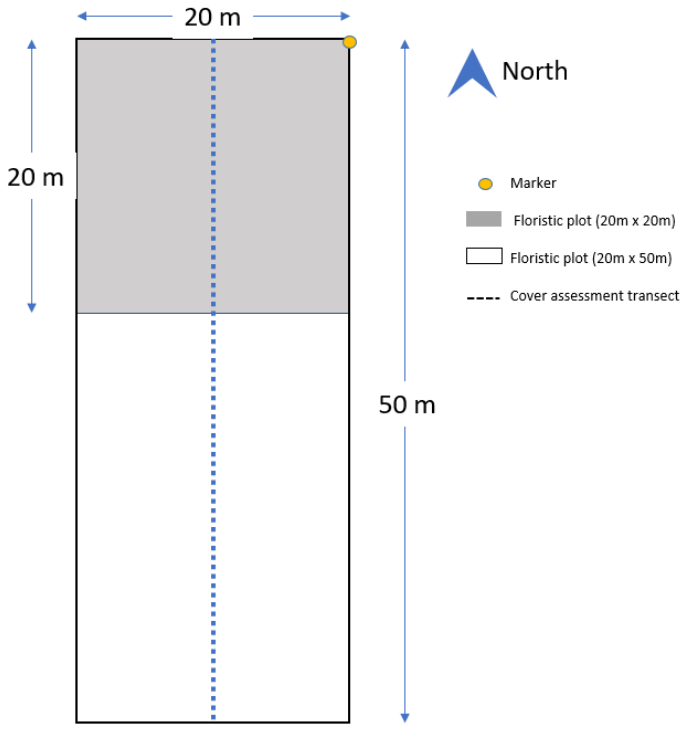
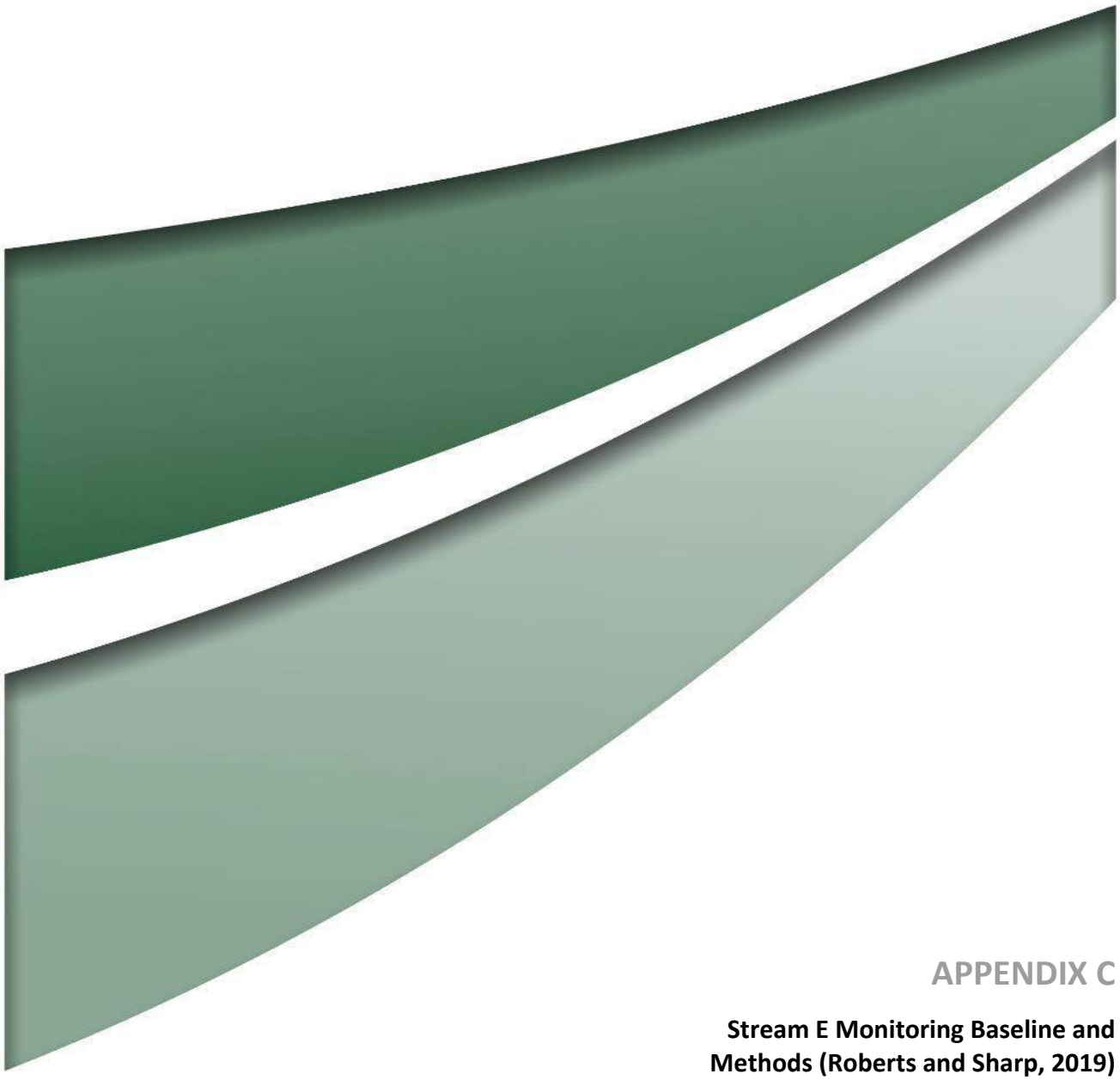


Figure B1 Plot and transect monitoring location layout



APPENDIX C

Stream E Monitoring Baseline and Methods (Roberts and Sharp, 2019)

Pool and Bench Vegetation of Stream E, Ginninderry:

Baseline in Spring 2018

Jane Roberts and Sarah Sharp

June 2019

For further Information on Stream E, contact:

Steve Harding

Project Director

Riverview Developments

For further information on Ginninderry:

check the website: https://ginninderry.com/about/

Citation: Please cite this report as:

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Contents

Preamble

Ginninderry is a new residential area and an open space network in the West Belconnen area of the ACT. About half of the 1600 ha will be residences, perched on ridges above the Murrumbidgee River, with the remainder being a mix of open space and a conservation corridor along the Murrumbidgee River and Ginninderra Creek. Development is to proceed progressively from south to north.

The conservation corridor is to be a natural asset for residents in Ginninderry, and its existing natural values are to be protected. Of particular significance are patches of two ecological communities (White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland, and Natural Temperate Grassland of South Eastern Highlands) both recognised as critically endangered under the EPBC Act, and the Pink-tailed Worm-Lizard *Aprasia parapulchella,* listed as vulnerable under EPBC Act. The natural values are diverse, ranging from aesthetic (it is a magnificent landscape with panoramic views out to the Brindabella ranges) to historical and indigenous values, as well as aquatic and riparian values. The series of first and second order streams that run from the ridges to the river provide a distinctive and unusual habitat in this cleared rural landscape, and add to the ecological biodiversity of the corridor. In addition, the streams connect upland areas with the Murrumbidgee River, so are potentially important in ameliorating quality of water reaching the Murrumbidgee River.

The proposed residential development will affect the pattern and quality of run-off. Modelling suggests (Roberts 2015) that Stream E is likely to have more reliable and slightly higher flows in future. This could alter in-stream vegetation of Stream E with consequences for its natural aquatic-riparian ecological values and for its function in treating water quality prior to reaching the Murrumbidgee River; and, as development progresses across the entire area, other streams in other catchments connecting the upland to the Murrumbidgee River will also be affected.

As of late 2018, the early stages of Ginninderry development were under way. The first residential area was under construction in the vicinity of Stockdill Drive; a stormwater retention basin and bypass around a deep gully had been completed. It was timely, therefore, to establish monitoring programs on water quality and ecological condition of Stream E, which is the stream downstream of the early phases of the development.

Baseline Survey

Steve Harding, Riverview Projects - Project Director invited Jane Roberts (e-mail 28th March 2018) to undertake '*detailed baseline survey work*' for Stream E in the Murrumbidgee Corridor adjacent to Ginninderry.

Establishing a baseline is normally the first step in implementing a monitoring program but no vegetation monitoring program had been designed for Stream E. However, some of the requirements for such a monitoring program were broadly known, and these were:

- *"to ensure we have an accurate baseline survey of the existing vegetation in this stream system to enable us to measure the changes over time and help inform any adaptive management practices to be managed by the proposed conservation management trust* "(Steve Harding)

- The work will be done by, or the responsibility of, a proposed conservation management trust, and therefore possibly be done by volunteers; and ideally there should be something that can be plotted as a time series (Jason Cummings, pers. comm.).

These requirements suggest that condition monitoring is what will be most appropriate for tracking changes in Stream E, as opposed to intervention monitoring. Intervention monitoring is more powerful but is impossible to set up for Stream E, due to the lack of 'control' streams (ie streams which are similar to Stream E in all respects except for residential development in the head of the catchment).

The baseline survey was therefore designed as if it were the beginnings of a long-term condition monitoring project.

Purpose of this Report

This report presents the findings of the Baseline Survey from Spring 2018. It is structured as follows:

Section 1: Stream E: describes Stream E, focussing on features and characteristics relevant to designing a baseline survey of vegetation.

Section 2: Approach: describes the approach to doing the Baseline Survey, being mindful of monitoring in the longer-term.

Section 3: Baseline Survey – Method: outlines the Baseline Survey done in spring 2018, presenting the sites, the structure of the Survey and what was recorded.

Section 4: Baseline Survey – Spring 2018: presents the findings.

Section 5: Repeating the Survey: advises on repeating the Baseline Survey, gives some ideas and caveats on interpretation, and sets out author's ideas on likely trajectory for vegetation of Stream E.

A Glossary is provided. The Appendices contain information on Stream E (Appx 1), on Baseline Survey of spring 2018 (Appx 2, 3 and 4), and information and material to help in repeating the Survey and reporting on it (Appx 5, 6, 7, 8, 9 and 10).

1: Stream E

1.1: Vegetation in the Murrumbidgee river corridor

Stream E is in the Murrumbidgee river corridor. This part of the corridor is a steep, degraded and eroded landscape, and largely cleared of its pre-settlement woodland. A characteristic of this corridor is the series of short streams, such as Stream E, flowing from high ground directly into the Murrumbidgee River, each with its own catchment. Catchment E is one of the largest in the Ginninderry project area.

In profile, the river corridor is characterised by: gullied uplands on rounded slopes; stepped slopes, with alternating steep and not-so steep parts, with the steep parts being rocky; colluvial flats, with considerable post-European deposits, adjacent to the Murrumbidgee River. For study purposes, Stream E was divided into seven sections, coded a1 to a7 (Figure 1), each with distinct topographic characteristics (Roberts 2014).

Gullied Uplands

Section a1: upper part of deep erosion gully; flow path is deeply incised, channel is narrow becoming deeper.

Section a2: lower part of deep erosion gully, channel wider and becoming shallower; stream flows over small rocky steps in lowest part of this section.

Section a3: overall has a gentle slope; stream not much incised; a few low rocky steps

Stepped and steep slopes

Section a4: overall slope is steep; with rocky cascades and boulders, waterfalls

Section a5: stream incised into colluvium, but not deeply; channel not always distinct

Colluvial flats

Section a6: stream incised into post-Settlement and pre-Settlement deposits, sometimes as much as 2 m deep; overall has gentle grade, with some steps, due to outcrops and boulders, but these are not high

Section a7: stream only slightly incised, gentle slope overall; some very small steps.

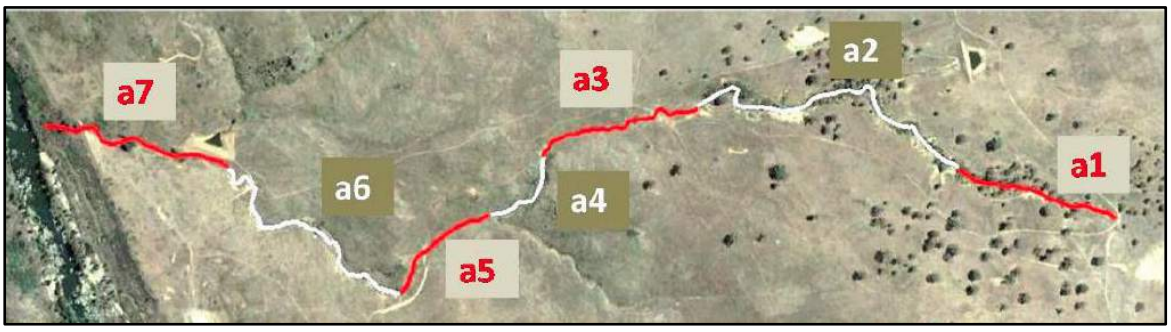

Figure 1: Seven sections (a1 to a7) of Stream E

Developing a vegetation baseline description for Stream E meant starting from scratch. The vegetation of the corridor is known, but at a broad scale that is not suitable for tracking changes in a

small stream such as Stream E. For example, the riparian vegetation immediately adjacent to the Murrumbidgee River was surveyed and assessed by Johnston et al (2011) as part of an ACT-wide study of major rivers. The riparian vegetation typology developed for that study is intended for large upland rivers, such as the Murrumbidgee and Molonglo Rivers, and is not readily applied to in-stream vegetation of small near-permanent streams such as Stream E. Similarly, the vegetation mapping done of the Ginninderry part of the corridor is also too broadscale to be useful for benchmarking Stream E. It recognised thirteen vegetation communities (Riverview Vegetation Assessment map – 2017, downloaded from Publications folder in Ginninderry website 29th March 2018), and was done at a scale that does not recognise small vegetation remnants. Again, the standardised protocol for assessing vegetation in the conservation corridor study (Sharp 2015) deals with terrestrial vegetation, and targets relatively large vegetation patches with relatively homogeneous structure. This protocol is also not suitable for mapping or describing Stream E, where wetland and riparian vegetation patches may be only a few square metres in area.

1.2: Features of Stream E

Stream E is so called because it is the main stream in sub-catchment 'E'. This is one of several sub-catchments in the proposed conservation corridor, all of which, for planning purposes, have been coded alphabetically (A, B, C etc). Catchment E is one of the largest in area. Because of the moderate rainfall and steepness of the terrain, the streams in these sub-catchments were expected to flow only in response to rain, ie intermittently. It has been something of a surprise to discover that Stream E is near-permanent, and is sustained by groundwater inflows. This near-permanency was established by checking historic aerial imagery, back to 2004, and is evident in early maps that use the word 'springs' for Stream E and nearby creeks.

Stream E is narrow, barely a few metres wide, yet has pools, runs and riparian benches. This makes Stream E rather special for this part of the river corridor. Scrutinising aerial and satellite imagery shows that Stream E has more pools along its length than other streams in this part of the corridor.

Pools

The ecological appraisal of Stream E in August 2014 noted that pools were unexpectedly numerous, and that, although small, some were as much as 0.75 or possibly 1 m deep, and that most pools supported some aquatic vegetation (Roberts 2014). The pools are remarkably persistent, except in extreme drought: they had water in the early stages of the Millennium Drought (in 2004 imagery) but did dry out towards the end (evident in 2009 imagery). The exact number of pools along Stream E is not known, but is at least 30. A census using high resolution colour aerial imagery for 2014 (ACT Government's ACTmapi) recorded 32 pools but without ground-truthing (Appendix 1). The numbers assigned in this census are used for the baseline survey.

The relatively high density of pools (>30 pools in 1.5 km) and their persistence help to make Stream E rather special for this part of the corridor.

Pools along Stream E are surprisingly diverse in size and form, possibly due to having been formed by slightly differing fluvial processes. These pools can be categorised into four main types (Table 1): Downstream Control (DSC), Boulder Step (BS), no obvious downstream control (UNC) and Rock pools (RP). Differences in pool hydrology (water depth, water persistence), substrate (bedrock, silt or sand), shape (linear, rounded, internal slope) and degree of canopy overhang (shading) influence presence and abundance of aquatic plants.

This diversity in pools, and their relative abundance along Stream E, and the tight relationship between hydrology and water or wetland plants makes in-stream vegetation useful as an ecological indicator of potential changes to flow regime and water quality.

Table 1: Pool types in Stream E

Type of pool	Characteristics of pool
DSC: Downstream Control Pool is upstream of a bed-rock control	Pool Shape: Sinuous to linear. Pool Depth: Shallow water. Pool Substrate: Pool is much in-filled by loose fine sediment. Pool Definition: Upstream end defined by transition from pool to flowing water. Downstream end defined by transition from pool to steeper rocky section, flowing water.
BS: Boulder Step Pool is downstream of a large or prominent bedrock control (a boulder step). Typically it has a Type [a] pool above the boulder step.	Pool Shape: Somewhat rounded, with steep sides, often rocky or boulders Pool Depth: Deep (to 1 m) water: deepest close to boulder step, and shallower on downstream side. Pool Substrate: Pool is only slightly in-filled: typically sandy gritty substrate over black anoxic ooze. Pool Definition: Upstream end is defined by the boulder step. Downstream end is defined by the transition from pool to an out-flowing channel, which is sometimes well-defined rather than a diffuse outflow.
UNC: No bedrock control evident	Pool Shape: Sinuous or crescent-shaped, to linear Pool Depth: Medium; generally deepest towards the middle. Pool Substrate: Benthos covered in sediment, generally fine and easily re-suspended, of varying depth. Pool Definition: Upstream and downstream ends are defined by: change in shape (widening, narrowing) and change in flow (decrease, increase respectively)
RP: **Rock Pools**	Pool Shape: Variable, determined by rock shapes and cleavages. Pool Depth: Shallow. Flow may even be sub-surface and under rocks in some parts Pool Substrate: Rock. Apparently very little deposition. Pool Definition: Upstream and downstream ends are defined by: change in shape (widening, narrowing) and change in flow (decrease, increase respectively)

Runs

Runs are channels that connect pools (excluding rocky cascades or waterfalls). Runs on Stream E are narrow, flow much faster than pools, and are shallow (Figure 2), even when deeply incised. Runs are mostly open and unshaded (due to clearing of adjacent woodland). A few are so infilled or covered by blackberries as to be inconspicuous. Recent tree planting beside parts of Stream E will, in the long run, change its character from open to shaded. Diversity of runs is due to variations in slope, whether incised, substrate and presence of boulders or rocks (Figure 2).

