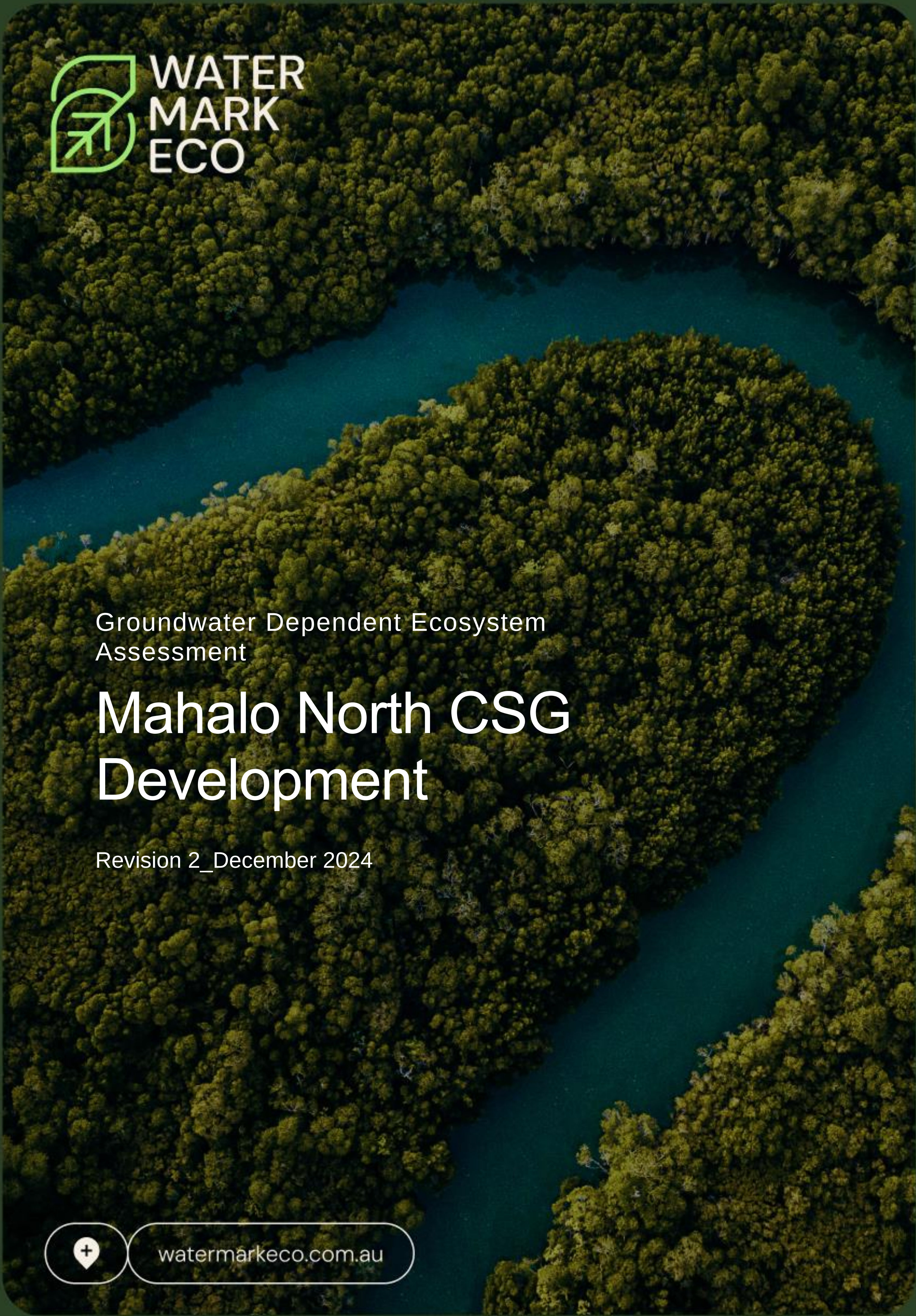

Groundwater Dependent Ecosystem Assessment

Mahalo North CSG Development

Revision 2_December 2024

watermarkeco.com.au

Project No. 2024_19

Project Manager: David Stanton

Client: Epic Environmental

Purpose: Groundwater Dependent Ecosystem (GDE) risk assessment for the Mahalo North CSG development

Report	Revision	Date Issued	Issued By.	Purpose
Groundwater Dependent Ecosystem Assessment – Mahalo North CSG Development	REV 1	15 November 2024	David Stanton	Preliminary report prior to stable isotope results
	REV 2	04 December 2024	David Stanton	Revision 2 report following incorporation of stable isotope data

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Purpose of the report: Watermark Eco has produced this report for Epic Environmental (the "Client"). The information and any recommendations in this report are particular to the Specified Purpose and are based on facts, matters and circumstances particular to the subject matter of the report and the specified purpose (Groundwater Dependent Ecosystem risk assessment) at the time of production. This report is not to be used, nor is it suitable, for any purpose other than the Specified Purpose. Watermark Eco disclaims all liability for any loss and/or damage whatsoever arising either directly or indirectly as a result of any application, use or reliance upon the report for any purpose other than the Specified Purpose.