Figure 2: Diversity of runs

Left: a steep area in section a5. Right: incised into post-Settlement colluvium in section a6.

Benches

A bench is a depositional geomorphic feature, found on either side of the stream channel (Figure 3): its surface is well above the bed of the adjacent runs. Along Stream E, benches are typically green, and often a vigorous green (in marked contrast to the adjacent hillside), indicating a higher soil moisture than on the hill-slope, due either to capillary rise from adjacent stream, or to periodic inundation under high flow (or both). Most of the benches beside Stream E are small, being short, only 5-10 m long, and generally flattish.

Bench vegetation is more terrestrial than aquatic in character, but is distinctive from both the aquatic plants in the stream and the terrestrial vegetation on the hillside. It is likely to change in response to changes in land management and in flow regime.

Figure 3: Green benches, May 2014

1.3: Vegetation of Stream E

There are two types of aquatic plants found in Stream E: emergent macrophytes and submerged macrophytes. These are described (below) based on three visits in autumn-winter-spring (August 2014; May 2018; October 2018).

Tall emergent macrophytes

Emergent macrophytes are non-woody graminoid plant species with eco-physiological adaptations that allow them to grow in saturated soil or in water. "Tall" emergent macrophytes can grow in water as much as 1.5 m deep, and generally are more than 1.25 m tall (from soil surface) when fully grown in mid-summer.

Stream E has three species of tall emergent macrophytes, all native: Narrow-leafed cumbungi *Typha domingensis*, Common Reed *Phragmites australis*, and River Club-sedge *Schoenoplectus tabernaemontani*. All three are native perennial species, and are rhizomatous: all three are summer-growers, their canopy dying back through autumn, and a new canopy forming in spring. They differ in appearance and in character: *Typha domingensis* has long strap-like leaves growing from rhizome apex which is below-ground, and has no obvious stem, *Phragmites australis* has flag leaves on a cane-like vertical stem, and *Schoenoplectus tabernaemontani* has a hollow photosynthetic stem like a tube ('culm') with no leaves. *Typha domingensis* and *Phragmites australis* are both fast-growing, vigorous and invasive, with young growth is palatable to stock whereas *Schoenoplectus tabernaemontani* is much slower-growing. It can be crowded out by either of the other two species, especially if nutrient enrichment happens.

Figure 4: Tall emergent macrophytes of Stream E, spring 2018
Left: River Club-sedge *Schoenoplectus tabernaemontani*. Right: Narrow-leafed Cumbungi *Typha domingensis*

Submerged macrophytes

Submerged macrophytes are non-woody wetland species that have eco-physiological adaptations that allow them to grow underwater. Submerged macrophytes can grow vigorously and densely but are generally flimsy and easily damaged or uprooted, for example by trampling. They are easily damaged by high flows, and their growth is affected by water quality. For example, turbid water, because it reduces light, restricts growth and if turbid conditions persist then plant growth will be adversely affected; nutrient enrichment may initially encourage growth but as this may also encourage growth of epiphytic or filamentous algae which can prevent light reaching leaves, then the effect may also be adverse.

In spring 2018, Stream E had 3 species of submerged macrophytes, all native: *Potamogeton crispus, Chara sp.* and *Nitella* sp., these two Charophytes being provisionally identified as *Chara australis* and *Nitella pseudoflabellata* following information in Casanova (2003). Charophytes are actually algae but are routinely included as aquatic plants in wetland plant guides. Identification of Charophytes to species level requires special expertise and knowledge of the family, aided by access to a high powered quality microscope. There are only a few such experts in Australia.

In Stream E, the leaves of submerged macrophytes typically have a covering of fine sediment that has settled there (Figure 5). This fine sediment is easily washed off and the tissue underneath may be green or viable or yellowing and senescent.

Figure 5: Submerged macrophytes in Stream E, spring 2018, with coating of fines.
Left: Curly Pondweed *Potamogeton crispus*. Right: *Nitella pseudoflabellata*.

2: Approach

2.1: Ecological Condition

Ecological condition describes the state of an ecosystem at a particular point in time. By repeating this, the ecological state of an ecosystem can be tracked through time, ie condition monitoring.

Condition monitoring is a special type of monitoring, with the following characteristics. Monitoring and reporting are done using a set of indicators, carefully chosen to collectively describe ecosystem condition; sampling is extensive rather than detailed; interpretation and reporting are usually descriptive rather than diagnostic; it has a long-term perspective.

Condition monitoring can be referential, meaning the observed condition is compared with a reference condition, which may be historical or pristine. Neither of these is known for Stream E. Instead of a reference, observations will in future be compared with the Baseline Survey of 2018.

The Baseline Survey uses simple vegetation attributes (Section 3.3). When Stream E is re-surveyed, these simple vegetation attributes will become a monitoring program. The attributes have been chosen because of their sensitivity to changes likely to result from residential development at Ginninderry, further upstream. Because it grows in water, aquatic vegetation is affected by changes in flow regime and water quality.

2.2: Considerations

Methods: Of necessity, the baseline survey of Spring 2018 had to be field-based. This was because, although desirable to use remote sensing or aerial imagery, it was not feasible so was not an option. Neither the freely available satellite imagery such as Google Earth nor the low-level high-resolution colour aerial imagery such as ACTmapi have an image resolution fine enough to clearly and unambiguously detect small vegetation patches, such as those occurring along Stream E.

There are four basic methods for field surveys: quadrats, transects, mapping, and photographs. The baseline survey used quadrats, mapping and photographs, but not transects which proved time-inefficient during a trial. Mapping units are described below.

Monitoring Sites: Ideally, sites should be distributed to cover the full range of environmental conditions along Stream E (at least along sections a3 to a7) so preferably there should be at least one and preferably two sites per ecological section (Figure 1). Ideally, also, each site should have both geomorphic features: pools (for aquatic vegetation) and benches (for riparian vegetation).

2.3: Vegetation Mapping Units

Ideally, vegetation mapping units used for Stream E should be consistent with those used elsewhere in the ACT, but this was not possible as there is no system for mapping wetland vegetation that can be used for such small features (Section 1.2): and hence, one had to be developed.

The mapping units used here for in-stream vegetation are based on growth form and height of dominant species. This results in the following five vegetation mapping units (Table 2): emergent macrophytes (coded EmM), submerged macrophytes (coded SubM), rushland (RU), sedgeland (SG), and herbland (HB). If needed, these can be combined: an example from spring 2018 being RUHB for a mix of rushland and herbland. The plant density is given also (coded as ‘o’ for open, ‘d’ for dense), subjectively judged with open meaning bare patches or discontinuous vegetation.

Mapping units include also instream features (water, rocks, for example) and terrestrial vegetation (coded Terr Veg) to help show pool boundaries, but with no detail.

Table 2: Mapping Units for pool vegetation in Stream E

Map Code	Mapping Unit	Description	Notes
In the Pool			
EmM	Emergent macrophyte	Stands of one species (rarely two) of tall wetland graminoids: *Phragmites australis* *Schoenoplectus validus* *Typha domingensis*	Typical or Dominant species varies between pools If patch is dense or open to sparse, then 'd' or 'o' is added to the code as a subscript.
SubM	Submerged macrophytes	Monospecific patches of *Chara australis* *Nitella sp.* *Potamogeton crispus*	Species vary between pools Coloured yellow in maps
	Water surface	No vegetation evident	Coloured blue in maps. Algal scums are not mapped.
On Wet / Moist Muds including shallow (few cm) water			
RU	Low Rushland	Dominated by: *Juncus articulatus*	If patch is dense or open to sparse, then 'd' or 'o' is added to the code as a subscript. If this forms a mosaic with bare mud, then it is shown as '+bm'
HB	Low Herbland	Dominated by: *Nasturtium officinale*	If patch is dense or open to sparse, then 'd' or 'o' is added to the code as a subscript. If this forms a mosaic with bare mud, then it is shown as '+bm'
RU HB	Mixed Rushland herbland	Dominated by: *Juncus articulatus and* *Nasturtium officinale*	If patch is dense or open to sparse, then 'd' or 'o' is added to the code as a subscript. If this forms a mosaic with bare mud, then it is shown as '+bm'
SSG (also SG)	Short Sedge & Grassland	Dominated by graminoids such as: *Cyperus eragrostis* *Carex gaudichaudiana*	
bm	bare mud	Entirely or almost entirely bare of live vegetation	
On the Rocks			
wrf	wet rock face	Refers to wetted area at 'normal' flow. Is one or more of : Wet and bare of vegetation Forbs mainly Grasses mainly Mosses mainly	
R	bare rock	Refers to dry area at 'normal' flow.	Coloured pale grey in maps
In the Riparian Zone			
Terr Veg	Terrestrial Vegetation	Usually mostly grasses, introduced, such as *Phalaris aquatica*	
By	Blackberry		
Other			
MP	Marker Peg	MP u = upstream marker peg MP = downstream marker peg	Marker pegs define upper and lower limit of a pool

3: Baseline Survey - Methods

3.1: Sites

The baseline survey was done at eleven sites in sections a3 to a7. It is about 1.3 km from the most upstream site, positioned downstream of the stormwater input (and future treatment pond) in section a3 to the most downstream site, which is where the trail beside the Murrumbidgee River crosses Stream E (Figure 6). Sites are named by the number of the pool (for example e01, e04) in the pool census, except for two sites on steep sections in amongst boulders which are labelled 'rc' for rocky cascades. Site rc1 has no pool, and is only a bench, so there are ten sites with pools.

All results are presented in downstream order, from e01 to e32.

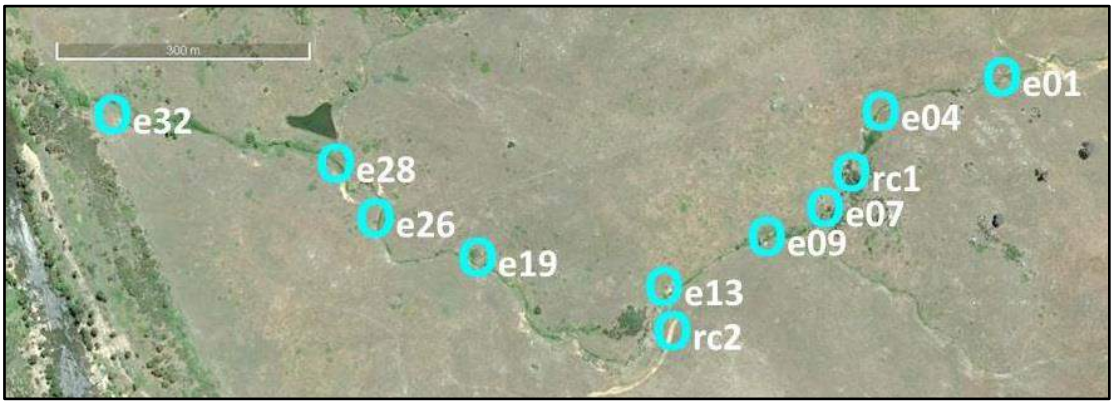

Figure 6: Location of eleven baseline survey sites on Stream E

General characteristics of each site are given below (Table 3), with pool type taken from Table 1. Site co-ordinates refer to middle of the pool, as given in the pool census (Appendix 1). These are used for locating sites in the field. Site co-ordinates do not refer to bench quadrats or pool marker pegs: these have their own co-ordinates, and are given separately.

Table 3: Site characteristics

Site	Ecological Section	General Points	Pool type
E01	Section a3	Open. Site is downstream of fence and stormwater input	Downstream Control
E04	Section a3	Open. Nearby and upstream are recent tree plantings on steeper northern side. This has been a stock crossing place.	Downstream Control
RC1	Section a4	In rocky gully. Vegetation here is slightly protected from stock and feral herbivores by awkward access. Vigorous shrubs on gully walls.	(no pool).
E07	Section a4	Gully is transitioning to open area.	Boulder Step
E09	Section a5	Open area. Boulder between Pools e08 and e09 has been a stock and vehicle crossing place.	Boulder Step
E13	Section a5	Open area. Boulder at head of pool e13 is used as a stock and	Boulder Step

Site	Ecological Section	General Points	Pool type
		vehicle crossing place	
Rc2	Section a5	In rocky gully. Small trickling waterfall just upstream of site.	Rock pool
E19	Section a6	Stream incised. Adjacent hillsides are steep, especially on right bank (northern side). Blackberry is growing over and onto in-stream emergent macrophytes.	No obvious control
E26	Section a6	Open area	Boulder Step
E28	Section a7	Stream incised. Adjacent banks are steep.	No obvious control
E32	Section a7	Shaded by high steep shrubby bank to north. Left bank is gentler. Trail crosses Stream E immediately downstream.	No obvious control

Pools: A plastic yellow peg with yellow flagging tape was used to mark the upper and lower limit of each pool. These upper and lower limits define the area being considered when estimating area of tall emergent macrophytes, so re-locating them accurately is important. As a general guide, the upper limit is, as best can be determined, the point of transition from flowing to relatively still water, and is also marked by increase in width of surface water from run to pool; for the lower limit, it is the converse. Marker pegs were nearly always placed on the left bank (southern side) of Stream E, as this is the easy side to access.

Marker peg co-ordinates were recorded using a hand-held Garmin GPS, in decimal degrees. Accuracy of these hand-held GPS is generally to 5 m but may sometimes be 3 m. Although good, such co-ordinates are not precise enough for defining the extent of the pools on Stream E, which are relatively small features, and it is unwise to rely solely on the co-ordinates when re-locating the marker peg positions. Instead, position of marker pegs should be informed by visual prompts from the photo-record and vegetation mapping.

Site rc2, which is a pool but is not on the pool census (Appendix 1), has only one set of co-ordinates (upper limit) through inadvertent omission.

Benches: Sites generally have a small bench associated with each pool. This bench is usually adjacent to the pool, but a few are slightly distant, and further downstream. The distance between pool and bench is greatest at sites rc2 and e28. There was no bench at e28, and a water-logged area downstream of pool e28 was used instead. The stream just below this had become blocked through time, causing flow to spread out, and the stream to lose definition.

Bench co-ordinates refer to the quadrat on the bench, rather than the bench itself. The quadrat is rectangular, 5 x 1 m, and is set out on the bench (squeezed in, in some cases) with long side parallel to the stream. Bench co-ordinates are for the upstream and downstream short side, respectively (Figure 7). As with the marker pegs, co-ordinates were recorded using a hand-held Garmin GPS.

There is only one set of co-ordinates (upstream) for e04, as the downstream co-ordinates were inadvertently omitted.

Figure 7: Quadrat set up on bench for Site e19, with downstream marker peg for pool.

3.2: Timing

The baseline survey was done in spring 2018. Field work began on 11th October and was completed on 5th November 2018, taking 1-2 days in total. The preceding winter had been dry. The in-stream and bench vegetation was in transition from winter dormancy to summer growth: many plants were in the early stages of spring growth, and not yet at full height.

3.3: Information Recorded

The baseline survey used two general descriptions and three-four indicators for each pool and bench (Table 4). General descriptions are qualitative information (not measured), whereas the Indicators are quantitative (measured) and the data can be plotted to show changes.

Table 4. Structure of Baseline Survey

	Pools	Benches
General Descriptions	Photographs Vegetation map	Bench vegetation Bench dominant species
Indicators	Tall emergent macrophytes Submerged macrophytes Sediment Depth	Bare ground Annuals Nativeness Grasses

An outline of general descriptions and each indicator is given below. For the bench, the General Description is for the whole bench, whereas the indicators are for the quadrat.

General descriptions and indicators were chosen to give a balance between non-specialist and specialist information (see also Section 5.1: Implementation). This is most evident with Benches

(Table 4). The method requires that dominant plants are identified to species level. This will not be demanding on plant identification skills as it is only the most abundant that need to be identified, up to a maximum of five species; and as these are abundant, there is a high likelihood of finding plant material suitable for identification.

On the other hand, Nativeness does require identification to species level. Nativeness means the percentage of vegetation that is native (ie is not introduced) and can be applied to species, or their abundance: it is widely used in condition assessments, an example being RARC (Rapid Appraisal of Riparian Condition: Jansen et al 2007). Species to be identified along Stream E, especially on benches, will include some that are small, immature and not necessarily carrying the reproductive structures needed for identification. For this reason, the Nativeness indicator is restricted to species that are not grasses (ie not in family Poaceae). This is because identification to species-level for all grasses present can be challenging and time-consuming, especially when specimens are present only in trace amounts. If not identified competently, this could lead to high (and not necessarily accurate) variability in what grass species are recorded: identification errors would thus lead to false indications of species richness. Nativeness is restricted to non-grass species in order to minimise this type of error, and to reduce the task. Instead of identifying all grasses, the Grasses indicator for benches (Table 4) is arrived at by calculation from other data.

Pools: General Description

Photographs: The plan was to take two reference photographs per pool: one with the observer looking upstream and one looking downstream. However one photograph proved unusable (e01 looking upstream) and one was impossible to take in a way that would be useful in future (rc1 looking downstream), hence there are only 20 reference photographs for Spring 2018, instead of 22.

Vegetation Map: A map, as realistic as possible, was drawn by hand showing the vegetation mapping units in each pool, along with notes on species present and their abundance.

Pools: Indicators

Tall emergent macrophytes: The area (m^2) of each species was estimated for each pool, considering only the area between the marker pegs.

Submerged macrophytes: The area (m^2) of each species was estimated for each pool, considering only the area between the marker pegs.

Sediment Depth: Measurements were made by wading into the pool, using a metal metre rule to record depth (cm) of water and of unconsolidated (loose) sediment above base of pool. Measurements were made in the deepest part of the pool, as determined by probing.

Benches: General Description

Bench vegetation: The type of vegetation on the bench, its general height, and height evenness or variability was noted.

Bench dominant species: The species that were dominant on the bench were noted, up to five. The presence of pest plants was noted.

Benches: Indicators

A rectangular 5 x 1 m quadrat was set out on the bench, and the following estimated:

Bare ground: Amount of bare unvegetated ground (as % of quadrat)

Annuals: Amount (ie cover) of short-lived species (as % of quadrat)

Nativeness: The name and cover of each species in the quadrat (other than grasses but including shrubs) was recorded. For each site, Nativeness was then calculated for species, and for cover, and averages calculated across all eleven sites.

Grasses: Amount (ie cover) that is grasses (as % quadrat) was not estimated in the field but calculated later using information under Nativeness.

4: Baseline Survey - Spring 2018

4.1: General points

Baseline survey was done on 11th October and 5th November 2018, following a trial run on 8th and 9th October. The field protocol used on the trial run proved to be too intensive so was revised substantially. However, the two days spent in the field on the trial run were enormously valuable for becoming familiar with the site, and confident with identification of plant species.

All species recorded in or near bench quadrats, and in or as part of records for pools are listed in Appendix 2. Nomenclature follows Census of the Flora of the Australian Capital Territory (Lepschi et al 2017), and the common names used her follow the Census. The baseline survey uses the recently updated names, even though their synonyms are currently more familiar to most practitioners, and are the names most likely to be found in field guides. The three wetland species where this applies are Watercress *Nasturtium officinale*, River Clubrush *Schoenoplectus tabernaemontani*, and Scarlet Pimpernel *Lysimachia arvensis* which have been widely known as *Rorippa nasturtium-aquaticum*, *Schoenoplectus validus* and *Anagallis arvensis* respectively.

Note that the ACT Census is for vascular plants and does not (at this stage) include charophytes (also known as Stoneworts). Names for charophytes are taken from descriptions in Casanova (2003).

Declared Pest Plants: Six species of declared pest plants under ACT legislation were noted while surveying the benches. The six species comprised two thistles (Saffron Thistle *Carthamus lanatus* and Spear Thistle *Cirsium vulgare),* one forb (St John's Wort *Hypericum perforatum*), two shrubs (Sweet Briar *Rosa rubiginosa* and Blackberry *Rubus fruticosus*) and a tree (willow *Salix* sp.) which was on the edge of rc2. None of these was particularly abundant or common on the benches in the Baseline Survey (see Section 4.3 below: compilation table). All are typical of grazed pasture.

Some of these were abundant in other parts of Stream E, and some were abundant on slopes leading down to Stream E. Large clumps of blackberry occasionally straddle Stream E, notably in the lower colluvial reaches, and blackberry grows into Common Reed growing in runs and pools.

No declared pest plants were noted in the pools, or on mudflats.

4.2: Pools

General Description

Photo-Record: The reference photos for the 11 sites in Spring 2018 (Appendix 3) show pool vegetation in transition from winter to mid-summer vigorous growth. It was noticeable that the tall emergent macrophytes were not yet at full height, were not yet flowering, and were not yet at mid-summer density (ie shoots were still emerging). It was also noticeable just how diverse and species-rich were some parts of the stream and pools, notably the vegetation on mudflats. Here the richness and diversity was due to a mix of two groups of species: early and cool season grasses, sedges and forbs some of which were flowering, along with warm season species that were just beginning to grow. This richness and diversity was less evident in mid-late summer, as by then the summer-growing species had replaced the early species and over-grown the small ones.

Vegetation Maps: Maps of pool vegetation for ten sites (not rc1 because it did not have a pool) are in Appendix 4. Note that these are indicative maps, reliable for the vegetation types present and their general spatial arrangement in the pool, but not accurate for area of patch sizes.

Each map has a summary table underneath, outlining the species composition per mapping unit. These descriptions are expected to be useful in future to determine if vegetation is changing significantly. The mapping units include terrestrial vegetation but the species composition is not addressed.

Indicators

Sediment Depth: At the deepest spots, total depth (from firm base to water surface) ranged from about 30 cm to 100 cm (Table 5), and depth of fine loose sediment at these deepest spots ranged from zero to 25 cm. The deepest spots either had little to no fine sediment present and a firm if gritty base (or rock or boulders), or else had several cm of fine sediment over a relatively firm base. The pools with firm or rocky base in their deepest parts are in the steeper parts of the landscape (sections a4 and a5) and are either relatively deep boulder step pools (e07, e09 and e13) or a flowing rock pool in a cleft (rc2); whereas pools with deeper sediment, that is those that are infilling or have infilled, are in flatter sections of the Stream E profile.

It is likely that pools in the steeper middle section, with faster flow, will respond differently to disturbances and increased flows than pools in flatter sections.

Table 5: Pool Indicator –Sediment Depth

	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32	mean
Section	A3	A3	A4	A4	A5	A5	A5	A6	A6	A7	A7	
Pool Type	DSC	DSC	n.a.	BS	BS	BS	RP	UNC	BS	UNC	UNC	
Total (cm)	32	30	n.a.	94	89	100	42	40	50	50	58	n.a.
Water (cm)	22	8	n.a.	94	88.5	97	42	30	40	20	33	n.a.
Sediment (cm)	10	22	n.a.	0	0.5	3	0	10	10	30	25	n.a.
Sediment as % Total	31	73	n.a.	0	1	3	0	25	20	60	43	25.6

Boulder step pools with no soft sediment in the deepest spot did have some loose sediment elsewhere in the pool. Typically these had deposits of loose silt or unconsolidated sediment on the gentler slope, immediately downstream of the deepest part, as shown in the schematic cross-section (Figure 8). These deposits were typically colonised by dense submerged macrophytes. This combination of steep or vertical walls on the upstream side, scouring the deepest point, deposits on the downstream bed resulted in a subsurface topography (Figure 8) that was characteristic of boulder step pools. This subsurface topography controlled the in-stream growth of plants, resulting in strong zonation patterns, as at e08.

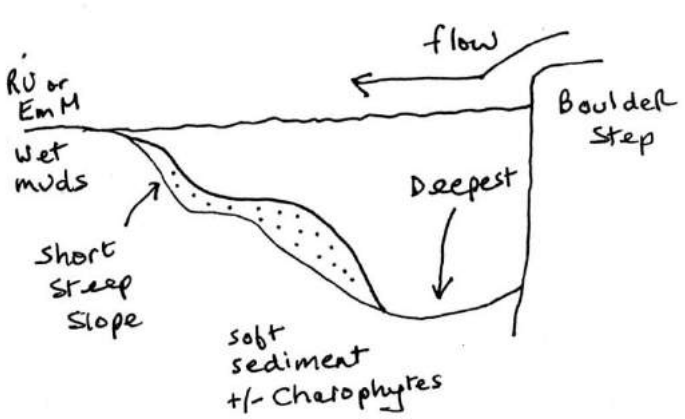

Figure 8: Boulder step pool in cross-section.

Tall Emergent Macrophytes: All pools had at least one species of tall emergent macrophyte, but only one pool (e28) had all three species (Table 6). *Schoenoplectus tabernaemontani* was more common than the other two species, as it occurred in 7 out of 10 pools, whereas *Phragmites australis* and *Typha domingensis* occurred in only 4 pools. Unlike *Phragmites* and *Typha*, *Schoenoplectus* did not form large patches. The occurrence of these three species in pools shows *Phragmites australis* as being in mid and lower sections but *Schoenoplectus tabernaemontani* and *Typha domingensis* occurring throughout.

The total area of tall emergent macrophytes per pool (ie between marker pegs) ranged from being barely present with 0.2 m^2 (e04 and e32) to 21 m^2 (e19) which covered nearly the entire pool area.

Tall emergent macrophytes are shown as mapping unit EmM in the Vegetation Maps in Appendix 4.

Table 6: Pool Indicator - Tall Emergent Macrophytes

Area (m^2)	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32
Phragmites australis	0	0	n.a.	0	3.5	0	0	21	4.5	0.5	0
S. tabernaemontani	0.1	0.2	n.a.	0.8	1.75	0	1.4	0	0.5	0.1	0
Typha domingensis	2	0	n.a.	0	0	5.5	0	0	0	0.2	0.2
Total area of EmM	**2.1**	**0.2**	**n.a.**	**0.8**	**5.25**	**5.5**	**1.4**	**21**	**5**	**0.8**	**0.2**
Number Species	**2**	**1**		**1**	**2**	**1**	**1**	**1**	**2**	**3**	**1**

Submerged Macrophytes: Seven out of ten pools had one or two species of submerged macrophytes, and three pools had none (Table 7). *Chara australis* was the most widespread submerged macrophyte, occurring in six out of 10 pools, whereas *Nitella pseudoflabellata* occurred in just one pool (e19), where it was a small patch in a somewhat shaded position. *Potamogeton crispus* was present in three pools (e26, e28 and e32), the lowest ones. These are all native species.

The area of submerged macrophytes was generally low, with 0.2 to 4.5 m^2 per pool, with the notable exception of e26 where dense beds of Curly Pondweed *Potamogeton crispus* covered 25 m^2, equivalent to most of the pool. The extent of Curly Pondweed is very evident in the reference photographs and vegetation maps in Appendices 3 and 4).

Table 7: Pool Indicator - Submerged Macrophytes

Area (m^2)	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32
Chara australis	0	0	n.a.	4	1.5	4.5	0	0.9	0.7	0	1
N. pseudoflabellata	0	0	n.a.	0	0	0	0	0.12	0	0	0
Potamogeton crispus	0	0	n.a.	0	0	0	0	0	25	0.2	7
Total area of SubM	**0**	**0**	**n.a.**	**4**	**1.5**	**4.5**	**0**	**1.02**	**25.7**	**0.2**	**8**
Number Species	**0**	**0**		**1**	**1**	**1**	**0**	**2**	**2**	**1**	**1**

4.3: Benches

General Description

Bench vegetation: The bench vegetation was a grassland at ten of the 11 sites, and a rushland at the eleventh site, the waterlogged e28. The grassland was low (height range from 5 to 25 cm) except at two sites, both in rocky cascades, where it was noticeably taller, 30-40 cm (a medium grassland). Bench sites were open, unshaded by trees except for rc2 which was shaded by a willow.

Bench Dominants: The dominant species for each bench (ie the most abundant species, up to five) were nearly all grasses (with two exceptions) and were nearly all introduced (with just one exception) (Table 8). The two species that were not grasses (not in Poaceae) were Jointed Rush *Juncus articulatus* and clover *Trifolium* sp., and the only dominant that was native was Red Leg Grass *Bothriochloa macra*. All the dominant species are common in disturbed rural settings.

The species that were most frequently noted as a site dominant were Kikuyu *Cenchrus clandestinus*, Soft Brome *Bromus hordeaceus* and Yorkshire Fog *Holcus lanatus*: each of these was dominant on 6 benches. The vivid green colour of benches (Figure 3) is mostly kikuyu.

Most of the benches were fairly similar to each other, in that they shared one or even two dominant species, except for benches at e28 and e32 which were quite distinctive. At e28, the dominant species was Jointed Rush *Juncus articulatus*, an introduced rush: the presence and abundance of Jointed Rush was not surprising given that this site was not strictly a bench but a water-logged in-filled area. The bench at e32 was the only bench where one of the dominant grasses was native: but it was also the only bench with a recognised pest species African Love Grass *Eragrostis curvula*.

Table 8: Bench – Dominants

	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32	FRQ
Avena sp						X	X					2
Bothriochloa macra											X	1
Briza minor							X		X			2
Bromus diandrus			X									1
Bromus hordeaceus		X	X	X	X	X	X					6
Cenchrus clandestinus	X	X	X		X			X	X			6
Eragrostis curvula											X	1
Holcus lanatus	X	X		X	X	X	X					6
Juncus articulatus										X		1

	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32	FRQ
Lolium perenne		X	X	X	X							4
Lolium rigidum	X					X	X					3
Paspalum dilatatum											X	1
Trifolium spp											X	1
Vulpia spp.			X			X						2
Number (total)	3	4	5	3	4	5	5	1	2	1	4	
Number (native)	0	0	0	0	0	0	0	0	0	0	1	

Indicators

Bare Ground: Eight benches were well vegetated, with 5% or less of the quadrat bare (Table 9) however at the other three sites, 20-40% of quadrat was bare ground. These three sites were all in upper parts of Stream E, in ecological sections a3 and a4. Bare ground means ground that was not vegetated at time of the survey: this excludes rocks, which were hardly present in the quadrats.

Annuals: The cover of annual and short-lived herbs ranged from none to nearly half (0 to 42%) of the quadrat (Table 9). Cover of annuals was higher in upper and middle parts of Stream E (ranging from 15 to 42% in ecological sections a3, a4 and a5) and especially in the rocky cascades: it was generally quite low (<10%) on benches in the lowest sections, a6 and a7 (colluvial flats: Section 1).

The pattern for annuals thus follows the pattern for bare ground. Perennial cover exceeds annual cover at all sites except benches in the rocky cascades.

Table 9: Benches - Cover

Cover %	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32
Perennial herbs	44	40	18.5	80	59.5	55	34	82	94.5	85	84.5
Annual herbs	25	15	40	19.5	33	42	35	8	5	0	10
Shrubs	1	0	0.5	0	0.5	0	1	0	0	0	0
Litter	5	5	1	0	5	0	30	10	0.5	0	0.5
Bare ground	20	40	40	0	0	3	0	0	0	15	5
Rocks	5	0	0	0.5	2	0	0	0	0	0	0
Total	100	100	100	100	100	100	100	100	100	100	100

Nativeness: The compilation of all species (other than grasses) recorded in each quadrat for all sites is shown below (Table 10). The total number of species was 31, of which two were shrubs: Sweet Briar *Rosa rubiginosa* and Blackberry *Rubus fructicosus.* Most of these 31 species were introduced, and included 5 species declared Pest Plants (see Section 4.1). Only 8 (or 26%) were native species (indicated by N in the Origin column of Table 10) and of these, all except two were wetland plants: Sheeps Burr *Acaena ovina* and Native Geranium *Geranium solanderi*.

Individually, none of these 31 species was abundant, except for Jointed Rush (71% cover) at the water-logged site (e28). Typically they had only 0.5-1% cover per quadrat, rarely as much as 4 to 6% (Table 10). Most were recorded infrequently, only 1 or2 times, with two notable exceptions:

Ribwort *Plantago lanceolata* and Sub Clover *Trifolium subterraneum* were common, being recorded in 9 out of 11 quadrats, and 8 out of 11 quadrats, respectively (Table 10).

Table 10: Benches – Compilation

Key: O = Origin (N = native, X = introduced), and L = longevity (A = annual, biennial, P = perennial).

	O	L	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32	FRQ
Acaena ovina	N	P											0.5	**1**
Carthamus lanatus	X	A	0.5											**1**
Cerastium glomeratum	X	A								1				**1**
Cirsium vulgare	X	A		5									0.5	**2**
Crepis capillaris	X	A		0.5	0.5									**2**
Eleocharis acuta	N	P										4		**1**
Galium aparine	X	A			0.5									**1**
Geranium solanderi	N	P			0.5									**1**
Hypericum perforatum	X	P											0.5	**1**
Hypochaeris radicata	X	P						1			1			**2**
Juncus articulatus	X	P	1	0.5								71		**3**
Juncus bufonius	N	A		0.5										**1**
Juncus subsecundus	N	P			0.5						0.5			**2**
Lysimacha anagallis	X	A			0.5			0.5						**2**
Lythrum hyssopifolia	N	A	1											**1**
Plantago lanceolata	X	A	0.5	0.5		0.5	0.5	0.5	0.5	1	1		0.5	**9**
Polygonum aviculare	X	A	1											**1**
Potamogeton crispus	N	P		0.5								6		**1**
Rumex crispus	X	P	1						0.5	0.5		0.5		**4**
Sanguisorba minor	X	P							0.5					**1**
Schoenoplectus tabernaemontani	N	P							5					**1**
Taraxacum officinale	X	P							0.5					**1**
Trifolium arvense	X	A								0.5				**1**
Trifolium dubium	X	A						0.5		2				**2**
Trifolium subterraneum	X	P	1	1		0.5	0.5	0.5	2		6		5	**8**
Trifolium sp.	X												1	**1**
Verbena incompta	X	AP							1					**1**
V. anagallis-aquatica	X	P		0.5								2		**2**
Vicia sativa	X	A				0.5		0.5		6	0.5		0.5	**5**
Shrubs														
Rosa rubiginosa	X	P	1											**1**
Rubus fructicosos	X	P			0.5		0.5		1					**3**
Number (total)	**31**		**8**	**8**	**6**	**3**	**3**	**6**	**7**	**6**	**4**	**5**	**7**	**5.7**
Number (native)	**8**		**1**	**2**	**2**	**0**	**0**	**0**	**1**	**0**	**1**	**3**	**1**	**1**
Cover % (total)			**7**	**9**	**3**	**1.5**	**1.5**	**3**	**10**	**11**	**9**	**84**	**9**	**13.5**
Cover % (native)			**1**	**1**	**1**	**0**	**0**	**0**	**5**	**0**	**0.5**	**10**	**0.5**	**1.8**

The summary rows at the bottom of compilation table (Table 10) show the pattern across all the sites. The number of species (other than grasses) per bench quadrat ranged from 3 to 8, giving an average of 5.7 per quadrat. The number of these that were native ranged from 0 to 3, giving an average of only 1 native species per quadrat. Similarly, the cover of species (other than grasses) ranged from 1.5 to 84% per quadrat, giving an average of 13.5% per quadrat. Of this the cover that was native ranged from 0 to 10%, and averaged only 1.8% per quadrat.

For Nativeness, the compilation in the bottom rows of Table 10 is taken one step further, by considering the number of native species as a percentage of total, and the cover of native species as a percentage of total cover (Table 11). Species nativeness ranged from 0 to 60% in bench quadrats, but averaged only 16.8%. Cover nativeness ranged from 0 to 50% but averaged only 11.9%. Four of the eleven quadrats have only introduced species, and this keeps the average low for both species nativeness and cover nativeness. The four quadrats in question (e07, e09, e13 and e19) are clustered in the middle steeper sections of Stream E (Table 3).

Table 11: Benches – Nativeness

	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32	mean
Number (total)	**8**	**8**	**6**	**3**	**3**	**6**	**7**	**6**	**4**	**5**	**7**	**5.7**
Number (native)	**1**	**2**	**2**	**0**	**0**	**0**	**1**	**0**	**1**	**3**	**1**	**1.0**
Species Nativeness (%)	12.5	25.0	33.3	0	0	0	14.3	0	25.0	60.0	14.3	**16.8**
Cover % (total)	**7**	**9**	**3**	**1.5**	**1.5**	**3**	**10**	**11**	**9**	**84**	**9**	**13.4**
Cover % (native)	**1**	**1**	**1**	**0**	**0**	**0**	**5**	**0**	**0.5**	**10**	**0.5**	**1.7**
Cover Nativeness (%)	14.3	11.1	33.3	0	0	0	50.0	0	5.6	11.9	5.6	**11.9**

Grasses: The very low cover of species other than grasses (1.5 to 11%, not counting the waterlogged site which had 84% cover, Table 11) meant that most of the vegetation cover on benches was grasses. The overall mean for grass cover per quadrat was high, 86.4% (Table 12). Grass cover per quadrat ranged from 89 to 98.5% for bench quadrats categorised as grasslands in General Description, but was much lower at the water-logged site (only 16%) which was categorised as a rushland.