Please contact me if further information is required concerning any aspect of this document

Yours Sincerely,

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Glossary

Alluvial aquifer	An aquifer comprising unconsolidated sediments deposited by flowing water usually occurring beneath or adjacent to the channel of a river.
Aquifer	A geological formation or structure that stores or transmits water to wells or springs. Aquifers typically supply economic volumes of groundwater
Aquatic GDE	Vegetation supported by surface expression of groundwater (e.g., spring fed watercourses and associated fringing vegetation).
Base flow	Streamflow derived from groundwater seepage into a stream.
Capillary fringe	The unsaturated zone above the water table containing water in direct contact with the water table though at pressures that are less than atmospheric. Water is usually held by soil pores against gravity by capillary tension.
Confined aquifer	A layer of soil or rock below the land surface that is saturated with water with impermeable material above and below providing confining layers with the water in the aquifer under pressure.
Evapotranspiration	The movement of water from the landscape to the atmosphere including the sum of evaporation from the lands surface and transpiration from vegetation through stomata
Facultative phreatophyte	A plant that occasionally or seasonally utilises groundwater to maintain high transpiration rates, usually when other water sources aren't available.
Fractured rock aquifer	An aquifer in which water flows through and is stored in fractures in the rock caused by folding and faulting.
Fluvial	Relating to processes produced by or found in rivers
Groundwater	Those areas in the sub-surface where all soil or rock interstitial porosity is saturated with water. Includes the saturated zone and the capillary fringe.
Groundwater dependent ecosystems (GDE)	An ecosystem that depends, either wholly or partially, on groundwater to meet their moisture requirements to maintain ecological processes.
Infiltration	Passage of water into the soil by forces of gravity and capillarity, dependent on the properties of the soil and moisture content.
Leaf water potential (LWP)	The total potential for water in a leaf, consisting of the balance between osmotic potential (exerted from solutes), turgor pressure (hydrostatic pressure) and matric potential (the pressure exerted by the walls of capillaries and colloids in the cell wall).
Leaf area index (LAI)	The ratio of total one-sided area of leaves on a plant divided by the area of the canopy when projected vertically on to the ground.
Obligate phreatophyte	A plant that is completed dependent on access to groundwater for survival
Percolation	The downward movement of water through the soil due to gravity and hydraulic forces.
Permeability	A materials ability to allow a substance to pass through it, such as the ability of soil or rocks to conduct water under the influence of gravity and hydraulic forces.
Permanent wilting point	The water content of the soil at which a plant can no longer extract water and leaves will wilt and die. Usually 1.5 Mpa (-217 psi). Generally applied to crops although Australian flora typically have much larger stress thresholds.
Phreatic zone	The zone of sub-surface saturation separated from the unsaturated zone in unconfined aquifers by the water table.

Soil water potential	A measure of the difference between the free energy state of soil water and that of pure water. Essentially a measure of the energy required to extract moisture from soil.
Stable isotope	An isotope that does not undergo radioactive decay.
Standard Wilting Point	The minimum LWP or corresponding soil moisture potential that can be tolerated before a plant wilts in response to negative water supply. This is accepted at -15 bars or -1.5 MPa (or -217.55 PSI).
Specific Yield	The ratio of the volume of water that a saturated rock or soil will yield by gravity to the total volume of the rock or soil.
Surface water	Movement of water above the earths' surface as runoff or capture in streams and closed depressions.
Transpiration	The process of water loss from leaves, through stomata, to the atmosphere.
Terrestrial GDE	Terrestrial vegetation supported by sub-surface expression of groundwater (i.e., tree has roots in the capillary fringe of groundwater table).
Unconfined aquifer	An aquifer whose upper surface is at atmospheric pressure, producing a water table, which can rise and fall in response to recharge by rainfall
Vadose zone	The unsaturated zone, above the water table in unconfined aquifers
Water Potential	The free energy potential of water as applied to soils, leaves plants and the atmosphere.
Wetting front	The boundary of soil wet by water from rainfall and dry soil as the water moves downward in the unsaturated zone.

Executive Summary

Comet Ridge Mahalo North Ltd (Comet Ridge) proposes to develop The Mahalo North Project (the Project), a greenfield CSG development located in the Bowen Basin, between Rolleston and Blackwater, in an area defined as Petroleum License Application (PLA) 1128. The Project aims to produce Coal Seam Gas (CSG) from the Bandanna Formation. Coal seam gas developments have the potential to alter natural groundwater regimes and impact groundwater quality. This report assesses the potential impacts of groundwater extraction on native vegetation in PLA1128, utilisating multiple lines of evidence, including pre-dawn leaf water potentials, soil moisture potentials, and analysis of stable isotope trends.

The study concludes that within the assessment area, brigalow (including the Brigalow Threatened Ecological Community) draws moisture predominantly from the shallow regions of the soil profile down to depths of 2.4 mbgl, where extremely dry and hard clays arrest deeper root penetration, which is consistent with previous studies on Brigalow, which suggest a shallow rooting system. No evidence from either biophysical or isotopic investigations indicates groundwater contributes significantly to the moisture sources supporting brigalow at the time of the assessment or that there is likely to be groundwater usage by the species on a temporal basis.