This re-enforces that grasses (annual and perennial combined) are by far the biggest component of ground cover on benches. It quantifies the General Description of grassland for ten of the eleven quadrats and rushland for the other, and thus makes it possible to plot information to show spatial and temporal trends.

Table 12: Benches – Grasses

	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32	mean
Cover (%)	93	91	97	98.5	98.5	96.5	89	89	91	16	91	86.4

4.4: Overview of Spring 2018 survey

Pools: The reference photographs, the vegetation maps and associated tables detailing the mapping units (Appendices 3 and 4) show the vegetation in the pools is quite diverse. This is evident in the range of species, the range of growth forms (grass, sedge, forb) and aquatic plants (submerged, emergent, and mudflat species), and the range of heights (from tiny to tall). These characteristics indicate that Stream E, despite being a small (narrow, and relatively shallow) stream, has vegetation that is structurally diverse. This contributes to its habitat value.

None of the pools is unique in term of species present or vegetation structure; instead the pools overlap in terms of what species are present, but differ in how abundant the species are. This is particularly evident with both sets of indicators, the tall emergent macrophytes (Table 6) and the submerged macrophytes (Table 7).

The maximum depth of pools is quite variable, as shown by the max depths which range from 30 to 100 cm (Table 5), with the deepest pools being one type of pool (boulder step) in the steepest parts of the Stream E profile. Pools are infilled at the deepest point to varying degrees, as shown by the values for Sediment as % of total depth which range from 0 to 73% . The cross-sectional profile (Figure 8) suggests a degree of scour is important in keeping the bottom of boulder step pools from in-filling.

Benches: The benches have a relatively high proportion of cover that is perennials. Although the species contributing to this perennial cover were not recorded directly, it can be inferred from the General Description and Indicators, that these perennial species were mostly introduced rather than native species. These introduced perennials included grass species that are rhizomatous and stoloniferous and form dense mats hugging the ground, such as Kikuyu *Cenchrus clandestina* or that form tussocks with dense fibrous root system such as Paspalum *Paspalum dilatatum*. As a consequence, these perennials provide an invaluable function protecting the soil against erosion. A conservation ideal could be to replace these by native species with equivalent protective functions, but such an ideal is for the long-term.

The majority of species on benches are introduced, and are grasses. There were only a few non-grass species per quadrat, and those that were present were nearly always introduced and low cover. The exception to this was the water-logged site, e28, which was very different from the benches. Despite being so different, this site should continue to be monitored, as it shows the type of vegetation that could develop if benches become more consistently wetter.

Overview: Although introduced species outnumber native species on benches, and are common in pools, it is clear that native species are more common and more abundant in pools. The species driving this are those which are most adapted to growing and reproducing in an aquatic environment, specifically, the tall emergent macrophytes and the submerged macrophytes. These two groups are (at present) all native species in Stream E. In contrast, the patches of vegetation occurring on wet muds and very shallow (few cm) of water are dominated by amphibious and moisture-tolerant terrestrial species that are pre-dominantly not native such as Jointed Rush *Juncus articulatus*, Blue Water Speedwell *Veronica anagallis-arvensis*, Umbrella Sedge *Cyperus eragrostis*, Watercress *Nasturtium officinale* and White Clover*Trifolium repens*.

This pattern of higher nativeness at thewet end of an environmental gradient is well-known, and has been noted in riverine and wetland systems in south-eastern Australia. The reason for this pattern is not fully understood. Where it has been observed and investigated, such as in the Barmah Forest

and billabongs of the River Murray floodplain, anthropogenic changes in flow regime have been implicated (Stokes et al 2010, Catford et al 2014).

There is some evidence that the in-stream vegetation along Stream E is fairly resilient and hence fairly dynamic. Three perennial aquatic and wetland species recorded in the Baseline Survey (the submerged macrophyte Curly Pondweed *Potamogeton crispus* and two tall emergent macrophytes Narrow Leafed Cumbungi *Typha domingensis* and Common Reed *Phragmites australis*) were also present and well-established in winter 2014 (Roberts 2014). The presence and extent of these species, so soon after the Millennium Drought, was rather surprising. It implied that either these species had persisted through the drought or were lost and then re-colonised.

On balance it seems more likely that the plants persisted through the Millennium Drought, via perennating organs such as rhizomes (in the case of *Typha* and *Phragmites*), turions (in the case of *Potamogeton crispus*), or oospores (in the case of Charophytes). In winter2014, healthy rhizomes of *Phragmites* were noticed in bank of Stream E (Figure 14), and their healthy condition and extensive network was interpreted as evidence of *Phragmites* persisting underground. Rhizomes of tall emergent macrophytes such as *Typha* and *Phragmites* are known to survive in the ground for about 6 years (Roberts and Marston 2011). The alternative, that these species re-established from seed or viable vegetative fragments brought in by wind or waterfowl, seems much less likely, as only one of these, *Typha domingensis*, produces seeds that are viable, abundant, and readily dispersed by wind.

What this suggests, overall, is that the composition and abundance of in-stream vegetation in Stream E probably fluctuates on a long-term basis, driven by patterns of rainfall and drought, as well as on a seasonal basis, driven by plant responses to temperature and daylength. These long-term and seasonal fluctuations will make it difficult to determine if any vegetation changes are due to residential development.

The Survey is not designed as a diagnostic tool, but as a feedback to future managers. It will be up to them to decide if interventions are necessary, and if so what those interventions should be, and where.

Figure 14: Stream E on colluvial flats in late winter, 2014.

Phragmites australis* was not evident aboveground (left) but was definitely present belowground (right) in Section 6, in August 2014. In 2018, this area was thick with *Phragmites australis.

However, there is a possibility that, with more reliable and slightly higher flows resulting from residential development plans (Preamble), some of the long-term fluctuations will be lost, leading to a more stable system. This would allow invasive and competitive plant species to take over, and eventually this ecological diversity could be lost. The baseline Survey of Spring 2018 is possibly on this stabilisation trajectory. The description would have been rather different if it had been established in Spring 2014.

5: Repeating the Survey

5.1: Implementation

Survey Methods: A description of the methods is given in Appendix 5 (pools) and Appendix 6 (Benches), along with details on re-locating marker pegs for pools (Appendix 7) and positioning of quadrats on benches (Appendix 8). These descriptions cover what to do in the field, what to record, and how to process the data, and are given in more detail than for the Baseline Survey (Section 3).

Blank copies of Field Sheets are provided (Appendix 7), and blank sample tables used for summarising observations and reporting on General Description and Indicators (Appendix 8).

A full set of 22 reference photographs should be taken at each survey, even though this was not achieved in spring 2018. Photographs will need to be archived safely, and labelled appropriately. Suggested labels are:

Pool_Direction_Year = e01_UP_2018

Survey Timing: Repeat surveys should be done at a similar time of as the Baseline Survey, that is after winter has ended, and after spring growth has been initiated, but before summer.

Standardising on a mid-spring sample time will make it easier to determine if vegetation has changed, and avoid confusion. Species composition changes dramatically from mid-spring to midsummer: in December 2018, the mudflats were dominated by a summer-growing grass (*Paspalum distichum*) which had been barely evident four weeks earlier.

Species Identification: Methods recommend that non-professionals spend 1-2 days (partly in the field) working up their plant identification skills to the level required, before doing the actual work.

Developing these skills will require using field guides, working with local experts, even checking field specimens with the herbarium. The following are useful for aquatic and wetland plants:

- *Field Guide to Plants of the Molonglo Valley* by Russell Barrett, Meredith Cosgrove and Richard Milner (2018), published by ACT Government and available from specialty shops such Botanical Bookshop, Australian National Botanic Gardens.
- *Glovebox guide waterplants of the ACT region.* Available on-line from Molonglo Catchment Group website.
- *Waterplants in Australia. A Field Guide* (4th edition) by Sainty and Jacobs (2004). Notable for its compact form, robust production, large number of species, quality of photographs. It also has chapters on topics not routinely covered in field guides such as Charophytes, willows.
- *Down by the riverside* by R. Falconer (2004). A regional guide centred on Goulburn, this covers aquatic and riparian species, including some of the grasses found along Stream E.
- *Canberra Nature Map*. A web-based photographic database that can be searched by species to learn appearance of species already recorded for Stream E.

Skills and Expertise: The General Descriptions and Indicators require levels of skill and field-botanical expertise ranging from basic to semi-professional, with variable time commitment. For example, locating each field site using GPS, and taking quality reference photographs of pools is considered a basic skill and does not require much time commitment apart from field work; estimating cover and accurately identifying non-grass species in bench quadrats requires good field botanical skills (see Section 3.3) and willingness to follow up on plant identifications; preparation of vegetation maps and tables describing mapping units needs careful field notes, and time

commitment after being in the field, and could be challenging. These are standard semi-professional skills, and many volunteers and non-professionals already have considerable expertise in these.

The intention was that future surveys would likely be done by volunteers, such as a community group (see Preamble). The range of skills and interests in a future community group is not predictable, and this sets a challenge to designing a survey. This challenge is addressed here by having a survey designed with multiple components, each requiring different levels of skills and time commitment (Table 13), and each with its minimal sampling frequency (see below).

Table 13: Survey skills

Geomorphic Feature	Survey		Skills Time
Pool	General Description	Reference Photo	Basic
	General Description	Vegetation Maps	Advanced
	Indicator	Maximum Depths	Basic
	Indicator	Emergent Macrophytes	Intermediate
	Indicator	Submerged Macrophytes	Intermediate
Bench	General Description	Vegetation Type	Basic
	General Description	Dominant Species	Intermediate
	Indicator	Bare Ground	Basic
	Indicator	Annuals	Intermediate
	Indicator	Nativeness	Advanced
	Indicator	Grasses	Advanced

Frequency of Re-survey: Ideally, the survey should be repeated, in total, every year. However, if this is not possible, then schedule the Survey based on skills level:

Basic: every Spring (essential)
Intermediate: every Spring (preferable), at least every second Spring
Advanced: every Spring (desirable) but every second Spring is acceptable.

Commitment to field-methods: Note that this situation could change, with the advent of unmanned aerial vehicles (UAVs). A trial along Stream E was done by Duanne White (Associate Professor in Earth Systems, University of Canberra) on 19th December 2018, with the drone at a low altitude (approx. 50 m).

The resulting imagery was of sufficiently good quality in terms of colour and resolution as to be worth considering for development as a routine monitoring tool for vegetation and geomorphology (Figure 9). The advantages of low elevation imagery such as via a drone are that it easily allows the whole of Stream E to be sampled: the disadvantages include the need for field-truthing. In contrast, the advantages of a field program are that information is at the level of species, and that it is possible to search underwater (important for submerged macrophytes), but however being constrained to specific sites.

Vegetation of pool e09 (boulder step) is shown in this report in various ways, quite consistently:

photographed from above using low elevation high resolution colour imagery (Figure 9);
diagram drawn in cross section (Figure 8)
photographed by observer using smart phone (Appendix 3)

hand drawn map showing vegetation units (Appendix 4).

Figure 9: Overhead view of Pool e09 on 19th December 2018.
Photo taken shortly after intense rainfall, on 18th December 2018. All flow is in channel. Banding of vegetation in pool e09 is clear. Stream E is flowing from left to right across the photo. The dense dark green downstream of pool e09 is Common Reed *Phragmites australis*.

5.2: Reporting and Interpretation

Options for data presentation and interpretation with just one survey (baseline survey of Spring 2018) are limited to spatial patterns, such as longitudinal patterns down Stream E, or associations between General Descriptions or Indicators with landscape or pool types.

In future, it will be possible to combine spatial and temporal trends in one plot, such as the hypothetical result below for Bench Indicator Bare Ground (Figure 10). This shows that, at the upland sites (e01, e04, rc1), the extent of bare ground hardly changed between the baseline survey of Spring 2018 and some future hypothetical year (Spring 20xx); that there was some increase at sites on colluvial flats (e26, e28 and e32); but did increase quite dramatically at sites on steep slopes.

A finding such as this, with a strong spatial signature, should trigger follow-up inspection and evaluation by managers s to need for intervention.

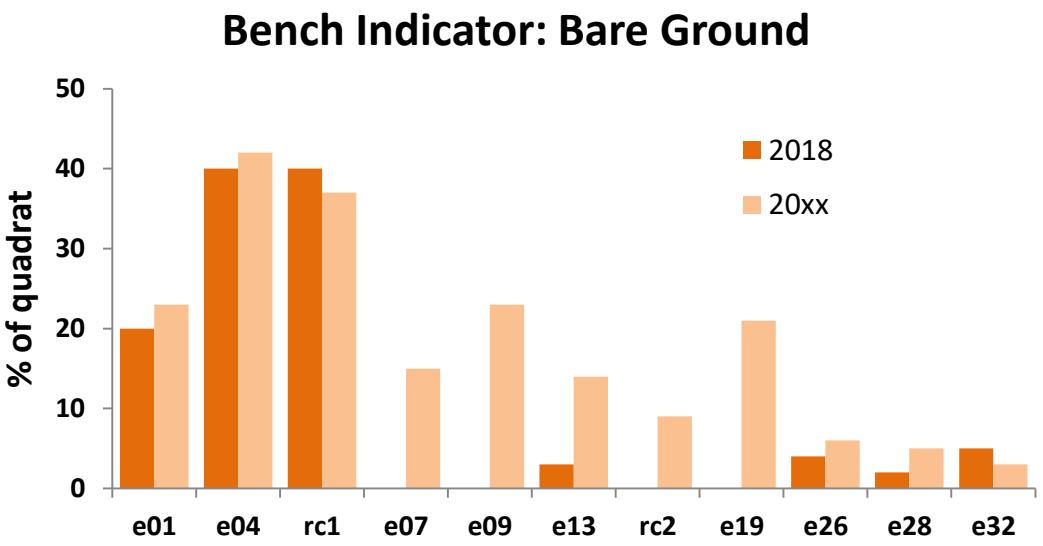

Figure 10: Hypothetical change in Bare Ground

Possible trends for Indicators arising out of de-stocking, increased flows, and altered patterns of sediment movement are summarised below (Table 14). Some proximal causes of change are indicated, to help evaluation.

Table 14: Possible changes in indicators

Geomorphic Feature & Indicator	Possible change
Pool: Indicator - Sediment Depth	Decreases in sediment depth in upstream pools indicate scouring or flushing has occurred but with no subsequent deposition. Increases in sediment in Boulder Step pools show deposition
Pool: Indicator - Emergent Macrophytes	Increases in area of emergent macrophytes in surveyed pools, especially *Typha* and *Phragmites*, can be expected if all domestic and feral stock are excluded. These two species are likely to establish in pools where they are not currently present, as persistent wet to moist conditions will lead to both vegetative expansion (particularly of *Phragmites*) and to distribution of seeds and vegetative fragments (particularly *Typha*). Reduction in *Schoenoplectus*, mostly likely due to competition by *Typha* and/or *Phragmites*. Reduction in area of emergent macrophytes (from one year to next) indicates intervention (management control), accident (fire) or pressure from grazing animals.
Pool: Indicator - Submerged Macrophytes	Reduction or loss of charophytes could be due to high flows, stock or feral trampling, or excessive sedimentation. Reduction or loss of submerged macrophytes could be due to being displaced by invasive tall emergent macrophytes.
Bench: Indicator - Bare Ground	Increase in bare ground could be due to persistent grazing, and/or repeated trampling, from domestic and/or feral animals, or passage of vehicles. Increase in bare ground could be linked to extreme regional weather such as a multi-year drought.

Geomorphic Feature & Indicator	Possible change
Bench: Indicator - Annuals	Increase in annuals parallels the Bare Ground indicator
Bench: Indicator – Perennial cover	Decrease in perennial cover could be linked to grazing or animal pressure, or persistent human disturbance by trampling or vehicle or bike.

5.3: Possible Trajectory

In the absence of any checks on their growth such as regular stock grazing, or long dry summer-autumns (8-months) or multi-year droughts when groundwater dries up, *Typha domingensis* and *Phragmites australis* are likely to expand along much of Stream E.

Figure 11: Flow path immediately downstream of pool e09

Flow (going from left to right) is concentrated into a small channel that leads into dense stand of *Phragmites* that completely occupies the downstream channel. Just at this point, indicated by the two rocks on each side, the flow path drops abruptly by about 20 cm. This drop is (in 2018) a barrier to upstream colonisation by *Phragmites*.

This increase in area is likely through vegetative expansion (rhizome growing underground) as well as through establishing from seed (particularly in the case of *Typha*) or vegetative fragments being washed downstream. They can be expected to colonise the channels except for sections in deep shade (under blackberry thickets, under willow canopies) or where the flow is subsurface as in parts of rocky cascades. They are likely to also colonise shallow pools, especially those already somewhat

in-filled with sediment, and shallow areas (to about 75 cm) in the deeper pools. If flow is persistent, then a narrow permanent flow-path may evolve through or around a patch: examples of this flow channelization are already evident at sites e09 and e19 (Figure 11).

A long-term prognosis is that, if unchecked, these two species are likely to gradually replace *Schoenoplectus tabernaemontani* and eventually reduce it to negligible or zero area. This expansion will reduce the area of submerged macrophytes, probably eliminating Curly Pondweed *Potamogeton crispus*, but small patches of Characeae may persist in the flow path. Because both *Typha* and *Phragmites* have deep rhizomes that can persist subsoil for several years, their expansion is likely to also impact mudflat vegetation, excluding it.

In summary, it is likely that *Typha* and *Phragmite*s will expand, if unchecked, resulting in a loss of plant species diversity and a loss of habitat diversity, relative to baseline of spring 2018. At present, the most effective means of checking is a brief burst of crash grazing in late spring, when leaves of *Typha* and *Phragmites* are still relatively young and palatable. However, as a management strategy, this poses its own risks to do with water quality and bank de-stabilisation, so is a balancing act.

5.4: Provisional Targets

Ecological condition is much more than a description of a system. A one-off assessment of ecological condition gives an understanding of a system; repeated assessment make it possible to track change. In the case of Stream E, the General Descriptions and Indicators from Spring 2018 give a picture of a stream at a particular point in time; repeat surveys will give some insight into whether (and possibly *how*) land management and the upstream residential development at Ginninderry are affecting Stream E.

Note that the surveys are not designed to be diagnostic tools. If repeat surveys show changes, then those changes need to be examined critically to understand why they have happened, and whether they are cause for concern. The ideas given above (Table 14) are only starting points for understanding why. Determining if change is a matter of concern is rather different. Standard practice is to anticipate this by setting targets or triggers for the monitoring sites.

The following are suggested as targets for Indicators for pools in Stream E:

Sediment depth in BS pools does not exceed 5% of total depth

Sediment depth in DSC and UNC pools does not exceed 80% of total depth

Area of emergent macrophytes does not expand to occupy whole pool

Submerged macrophytes continue to be present at seven out of ten pools

The following are suggested as targets for Indicators for benches on Stream E:

Perennial cover on benches does not fall below 70%

Grass cover on benches does not fall below 60%

Shrub cover on benches does not exceed 5%

The targets are provisional because knowledge of long-term fluctuations is not very good. They should be revised and integrated with the outcomes of the water quality monitoring currently undertaken by the University of Canberra.

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Glossary

Adaptive management	Adaptive management is a systematic approach for improving resource management by learning from management actions and assessing outcomes against pre-determined expectations.
Bank of stream: left or right	Stream banks are either left or right bank, as if the observer was looking downstream.
Charophytes	Charophytes are large green algae that look like a wetland plant growing under water. When present, they are usually considered as a wetland plant, and hence are included in some guides to wetland plants such as "*Waterplants in Australia*" (Sainty and Jacobs 2003).
Dominant species	Species that have the highest cover in a given area, and which characterise the area. This can refer to particular layer of vegetation such as dominant species in groundcover, mid storey and/or overstorey.
Emergent macrophytes	Emergent macrophytes are non-woody wetland plants that have physiological adaptations that allow them to grow in saturated soil or water. Terrestrial plants found in water in a pool after rainfall are not emergent macrophytes because they will not grow in these conditions but will eventually die.
Forb	A non-woody plant other than a graminoid.
Graminoid	A term meaning 'grass-like' which is used to refer collectively to grasses, sedges and/or rushes.
Growth form	The form or shape of individual plants (e.g. tree, shrub, grass, forb, sedge, rush).
Herb	A non-woody or slightly woody annual or sometimes perennial plant. This includes grasses and other graminoids.
Indicator	A quantitative value that is a single measure or combination of measures that is used to indicate condition of defined biological attributes and can be used to compare condition between sites or within a site over time. Several indicators can be combined to give a condition score or condition index, which is useful for reporting and describing trends.
Macrophyte	Macrophyte refers to wetland plants that grow in wet habitats such as ponds, lakes and rivers.

Nativeness	A term describing how much of vegetation is native. It can be applied to whatever vegetation attribute is of interest such as abundance, species richness. For the Baseline Survey, nativeness is restricted to species recorded in Bench quadrats, other than grasses.
Shrub	Woody plant that is either: multi-stemmed at ground level or nearly at ground level (up to 20 cm above ground); or single-stemmed but less than 5 m tall.
Submerged macrophytes	Submerged macrophytes are wetland plants that grow under water, and have leaves under water. Reproduction mostly occurs above water except in species such as Charophytes.
Tall emergent macrophytes	Tall emergent macrophytes are emergent macrophytes that can grow in water-logged soils or water as much as 1.5 m deep. Typically these are more than 1.25 m tall (from soil surface) when fully grown in mid-summer.
Tree	Woody plant more than 2 m tall, and usually with a single stem, and branches well-above the base.

Appendix 1: Census of Pools

This is a list of 32 pools that were evident in aerial imagery for 2014, from the ACT government ACT Map I website. The year 2014 proved the easiest to use, with better resolution and less ambiguity than in imagery for 2017 and 2018. The list is not comprehensive as a few very small pools were obscured by tree canopies and blackberry clumps. The list shows pool number, ecological section, and co-ordinates in decimal degrees.

Pool numbering is from e01 to e32, but is not perfectly sequential. It became evident in 2018 field work that there is no e27 or e29, and that both e07 and e08 were actually each two pools (shown as e07 and e07 a, e08 and e08a).

Section	ID	deg S	deg E
a3	e01	35.22745	148.98026
a3	e02	35.22753	148.97955
a3	e03	35.22758	148.97927
a3	e04	35.22779	148.97889
a3	e05	35.22798	148.97873
a4	e06	35.22888	148.97818
a4	e07	35.22898	148.97798
a4	e07a	35.22895	148.97806
a5	e08	35.22908	148.97747
a5	e08a	35.22905	148.97758
a5	e09	35.22913	148.97739
a5	e10	35.22928	148.97687
a5	e11	35.22942	148.97663
a5	e12	35.22952	148.97647
a5	e13	35.22969	148.97615
a5	e14	35.23019	148.97588
a6	e15	35.23040	148.97569
a6	e16	35.23039	148.97570
a6	e17	35.23009	148.97489
a6	e18	35.22979	148.97436
a6	e19	35.22929	148.97362
a6	e20	35.22927	148.97317
a6	e21	35.22928	148.97302
a6	e22	35.22927	148.97260
a6	e23	35.22892	148.97243
a6	e24	35.22863	148.97245
a6	e25	35.22856	148.97211
a6	e26	35.22840	148.97200
a7	e28	35.22796	148.97033
a7	e30	35.22790	148.96926
a7	e31	35.22776	148.96898
a7	e32	35.22761	148.96894

Appendix 2: Species List (Spring 2018)

Species recorded on field sheets or noted in the field.

(*) indicates introduced

Aspleniaceae
Asplenium sp.

Asteraceae
Carthamus lanatus (*)
Cirsium vulgare (*)
Crepis capillaris (*)
Hypochaeris radicata (*)
Taraxacum sp. (*)

Brassicaceae
Nasturtium officinale (*)

Caryophyllaceae
Cerastium glomeratum (*)

Characeae
Chara australis
Nitella pseudoflabellata

Cyperaceae
Carex appressa
Carex gaudichaudiana
Cyperus eragrostis (*)
Eleocharis acuta
Isolepis cernua
Schoenoplectus tabernaemontani
Schoenus apogon

Fabaceae
Acacia rubida
Trifolium arvense (*)
Trifolium dubium (*)
Trifolium repens (*)
Trifolium sp. (*)
Vicia sativa (*)

Geraniaceae
Geranium solanderi

Hypericaceae
Hypericum perforatum (*)

Juncaceae
Juncus articulatus (*)
Juncus bufonius
Juncus subsecundus

Lythraceae
Lythrum hyssopifolia

Plantaginaceae
Plantago lanceolata (*)
Veronica anagallis-aquatica (*)

Poaceae
Avena spp. (*)
Bothriochloa macra
Briza minor (*)
Bromus diandrus (*)
Bromus hordeaceus (*)
Cenchrus clandestinus (*)
Eragrostis curvula (*)
Glyceria declinata (*)
Holcus lanatus (*)
Lolium perenne (*)
Lolium rigidum (*)
Paspalum dilatatum (*)
Paspalum distichum (*)
Phalaris aquatica (*)
Phragmites australis
Vulpia spp. (*)

Polygonaceae
Polygonum aviculare (*)
Rumex crispus (*)

Potamogetonaceae
Potamogeton crispus

Primulaceae
Lysimachia arvensis (*)

Rosaceae
Acaena ovina
Pyracantha sp. (*)
Rosa rubiginosa (*)
Rubus fructicosus (*)
Rubus parvifolius
Sanguisorba minor (*)

Rubiaceae
Galium aparine (*)

Salicaceae
Salix fragilis (*)

Typhaceae
Typha domingensis

Verbenaceae
Verbena incompta **(*)**

Appendix 3: Pools – Reference Photographs (Spring 2018)

Pool e01 Looking upstream: 5th Nov 2018

(not available)

Pool e01 Looking downstream from top of pool: 5th Nov 2018

Pool e04 looking upstream: 5th Nov 2018

Pool e04 looking downstream: 5th Nov 2018

Colour distortion due to lightening the original photograph which was very dark.

RC1 (Rocky Cascades) looking upstream: 5th Nov 2018

Pool e07 looking upstream: 5th Nov 2018

Pool e07 looking downstream: 5th Nov 2018

Pool e09 looking across and upstream: 5th Nov 2018

Pool e09 looking across and downstream: 5th Nov 2018

Pool 13 looking across and upstream: 5th Nov 2018

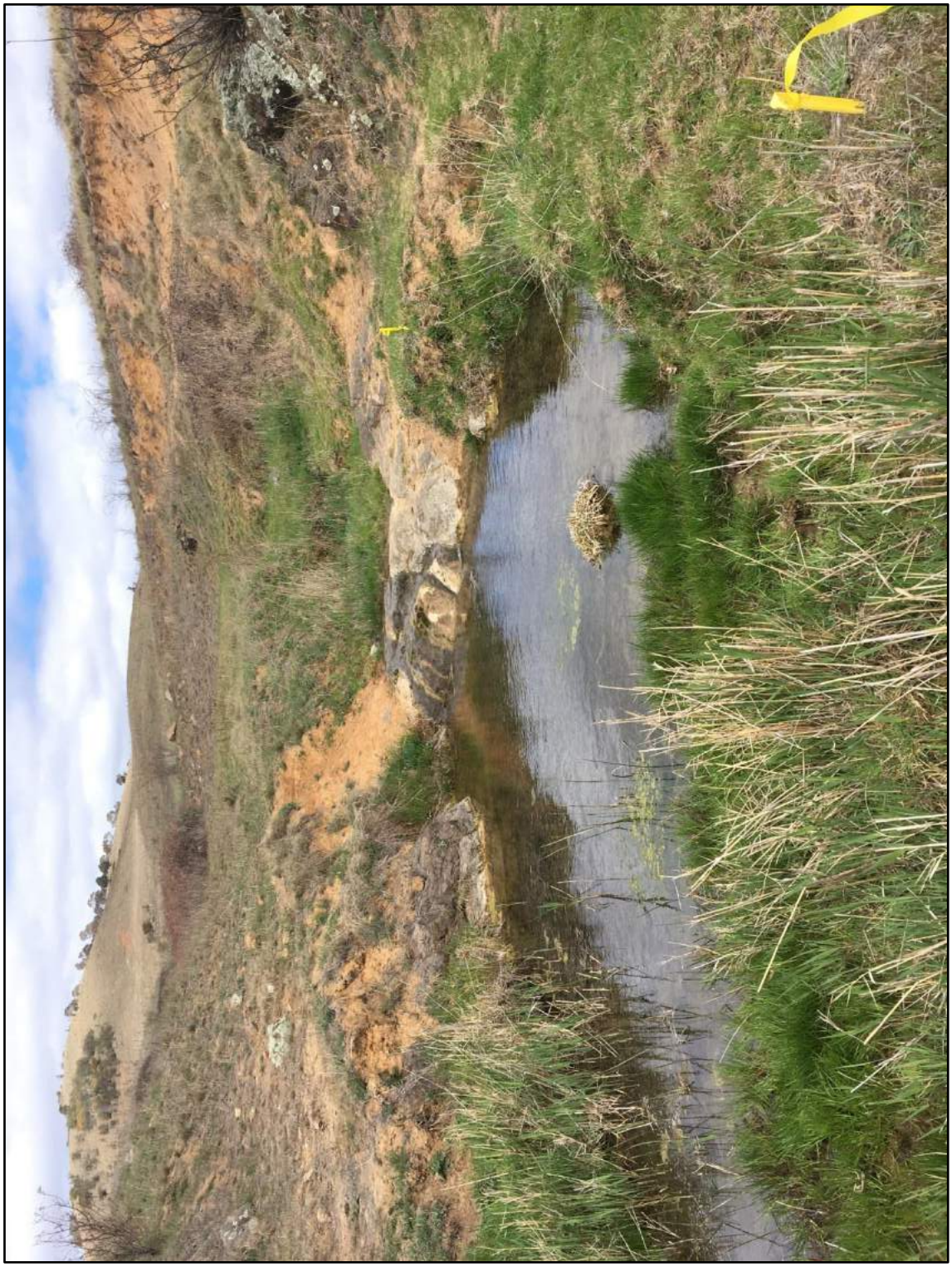
Pool e13 looking downstream: 5th Nov 2018

RC 2 (Rocky Cascades) looking upstream: 5th Nov 2018

RC 2 (Rocky Cascades) looking downstream: 5th Nov 2018

Pool e19 looking upstream at top of pool: 11th Oct 2018

Pool e19 looking downstream: 11th Oct 2018



Pool e26 looking upstream: 11th Oct 2018

Pool e26, looking across and downstream: 11th Oct 2018

Pool e28 looking upstream at upper pool: 11th Oct 2018

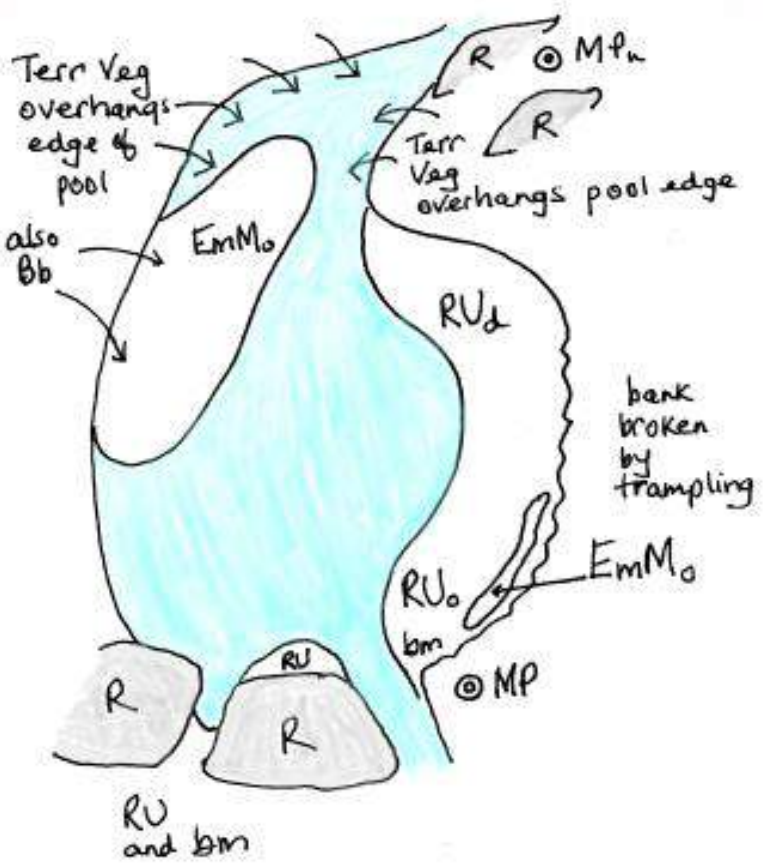
Pool e28 looking downstream to infilled area: 11th Oct 2018

Pool e32 looking upstream: 11th Oct 2018

Pool e32 looking downstream: 11th Oct 2018

Appendix 4: Pools - Vegetation Maps (Spring 2018)

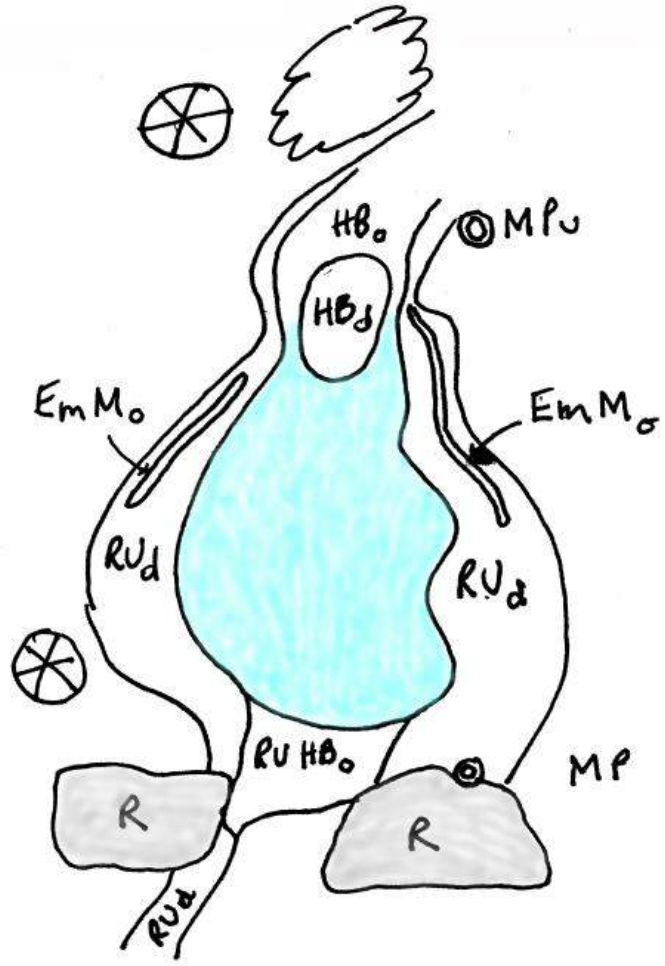
Site e01



Pool e01: Vegetation map looking upstream, 5th Nov 2018

SubM	None present at this time in this pool
EmM	Two species present: an open patch of new season growth of *Typha domingensis* on right (northern) side of pool, and a sparse strip of new season growth of *Schoenoplectus tabernaemontani* in amongst RU on left side (EmM o). Both patches appear to be young, maybe newly established: neither has any evidence of senescent mature culms from previous seasons.
RU	Patch of dense Rushland (Ru d) fringing left side of pool, in area that has been pugged and broken by livestock. Rushland is dominated by *Juncus articulatus*, an introduced perennial rush: other species present are introduced grasses and rush such as perennial (*Holcus lanatus, Paspalum distichum*) and annual grasses (*Lolium rigidum*, *Bromus* sp), and the annual rush *Juncus bufonius*.
bm	Bare muds
TerrV	Terrestrial grasses (eg *Phalaris* spp.) overhanging into pool: on steep northern side, also blackberry

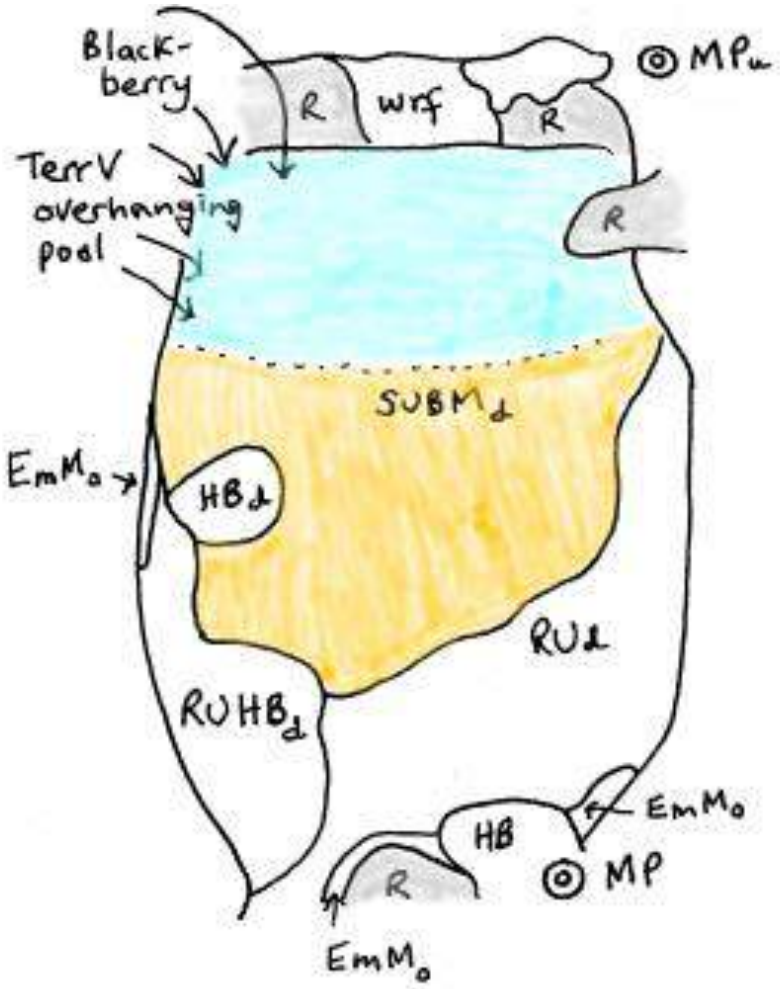
Site e04



Pool e04: Vegetation map looking upstream, 5th Nov 2018

SubM	None present at this time in this pool
EmM	One species present. *Schoenoplectus tabernaemontani* occurs in two bands (EmM o) along margins of upper part of pool (where mud flat transitions to river bank) on both sides. Both patches are new season growth. There is no evidence of mature senescent culms from a previous year.
RU	Dense Rushland of *Juncus articulatus* on wet muds fringes most of the pool: these wet muds have been trampled and pugged by livestock. The Rushland here is quite diverse and species-rich: most of these species are introduced: grasses (such as *Holcus lanatus, Paspalum distichum*), other rushes (*Juncus bufonius*), and forbs (*Rumex crispus, Veronica anagallis-aquatica, Nasturtium officinale, Trifolium repens*) with traces of the native sedge *Eleocharis acuta*, and forb *Lythrum hyssopifola*.
HB	Herbland of *Nasturtium officinale* occurs in two small patches, one dense and one open, towards the upper end of the pool at the inflow area.
RU-HB	Small area dominated by a mix of *Juncus articulatus* and *Nasturtium officinale* at the downstream end.
star	Upstream star is a large introduced shrub *Pyracantha*; downstream star refers to a treeguard.

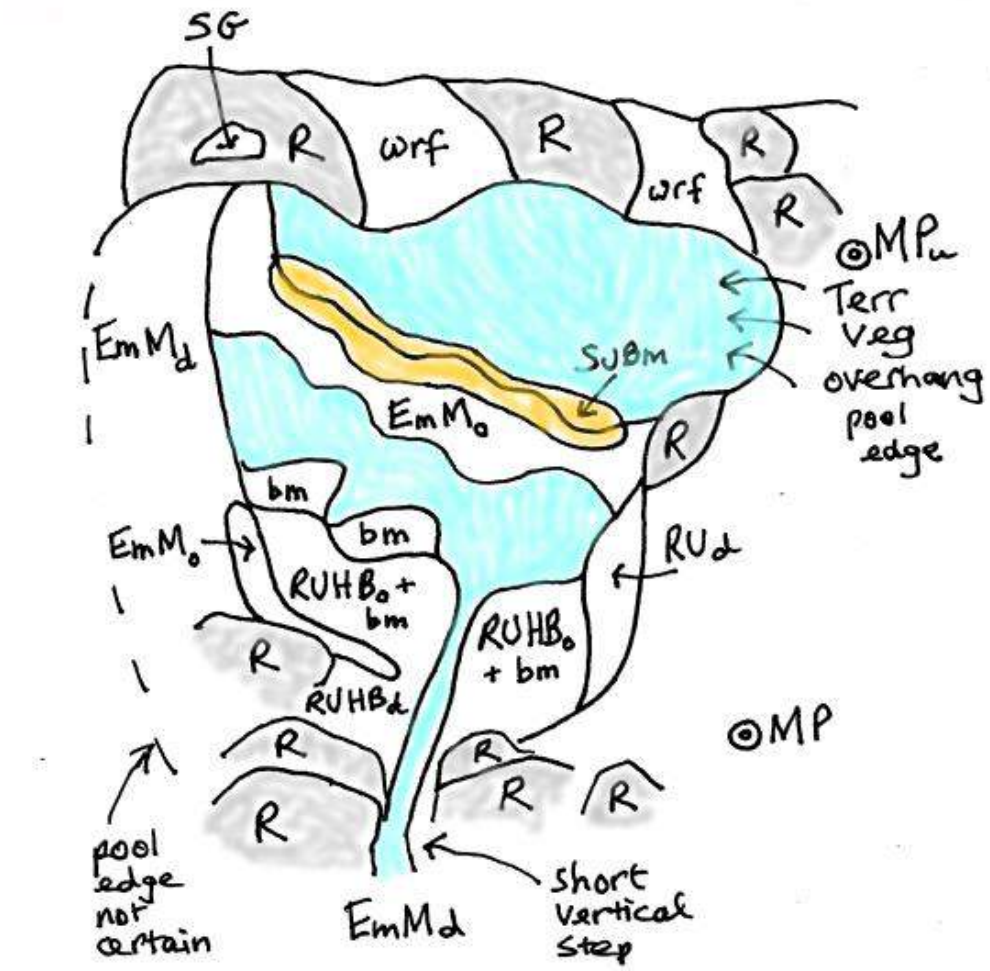
Site e07



Pool e07: Vegetation map looking upstream, 5th Nov 2018

SubM	One species present. *Chara australis* forms a dense patch in the middle of the pool on soft unconsolidated sediments, and is confined to the slope leading down to deepest part of pool. The deepest part of pool has a firm gritty sand bottom and no submerged macrophytes.
EmM	One species present. *Schoenoplectus tabernaemontani* occurs as three small sparse patches (EmM o) on margins of the pool. There is no evidence of any growth from previous years.
RU	Dense rushland dominated by *Juncus articulatus*, with introduced grass *Holcus lanatus*, introduced forbs *Rumex crispus*, *Trifolium* sp, *Veronica anagallis-aquatica*, and traces of native sedge *Eleocharis acuta*.
HB	Patch of *Nasturtium officinale*
RU-HB	Dominated by *Juncus articulatus* and *Nasturtium officinale* with the introduced grass *Holcus lanatus*
TerV	Blackberry overhanging the upstream right bank.

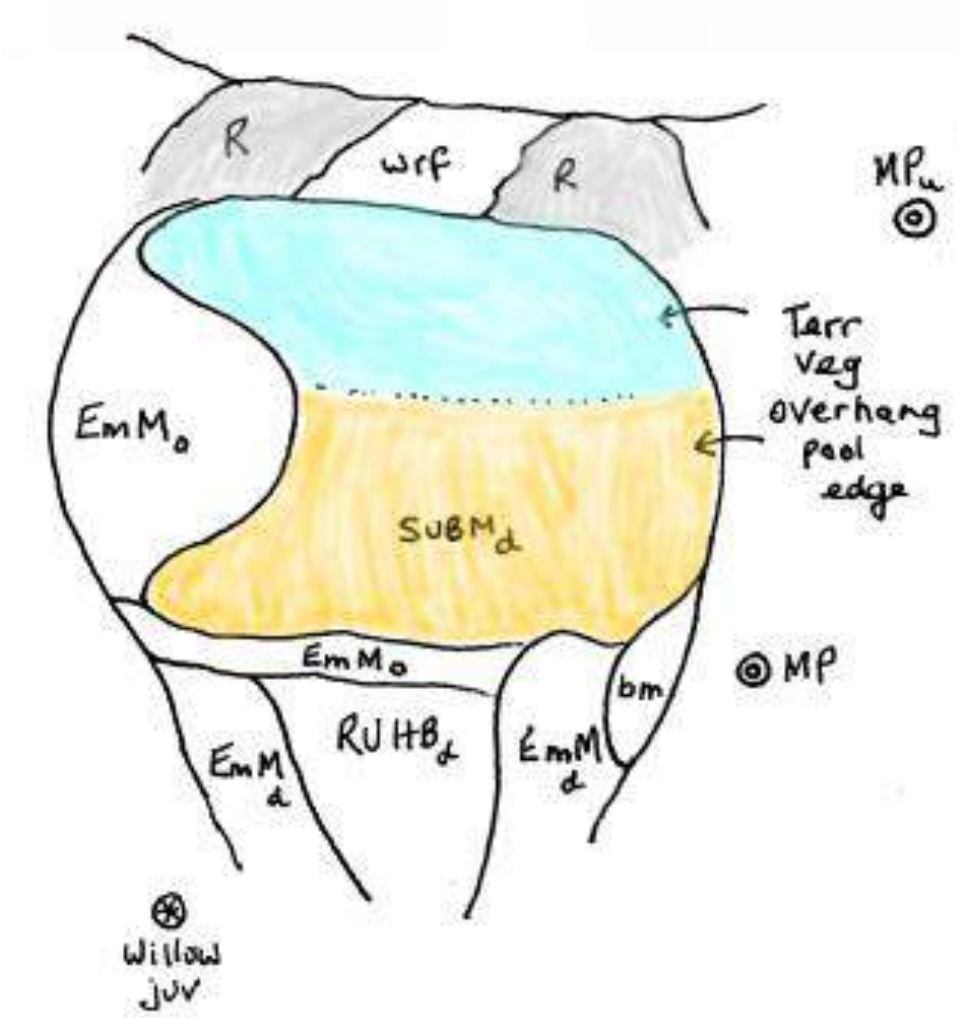
Pool e09



Pool e09: Vegetation map looking upstream, 5th Nov 2018

SubM	One species present. *Chara australis* is partly an understorey to *Schoenoplectus tabernaemontani,* and partly on soft sediments on slope falling down to deepest part of pool.
EmM	Two species present: *Schoenoplectus tabernaemontani* is the sparse band (EmM o) diagonal across the pool, and *Phragmites australis* is the very dense wide fringe (EmM d) along right bank (northern side). Both species are new season growth with no sign of any shoots from last year. *Phragmites australis* is very dense downstream of this pool, starting immediately below a short vertical step.
RU	Small patch of dense *Juncus articulatus*
RU-HB	Patches dominated by *Juncus articulatus* and *Nasturtium officinale*, with introduced forbs *Rumex crispus*, *Veronica anagallis-aquatica* and *Trifolium* sp. Patches of muds underneath this are black and anoxic.
bm	Small areas of bare mud
TerV	Tussocks of *Phalaris aquatica* around edge of pool

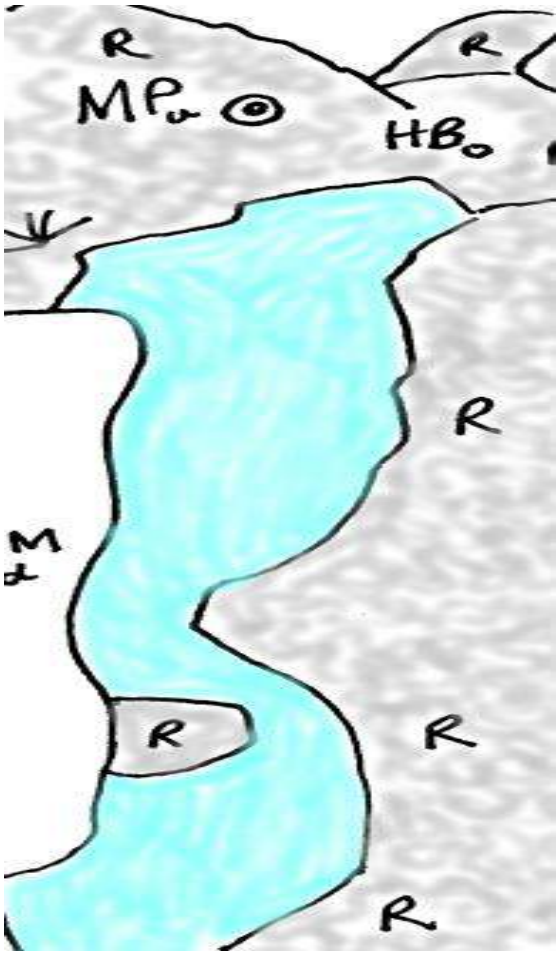
Pool e13



Pool e13: Vegetation map looking upstream, 5th Nov 2018

SubM	One species present. *Chara australis* forms extensive dense patch across the pool in vigorous condition, under 30-40 cm of water on slope leading down to deepest part of pool (which is macrophyte-free).
EmM	One species present: *Typha domingensis*, only new season growth: one large dense patch on the right bank (EmM d), and a narrow sparse band (EmM o) across downstream part of pool. The two dense patches immediately downstream of the Marker peg are also *Typha domingensis* (EmM d). The sparse band (EmM o) stretching across the pool has understorey of native sedge *Eleocharis acuta*, and *Juncus articulatus*.
RU-HB	Dominated by *Juncus articulatus* and *Nasturtium officinale* with introduced grasses *Lolium* spp and *Bromus* spp and introduced forbs such as *Veronica anagallis aquatica*, *Plantago*, and *Rumex crispus.*
TerV	Tussocks of *Phalaris aquatica* overhang the pool on left (southern) bank.

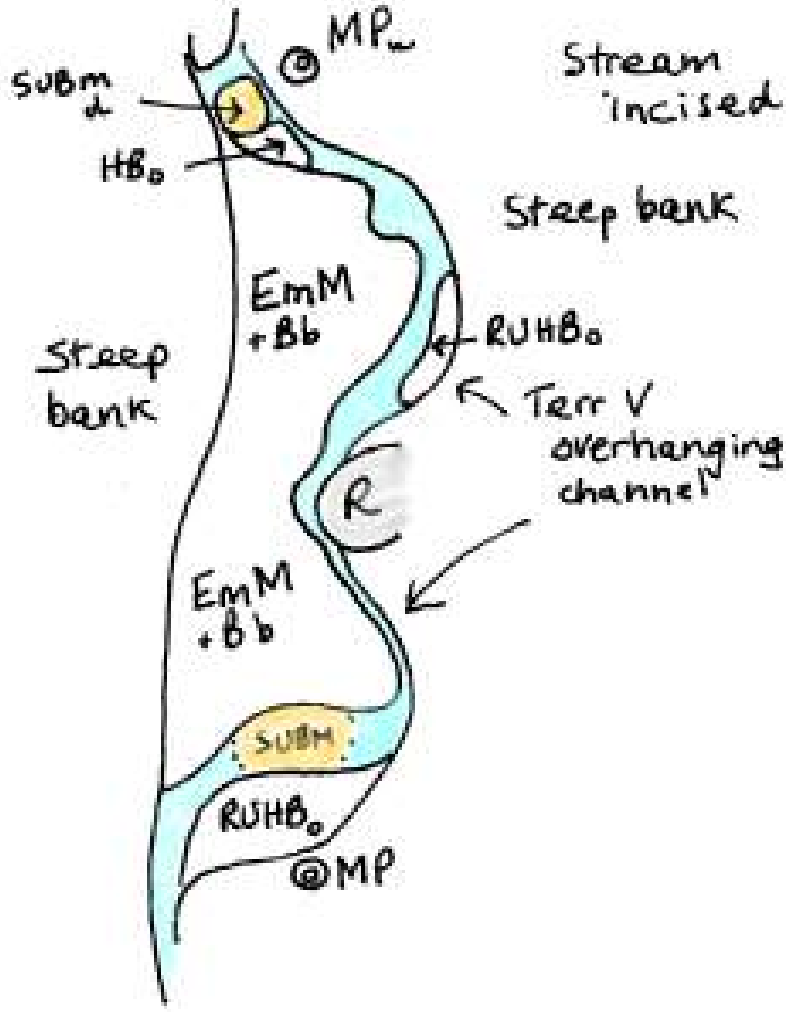
RC 2



Rc2: Vegetation map looking upstream, 5th Nov 2018

SubM	No SubM present. The upstream area had thick beds of dark green unbranched filamentous algae, harbouring a small bullet-shaped fish
EmM	One species present. *Schoenoplectus tabernaemontani* is a dense band on the right side of pool, helping to divert flow towards left of rock pool which is bare. This new season growth has some mature senescent culms from previous year(s). Traces of grasses, and forbs *Veronica anagallis-aquatica* and *Nasturtium officinale* present at downstream end of EmM patch.

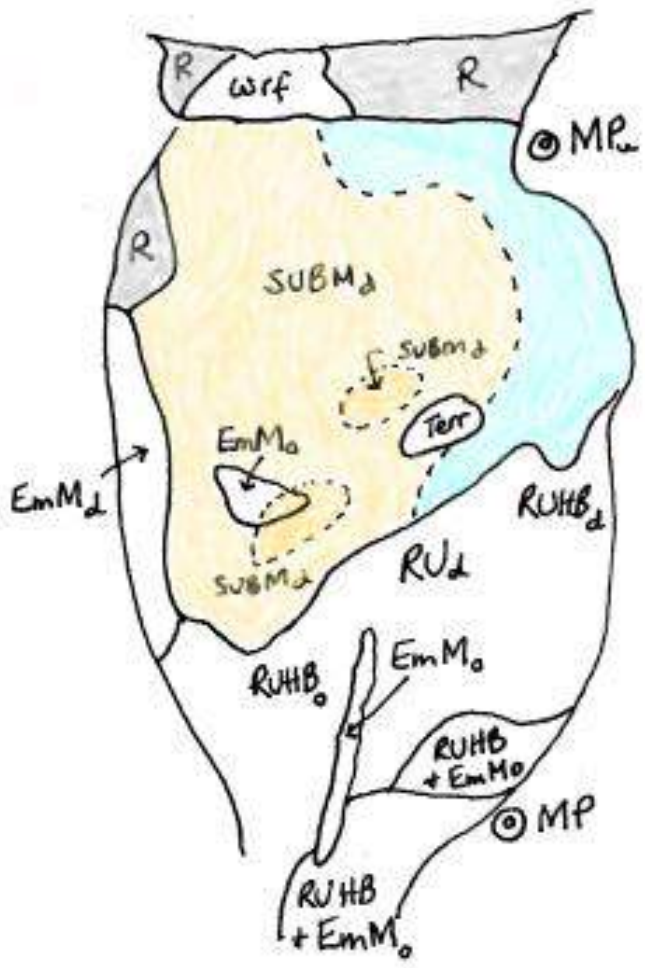
Pool e19



Pool e19: Vegetation map looking upstream, 11th Oct 2018

SubM	Two species present. *Nitella pseudoflabellata* occurs in small dense patch at head of pool, near in-stream boulders, just where stream changes from flowing to slow moving. *Chara australis* occurs as dense patch in flow path in lower poo. l
EmM	One species present. Dense growth of *Phragmites australis* on right side of pool, nearly occupying entire upper part of pool, and confining flow to narrow path on left side. Blackberry on bank is tangled into *Phragmites australis* (EmM + Bb). *Phragmites* is a mix of new season growth and dead culms from previous season(s).
HB	Small patch of *Nasturtium officinale* in upper part of pool, near *Nitella*.
RU-HB	Two patches evident. Downstream patch dominated by *Juncus articulatus* and *Nasturtium officinale*, and species rich with *Veronica anagallis-aquatica*, *Rumex crispus* and introduced grass *Paspalum distichum*. Small upstream patch is dominated by *Juncus articulatus* and *Nasturtium-officinal*e, with native sedge *Eleocharis acuta*, and introduced *Rumex crispus*

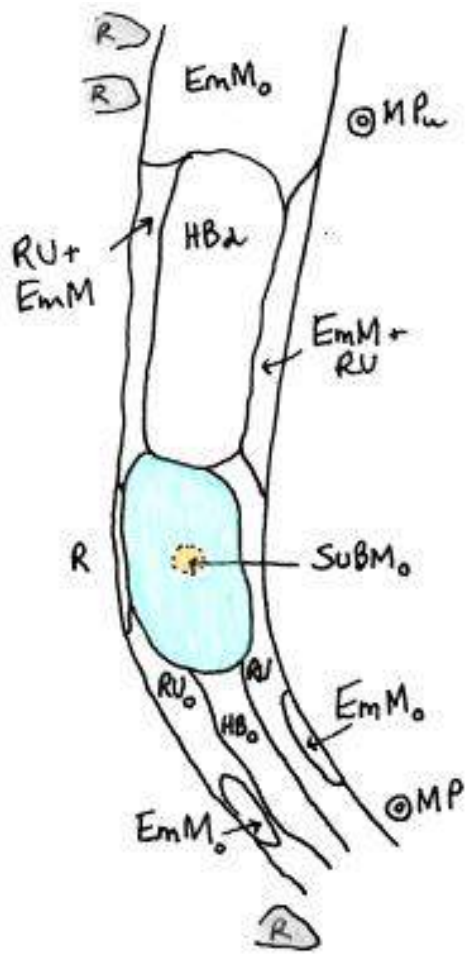
Pool e26



Pool e26: Vegetation map looking upstream, 11th Oct 2018

SubM	Two species present. *Potamogeton crispus* occurs across most of pool, as dense growth (SubM d), vegetative, leaves covered in fine sediment but foliage is green underneath. *Chara australis* grows in two small dense patches within bed of *P. crispus* (SubM d)
EmM	Two species present. *Schoenoplectus tabernaemontani* is restricted to a small patch mid pool (EmM o) of sparse new season growth. *Phragmites australis* occurs as a dense patch (EmM d) on the right side of the pool. *Phragmites* patches are a mix of new season growth and senescent culms from a previous season.
RU	Dominated by *Juncus articulatus* with some *Nasturtium officinale*
RU-HB	Dominated by *Juncus articulatus* and *Nasturtium officinale* with introduced grasses *Holcus lanatus*, *Paspalum dilatatum* and *Paspalum distichum*, and introduced forbs such as *Rumex crispus* and introduced sedge *Cyperus eragrostis*
RU-HB +EmM o	Two patches, open and mixed combinations of *Juncus articulatus* and *Nasturtium officinale* with some *Phragmites* at the downstream end of the pool.

Pool e28



Pool e28: Vegetation map looking upstream, 11th Oct 2018

SubM	One species present. *Potamogeton crispus* (SubM o) occurs as small dense patch in open water area, near deepest part of pool.
EmM	Three species present. *Phragmites australis* is open sparse growth (EmM o) at upstream end of pool including above the marker peg; and also occurs sparsely in Rushland (EmM + RU) along upper pool margins. *Schoenoplectus tabernaemontani* occurs in trace amounts on right side of pool, in margins of Rushland (EmM + RU). *Typha domingensis* is very sparse and heavily grazed, it occurs either side of the flow path at the downstream end of the poo (EmM o).
RU	Dominated by *Juncus articulatus* with some *Veronica anagallis aquatica*.
HB	Patches of *Nasturtium officinale*, upstream and downstream of deepest pool in main flow-path. Up[stem patch is dense, with traces of *Juncus articulatus* and native sedge *Eleocharis acuta* on margins. Downstream patch on spongy wet muds has some *Paspalum dilatatum* and *Nasturtium officinale*.
TerV	Large blackberry on left back (south side) of upper part of pool.

Pool e32

Pool e32: Vegetation map looking upstream, 11th Oct 2018

SubM	Two species present. *Potamogeton crispus* occurs as small dense patch in upper part of pool (SubM d) and also as a larger dense patch more centrally (SubM d). *Chara australis* co-occurs with *P. crispus* as patches in lower part of pool (these are not mapped separately)
EmM	One species present. *Typha domingensis*, small patch at very juvenile stages, occurs on left margin of upper pool in amongst water couch and jointed rush (EmM o).
RU	Rushland dominated by *Juncus articulatus* in upper part of pool. Patch on right side (steeper side) has some *Carex gaudichaudiana* and *Nasturtium officinale*. Patch on left side (gentle bank) has also present *Nasturtium officinale*, *Veronica anagallis aquatica* and *Plantago* sp.
HB	Dense patch of *Nasturtium officinale* in upper part of pool, mid flowpath
SG	Two patches, one upstream at inflow and one downstream. Upstream patch is dominated by native sedge *Carex gaudichaudiana*. Downstream Sedgeland patch dominated by introduced sedge *Cyperus eragrostis*, with understorey of seedlings and young growth not identified to species..

Appendix 5: Methods for Pools

Preliminary Field Visit

Allocate ½-1 day to check out the stream, locate the sites, and get familiar with the instream species, using the plant list from previous surveys as a guide plus whatever field guides are suitable.

Field Protocol

Equipment: Waders; metal or plastic metre rule or rigid non-rusting tape; digital camera (phone); marker pegs; survey sheets; pencil and rubber to draw vegetation maps; GPS; co-ordinates for marker pegs and photographs; plastic (snaplock) bags for collecting plant specimens for identification.

An example field sheet is given in Appendix 9.

At the pool: Set out the two marker pegs defining the upper and lower limits of the pool. This should be guided by a combination of the GPS co-ordinates and visual aids (photo-records and vegetation map).

Doing the general descriptions and estimating the indicators may be done in any order that suits. The sequence that evolved during the baseline survey was as follows:

> Prepare for mapping by walking around the pool, checking species and patches.
>
> Take the two reference photographs.
>
> Wade in (gently, taking care not to dislodge plants growing in or under water) using meter rule as a probe to find the deepest place and take water & sediment measurements: at same time, check under water for submerged macrophytes (especially if water is turbid on the day) and if necessary take a sample for identification (plastic bag).
>
> Prepare the field map of vegetation, taking additional photographs as reminders and records as needed.
>
> Record the dimensions and shape of patches of tall emergent and submerged macrophytes, using sketches: areas can be estimated afterwards.

Reference Photographs: Pool vegetation is recorded in two reference photographs, trying to include marker pegs (this may not always be possible): one taken at the bottom, looking upstream; and one taken at the top, looking downstream. Light quality and glare can be quite variable, and spoil a photograph: hence it is worth taking multiples of each reference photograph.

Additional photographs (other than the reference photographs) can also be taken. These are not essential, but can be very useful when finalising the vegetation map later, for recording anything of interest or that needs checking, or for illustrating in any reports: or simply for pleasure.

Sediment Depth: The deepest part of each pool is located, carefully, using the metal metre rule (or non-rusting metal tape) to poke and prod underwater. With a bit of practice, it is possible to detect the firm bottom, carefully avoiding boulders. Try to find the deepest part of the pool: this is where measurements are made.

The following measurements are then recorded off the metre rule:

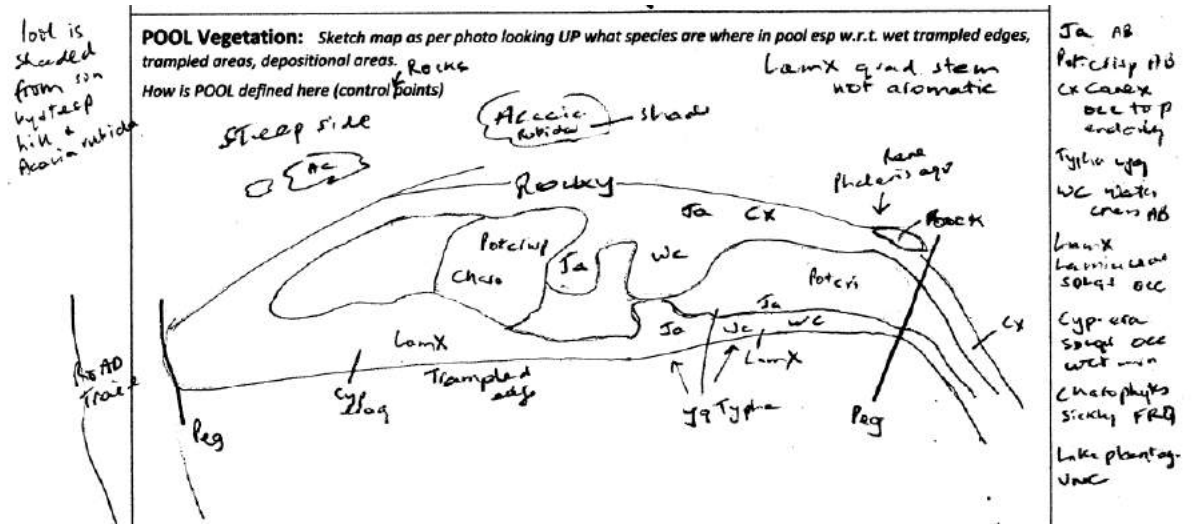
> Total depth = distance from firm bottom to water surface;
> Water depth = depth of water (from top of soft or unconsolidated sediments to water surface)

Sediment depth = distance from firm pool base to top of loose unconsolidated sediment.

Ideally this procedure should be repeated to get three sets of estimates.

Field map: A hand-drawn map of pool vegetation and relevant features is prepared in the field. It is useful to do this after recording maximum depths, as in deeper pools wading in and poking around is an opportunity to check identification and extent of submerged macrophytes.

An example from spring 2018 is given below:



Example - Field vegetation map for e32.

Observers develop their own style of species codes and abbreviations, and short-cuts, such as: Cx for *Carex gaudichaudiana*, WC for Water Cress *Rorippa nasturtium-aquaticum*, J art for *Juncus articulatus* and Cyp era for *Cyperus eragrostis*. Examples for abundance are: AB for abundant, TR for trace. After field work in spring 2018, the field sheet was revised, records of species abundance were simplified (see text), and terms such as FRQ (frequent), UNC (uncommon) were abandoned, although still evident in field maps such as above.

This map is drawn from the side, rather than looking upstream as recommended. This was easier in the field because it was a better vantage point for seeing the entire pool. However, this did present challenges when drawing the final version, and much use was made of the reference and other photographs.

Ideally, the map should be oriented so that the observer is at the lower limit of the pool, looking upstream, as this is how the maps are finalised. However, it can be easier in the field to do the drawing from the side, and re-orient later. The drawing should show, as best possible, vegetation patches that are present and their location; natural features (rocks, boulders, outcrops, steep banks); position of marker pegs; water surface or waterline around the pool, indicating where terrestrial vegetation overhangs. The features serve as landmarks: as well as defining the pool, they will help orient users in the future and help to evaluate vegetation change.

Notes on Species Abundance: The dominant species per mapping unit should be recorded (this may be two species sometimes) as this defines the mapping unit.

In addition, it is good practice to also record what other species are present, and whether only in trace amounts: this helps to describe the mapping unit.

TR (Trace): species present but only a few plants or stems (1-5 for small species, 1-2 for large species)
AB (Abundant or Dominant): species that dominate a vegetation patch, with many individual plants or many individual stems.
For species which are present but are neither TR nor AB, simply record name.

Typically, tall emergent macrophytes and submerged macrophytes grow very densely, crowding out other plants, and so form mono-specific patches (meaning just one species present).

Tall emergent macrophytes: Patches of tall emergent macrophytes are mapped when preparing the field vegetation map. The task here is to estimate the area of each patch as accurately as possible. This is done by treating each patch as a geometric shape (or a mix of two geometric shapes), and recording the critical dimensions for that shape using the metre rule or (even better) metal tape. Usually the critical dimensions are specific combinations of length, width, radius or diameter: geometric shapes to work with are rectangles, triangle, circles.

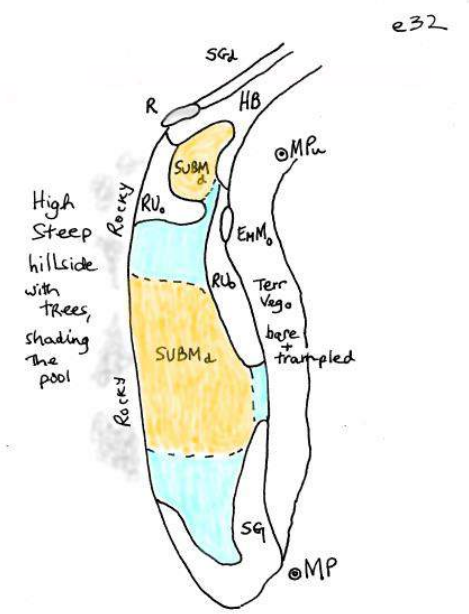
Submerged macrophytes: Estimating the area of each species of submerged macrophytes is done in the same way as for tall emergent macrophytes.

Outline the macrophyte patch on the field sheet; then decide what shape best describes the shape; and record the relevant dimensions to convert to an area (area units = m^2). For odd-shaped patches, it may be necessary to make more than one estimate (ie using different shapes) or else, break-down the odd shape into two recognisable shapes.

Post-Processing

Vegetation map (finalisation): The hand-drawn map needs to presented as a tidy and clearly labelled graphic. Theoretically, it is possible for skilled observers to draw a field map sufficiently well and clearly that it can be used as a final vegetation map. Personal experience was that the preparation of a clear tidy final version required more time than was available in the field, and that opportunity to integrate all forms of information (rough field map, species abundances, reference photographs, and other photographs) was essential and resulted in a better map and a more consistent style.

The example below is a finalised version of the field map above. Note that the field map was a mix of species information and patches but for the final version, this is translated into mapping units and the species information is transferred to the tables underneath the vegetation map.



Example – Finalised vegetation map for e32.

Details about individual mapping units (vegetation patches), such as their typical species composition, are given in a table of mapping units that accompanies each vegetation map.

The procedure used for map finalisation in spring 2018 was as follows. The field map was re-drawn on a new page, using a soft pencil (2B) to draw outlines and add labels, and based on the field map and photographs. A soft pencil was used because it is so easy to rub out, and to update drafts. Once finalised, the pencil outlines and labels were overdrawn with black ink; the ink was allowed to dry, and the pencil lines rubbed out, leaving a map with black lines on the page. This black-white drawing was then scanned; colours for water (blue), rocks (grey) and submerged macrophytes (yellow-orange) were added digitally to the image using Paint 3D software (a no frills option but adequate for purpose).

Pool Indicator – Sediment Depth: On the fieldsheet, calculate the average for each of the three depth estimates (Total; Water, Sediment) and enter this into the first three rows of the Pool Indicator –Sediment Depth table (example below). Then calculate Sediment as % of Total, and enter into last row. Finally, calculate the average for Sediment % and enter under the column headed mean.

Pool Indicator -Sediment Depth

Depth (cm)	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32	mean
Total			n.a.									n.a.
Water only			n.a.									n.a.
Sediment			n.a.									n.a.
Sediment as % of Total			n.a.									

Pool Indicator – Emergent Macrophytes and Submerged Macrophytes: For the Tall Emergent Macrophytes and for Submerged Macrophytes, calculate the area of each shape recorded on the

field sheet for each site; then work out the total area for each species per site on the field sheet. Enter all areas into the relevant Indicator table (examples below).

Pool Indicator - Tall Emergent Macrophytes

Area (m^2)	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32
Phragmites australis			n.a.								
S. tabernaemontani			n.a.								
Typha domingensis			n.a.								
Total area of EmM			**n.a.**								
Species Number											

Pool Indicator - Submerged Macrophytes

Area (m^2)	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32
Chara australis			n.a.								
N. pseudoflabellata			n.a.								
Potamogeton crispus			n.a.								
Total area of SubM			**n.a.**								
Species Number											

Copies of these Summary tables are in Appendix 10.

Site rc1 is included for Pools to ensure visual alignment with bench indicator tables.

Appendix 6: Methods for Benches

Preliminary Field Visit

If possible, allow ½ - 1 day to locate sites and to learn bench species, collecting specimens for identification if not already familiar with the species. The plant list from previous surveys is a useful guide. This Preliminary Field Visit is combined with the one for Pools.

Field Protocol

Equipment: Digital camera (phone); quadrat (4 corner pegs plus tape for sides) and tape measure to check quadrat dimensions; data sheets; GPS co-ordinates and photos for benches per site; visual guide/prompt for estimating percentage cover.

An example field sheet is given in Appendix 9.

At the bench: Set out 5 x 1 m quadrat on the bench. It is not essential that the quadrat be exactly in the same place as previous surveys but it must be on the same bench. Quadrat position can be confirmed in the field using GPS co-ordinates and photographs.

Doing the general descriptions and estimating the indicators may be done in any order that suits. The sequence that evolved during the baseline survey was as follows.

> Familiarisation with the bench by walking around, in preparation for recording general descriptions (Bench Vegetation, Bench Dominants) and quadrat data for indicators. This is an opportunity to take photographs and make general notes about presence of significant species (listed as invasive, or conservation value) on bench or adjoining hillside, or grazing or other impacts: such general notes are optional and not a part of the survey.
>
> Record Bench Vegetation and Bench Dominants.
>
> Record Quadrat Cover and Quadrat Composition

Bench Vegetation: Record the type of vegetation present on the bench, as well as its height, and whether height is uniform or variable. Vegetation type is based on growth form, and the options are:

> Rushland: if dominant species are rushes (family Juncaceae), or a mix of rushes and *Lomandra*.
>
> Sedgeland: if dominant species are sedges (family Cyperaceae)
>
> Grassland: if dominant species are grasses (family Poaceae)
>
> Shrubland: if dominant species is a shrub (such as briar or blackberry or wattle)
>
> Forbland: if dominant species are not grasses or sedges or rushes.

Height categories for non-woody vegetation are: low (5 to 25 cm), medium (>25 to 50 cm), tall (>50 cm to 1 m), and very tall (>1 to 2 m). These growth form categories and height definitions follow "*Australian Soil and Land Survey. Field Handbook*" (3rd edition).

Prompts for these are given on the Field Sheet (Appendix 9).

Bench Dominants: The dominant species, up to 5 per bench, are recorded. This is a visual appraisal but may require careful scrutiny. Accurate identification of the dominant species is important. There is no need to estimate their cover.

Prompts for these are given on the Field Sheet (Appendix 9).

If the survey is done early in spring, the plants may appear to be dead, with aboveground parts frosted or just last season's growth. This could happen if survey is done before new season growth has been initiated, or if the winter has been particularly cold or dry, and long. Careful checking is needed, looking for some living tissue at the base of leaves: this is enough to confirm the plant is alive.

Bench: Indicator - Cover: At each site, cover as a percentage of the 1 x 5 m quadrat is estimated for each of the following categories: perennial herbs; annual herbs; shrubs; bare ground (whether dry or saturated); rocks or boulders; litter. The cover estimates for these categories must total 100% for each bench. This indicator does not worry about how much of the perennial or annual cover is native or introduced.

Prompts for these are on the Field Sheet (Appendix 9).

Herbs means plants that are not trees, shrubs, mosses and includes grasses, sedges, forbs. Annual means short-lived or annual species. Litter means parts of plants, typically leaves, that have detached or broken off from the parent plant and have fallen onto the soil surface. With shrubs, the most likely species for Stream E are Blackberry and Sweet Briar or related species.

Bench Indicator – Nativeness: This indicator is for plants other than grasses, with grasses being strictly defined as taxa in family Poaceae.

The quadrat is searched for species that are not grasses and the cover of each species recorded. Experience from 2018 suggests that searching will need to be done carefully, as most of these non-grass species are present only as one or a few individuals or in small to tiny patches. Care is needed for this indicator, as sound identification of these non-grass species and their cover determines not just this indicator but also the next one (Grasses).

It can be hard to estimate cover for such small and uncommon species. One way to develop confidence and to develop consistency across a team is to draw out on paper a few square or rectangular guides, and to take this paper in the field as a visual guide. For example, when surveying a 5 x 1 m quadrat:

> 1% cover is equivalent to one 5 x 10 cm rectangle
> 2% cover is equivalent to one 10 x 10 cm square or one 5 x 20 cm rectangle or four 5 x 5 cm squares
> A circle that is 10 cm in diameter (5 cm radius) is about 78cm^2 or 1.5% cover.

Species which are present and which have cover much less than 1%, should be treated as being present in trace amount and can be simply assigned 0.5% cover.

Prompts for these are on the Field Sheet (Appendix 9).

Bench Indicator –Grasses: There is no field effort for this indicator. It is calculated from other information as described in Post-processing below.

Post-Processing

Bench Vegetation: There is no post-processing for Bench vegetation.

Bench Dominants: Finalise the Field Sheet for each site by adding in for each species, whether it is native or introduced. This information can be compiled from a number of sources: ACT Plant Census, regional plant guides, regional flora or other reliable websites or references.

Compile information from field sheets for all eleven sites into one table (example below), expanding the number of rows to fit in all the dominant species. In the FRQ column on the right (FRQ =

frequency), enter the number of sites where each species was dominant. At the bottom of each column, enter the number of species that were recognised as dominant for each site (Species Number) and the number of those that were native (Native Number).

Bench - Dominants

Species	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32	FRQ
Species Number												
Native Number												

Bench: Indicator – Cover: Compile the cover information from the eleven field sheets into one table (example below).

Benches - Cover (%) per quadrat

	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32
Perennial herbs											
Annual herbs											
Shrubs											
Litter											
Bare ground											
Rocks											
Total	100	100	100	100	100	100	100	100	100	100	100

Bench Indicator – Nativeness: This is done in three steps. The first is to complete each field sheet, adding in longevity (whether short-lived or perennial) and origin (whether introduced or native). Information on longevity and origin is available in standard references such as regional flora, ACT Plant Census, websites.

The second is to compile all eleven field sheets into one table (example of Compilation table below), expanding the number of rows to fit in all species. In the FRQ column, enter the number of sites (frequency) where each species was recorded. Then for each site, enter the total number of non-grass species recorded there, and then the number of those that were native: Number (total) and Number (native). Then for each site, add all the cover values and enter the total at the bottom of the table; and add all the cover values for native species, and enter that in the Compilation table.

Calculate and then enter the average in the column headed Mean for each of these: Number (total), Number (native) and Cover % (total) and Cover % (native).

Benches – Compilation of non-grass species

Key: O = Origin (N = native, X = introduced), and L = longevity (A = annual, biennial, P = perennial).

Species	O	L	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32	FRQ
									1					
Number (total)														
Number (native)														
Cover % (total)														
Cover % (native)														

The third step is to complete the Nativeness table (example below). The information for Number (total) and Number (native), and for Cover % (total) and Cover % (native) is imply copied forward from the Compilation table. Calculate Species Nativeness % for each bench by expressing Number (native) as a percentage of Number (total). Similarly, calculate the Cover % Nativeness for each bench by expressing

Finally, calculate the average for Species Nativeness and for Cover Nativeness across all sites, and enter in column under Mean.

Benches – Nativeness

	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32	Mean
Number (total)												
Number (native)												
Species Nativeness (%)												
Cover % (total)												
Cover % (native)												
Cover Nativeness (%)												

Bench Indicator – Grasses: The proportion of vegetation cover on bench quadrats that is obtained by a calculation, using information in two tables already completed. For each site, subtract Cover (% of total) in table Benches – Nativeness from herbaceous vegetation cover (perennial + annual) in the table Benches – Cover % quadrat; and enter in table below. Finally, calculate the average grass cover and enter in the column headed Mean.

Bench Indicator – Grasses

	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32	mean
Cover (%)												

Appendix 7: Pools – Location Marker Pegs

Site e01

Downstream Marker Peg

Positioned on left bank opposite large rounded flattish rock.

South = 35.22748

East = 148.98023

Upstream Marker Peg

Positioned on left bank where flow of incoming stream lessens and upstream of boulder.

South = 35.22748

East =148.98030

Site e04

Downstream Marker Peg

Positioned on left bank on leading edge of large rounded flattish rock just before pool narrows to outgoing stream, and opposite a tree guard. .

South = 35.22783

East = 148.97887

Upstream Marker Peg

Positioned on left bank where flow of incoming stream lessens, nearly opposite a pyracantha shrub, an a tree guard.

South = 35.22777

East = 148.97895

Site e07

Downstream Marker Peg

Positioned on left bank opposite a large rounded rock.

South = 35.22905

East =0178.97792

Upstream Marker Peg

Positioned on left bank aligned with lip of boulder step.

South = 35.22982

East = 148.97802

Site e09

Downstream Marker Peg

Positioned on left bank (visible to right of green bag) and aligned to boulders and rock on both sides of stream that constrict flow to very narrow channel (photo taken from right bank).

South = 35.22915

East = 148.97733

Upstream Marker Peg

Positioned on left bank aligned with base of boulder step.

South = 35.22917

East = 148.97742

Site e13

Downstream Marker Peg

Positioned on left bank and is aligned to leading edge of line of emergent macrophytes (photo taken from right bank).

South = 35.22972

East = 148.97617

Upstream Marker Peg

Positioned on left bank aligned with base of boulder step.

South = 35.22968

East = 148.97872

Site rc2

Downstream Marker Peg

Positioned on right side of pool, immediately opposite a distinct curve in sedge of rock pool; attached to plants for convenience.

South = n.a.

East = n.a.

Upstream Marker Peg

Positioned on right side at top of waterfall at head of this pool.

South = 35.22993

East = 148.97467

Site e19

Downstream Marker Peg

Positioned on left bank just where pool constricts down to a narrow flow path.

South = 35.22931667

East = 148.97361667

Upstream Marker Peg

Positioned on left bank at narrowest part of pool.

South = 35.229350

East = 148.97381667

Site e26

Downstream Marker Peg

Positioned on left bank

South = 35.228367

East = 148.971950

Upstream Marker Peg

Positioned on left bank on high spot aligned with waterline of boulder step.

South = 35.228417

East = 148.9719833

Site e28

Downstream Marker Peg

Positioned on left bank opposite cluster of rocky boulders on right bank.

South = 35.22793

East = 148.97023

Upstream Marker Peg

Positioned on left bank opposite rocks on right bank (not shown in photo: see planform diagram).

South = 35.22802

East = 148.97042

Site e32

Downstream Marker Peg

Positioned on left bank

South = 35.22762

East = 148.96878

Upstream Marker Peg

Positioned on left bank (just visible in photo) opposite rocks on right bank.

South = 35.22768

East = 148.96902

Appendix 8: Benches – Location Quadrats

Co-ordinates of bench quadrats

		Upper / Upstream		Lower / Downstream	
Site		**South**	**East**	**South**	**East**
E01	bench	35.22747	148.98020	35.22750	148.98015
Eo4	bench	35.22763	148.979.13	n.a.	n.a.
Rc1	bench	35.22843	148.97872	35.22845	148.97872
E07	bench	35.22898	148.97807	35.22902	148.97803
E09	bench	35.22915	148.97727	35.229159	148.97722
E13	bench	35.22983	148.97602	35.22987	148.97602
Rc2	bench	35.22993	148.97598	35.22995	148.97598
E19	bench	35.22929	148.97358	35.22928	148.97352
E26	bench	35.22835	148.97195	35.22832	148.97193
E28	infill	35.22788	148.97000	35.22788	148.96997
E32	bench	35.22765	148.96897	35.22763	148.96893

E01

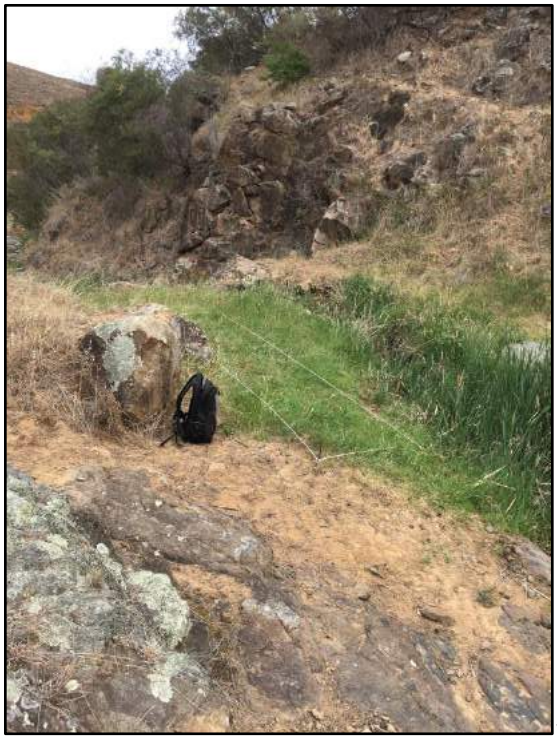
E04

Rc1

E07

E09

E13



v

Rc2

Appendix 9: Field Sheets

Stream E POOLS: General Description

Site: …… **Date**:…….. **Observer**:……..

Notes: ……

……

Reference photographs taken ?? ……..

Field Map: Vegetation patches +species

Stream E POOLS: Indicators

Site: …… **Date**:…….. **Observer**:……..

Notes: ……

……

Infilling: Record depths (cm), preferably doing this three times

	Total (cm)	Water (cm)	Sediment (cm)	Notes
First	……..	……..	……..	
Second	……..	……..	……..	
Third	……..	……..	……..	

Tall Emergent Macrophytes: Patch Shape, Size + Species

Submerged Macrophytes: Patch Shape, Size + Species

Stream E BENCHES:

Site: …… **Date**:…… **Observer**:……

Notes: ……

……

General Description

Bench Vegetation:

Cover is mostly (select one): grasses / sedges / rushes / forbs / shrubs ……

Ground cover Height (cm): …… Height: uniform / variable ……

For the purposes of Stream E:
Bench vegetation is a grassland if bench is dominated by grasses (Poaceae), is a sedgeland if dominated by sedges (Cyperaceae), is a rushland if dominated by rushes (Juncaceae) and is a shrubland if dominated by shrubs (mostly likely are Sweet Briar or Blackberry).
Height categories for Vegetation:
Low (5 to 25 cm), medium (>25 to 50 cm), tall (>50 cm to 1 m), and very tall (>1 to 2 m)
Vegetation types and heights follow *Australian Soil and Land Survey: Field Handbook* (3rd edition).

Bench Dominants:

List dominant species, up to 5 as appropriate for the site. If necessary, collect specimen for ID. Compile Family, and Introduced/Native on return from field.

Species	Family	Introduced/Native	Notes
1:……	……	……	……
2:……	……	……	……
3:……	……	……	……
4:……	……	……	……
5: ……	……	……	……

Indicator: from Quadrat Cover

Quadrat Vegetation Cover:

Bare Ground	Rocks	Shrubs	Perennials	Annuals	Litter	TOTAL
……	……	……	……	……	……	……

Bare Ground = unvegetated soil (dry or water-logged)
Rocks = rocks, large bounders (not soil)
Shrubs: woody usually multi-stemmed plants. Most likely are Sweet briar, Blackberry
Perennials = Long lived non-woody plants (grass, sedge, rush, forb)
Annuals = short-lived or annual plants
Litter = fallen plant material or blown, no longer attached to parent plant, obscuring ground

Stream E BENCHES:

Site: …… **Date**:…… **Observer**:……

Notes: ……

……

Indicator: Nativeness

Quadrat Species Cover (excluding Grasses):

List species in quadrat and estimate %cover of each NG species (non-grass species) in quadrat.
If necessary, use a code name and collect specimen for ID.
Compile longevity (annual or perennial) , and whether Introduced/Native after completing field work.

	NG Species	Longevity	Introduced/Native	Cover
1	……	……	……	……
2	……	……	……	……
3	……	……	……	……
4	……	……	……	……
5	……	……	……	……
6	……	……	……	……
7	……	……	……	……
8	……	……	……	……
9	……	……	……	……
10	……	……	……	……
11	……	……	……	……
12	……	……	……	……
13	……	……	……	……
14	……	……	……	……
15	……	……	……	……

Cover Guide

1% cover is equivalent to one 5 x 10 cm rectangle

2% cover is equivalent to one 10 x 10 cm square or one 5 x 20 cm rectangle or four 5 x 5 cm squares

A circle that is 10 cm in diameter (5 cm radius) is about 78cm^2 or 1.5% cover.

Appendix 10: Reporting Tables

Stream E POOLS: Indicators

Pool Indicator –Depths at deepest part

	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32	Mean
Total (cm)			n.a.									n.a.
Water (cm)			n.a.									n.a.
Sediment (cm)			n.a.									n.a.
Sediment as % Total			n.a.									

Pool Indicator – Area and species of Tall Emergent Macrophytes

Area (m^2)	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32
Phragmites australis			n.a.								
S. tabernaemontani			n.a.								
Typha domingensis			n.a.								
Total area of EmM			**n.a.**								
Number Species											

Pool Indicator – Area and species of Submerged Macrophytes

Area (m^2)	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32
Chara australis			n.a.								
N. pseudoflabellata			n.a.								
Potamogeton crispus			n.a.								
Total area of SubM			**n.a.**								
Number Species											

Stream E BENCHES: Indicators

Bench Indicator – Dominants

Increase number of rows for species as needed

Species	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32	FRQ
Number (total)												
Number (native)												

Bench Indicator - Cover

Cover (%)	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32
Perennial herbs											
Annual herbs											
Shrubs											
Litter											
Bare ground											
Rocks											
Total	100	100	100	100	100	100	100	100	100	100	100

Bench Indicator – Compilation

Increase number of rows for species as needed.

Key: O = Origin (N = native, X = introduced), and L = longevity (A = annual, biennial, P = perennial).

Species	O	L	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32	FRQ
									1					
Number (total)														
Number (native)														
Cover % (total)														
Cover % (native)														

Bench Indicator – Nativeness (other than grasses)

	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32	Mean
Number (total)												
Number (native)												
Species Nativeness (%)												
Cover % (total)												
Cover % (nativel)												
Cover Nativeness (%)												

Bench Indicator – Grasses

	e01	e04	rc1	e07	e09	e13	rc2	e19	e26	e28	e32	mean
Cover (%)												

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