Like brigalow, eucalyptus woodland habitats across PLA1128 comprise mostly shallow-rooted box species that rely on moisture from the shallow soil profile. Support for this conceptualization comes from both biophysical and isotopic evidence. Some eucalypt species, such as Dawson gum, have a strong affinity with brigalow, suggesting that they similarly derive moisture from similar shallow regions of the soil profile.

Based on this assessment, terrestrial GDEs do not occur within PLA1028, confirming that the impact of CSG development on groundwater-dependent assets will be negligible.

Contents

Figures

Glossary

Alluvial aquifer	An aquifer comprising unconsolidated sediments deposited by flowing water usually occurring beneath or adjacent to the channel of a river.
Aquifer	A geological formation or structure that stores or transmits water to wells or springs. Aquifers typically supply economic volumes of groundwater
Aquatic GDE	Ecosystem supported by surface expression of groundwater (e.g. spring fed watercourses and associated fringing vegetation).
Base flow	Streamflow derived from groundwater seepage into a stream.
Capillary fringe	The unsaturated zone above the water table containing water in direct contact with the water table though at pressures that are less than atmospheric. Water is usually held by soil pores against gravity by capillary tension.
Confined aquifer	A layer of soil or rock below the land surface that is saturated with water with impermeable material above and below providing confining layers with the water in the aquifer under pressure.
Edaphic	Relating to properties of soil or substrate including its physical and chemical properties and controls those factors impose on living organisms.
Evapotranspiration	The movement of water from the landscape to the atmosphere including the sum of evaporation from the lands surface and transpiration from vegetation through stomata
Evaporative enrichment (of stable isotopes).	In a surface water body subject to evaporation, the d2H/d18O values of a water sample collected after a period of strong evaporation will be higher (more enriched in the heavier isotope) than the values obtained from water collected during an earlier sampling event. This reflects the progressive evaporation of water and loss of the lighter isotope under local conditions (assuming that there is not additional water inflow).
Facultative phreatophyte	A plant that occasionally or seasonally utilises groundwater to maintain high transpiration rates, usually when other water sources aren't available.
Fractured rock aquifer	An aquifer in which water flows through and is stored in fractures in the rock caused by folding and faulting.
Fluvial	Relating to processes produced by or found in rivers
Groundwater	Those areas in the sub-surface where all soil or rock interstitial porosity is saturated with water. Includes the saturated zone and the capillary fringe.
Water table	The upper surface of the saturated zone in the ground, where all the pore space is filled with water.
Groundwater dependent ecosystems (GDE)	Natural ecosystems which require access to groundwater on a permanent or intermittent basis to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services (Richardson et al. 2011)

Infiltration	Passage of water into the soil by forces of gravity and capillarity, dependent on the properties of the soil and moisture content.
Leaf water potential (LWP)	The total potential for water in a leaf, consisting of the balance between osmotic potential (exerted from solutes), turgor pressure (hydrostatic pressure) and matric potential (the pressure exerted by the walls of capillaries and colloids in the cell wall).
Leaf area index (LAI)	The ratio of total one-sided area of leaves on a plant divided by the area of the canopy when projected vertically on to the ground.
Local Meteoric Water Line (LMWL)	Describes the relationship between hydrogen and oxygen isotope (Oxygen-18 and Deuterium) ratios in local natural meteoric waters. LMWL is usually developed from precipitation data collected from either a single location or a set of locations within a "localised" area of interest (USGS, 2018) and results are reported as the amount-weighted average d2H/d18O composition of water in rainfall. LMWL's define a constant relationship between d2H/d18O in local rainfall, and deviations from this relationship are imparted by stable isotope fractionation causally linked to evaporative processes (evaporative enrichment). Further information can be obtained from USGS (2004) and Crosbie et al (2012).
Obligate phreatophyte	A plant that is completely dependent on access to groundwater for survival
Osmotic potential	The lowering of free energy of water in a system due to the presence of solute particles.
Percolation	The downward movement of water through the soil due to gravity and hydraulic forces.
Perched groundwater system	A groundwater system or aquifer that sits above the regional aquifer due to a capture of infiltrating moisture on a discontinuous aquitard.
Permeability	A materials ability to allow a substance to pass through it, such as the ability of soil or rocks to conduct water under the influence of gravity and hydraulic forces.
Permanent wilting point	The water content of the soil at which a plant can no longer extract water and leaves will wilt and die. Usually -1.5 Mpa (-217 psi). Generally applied to crops although Australian flora typically have much larger stress thresholds.
Phreatic zone	The zone of sub-surface saturation separated from the unsaturated zone in unconfined aquifers by the water table.
Phreatophyte	Plants whose roots extend downward to the water table to obtain groundwater or water within the capillary fringe
Piston flow	The movement of a water front through the soil uniformly downwards to the aquifer, with the same velocity, negligible dispersion, pushing older water deeper into the soil profile.
Preferential flow	Movement of surface water rapidly from surface to aquifer along preferential flow paths, bypassing older moisture in the upper soil profile.
Stable isotope	A stable isotope is an isotope that does not undergo radioactive decay. Oxygen has three different isotopes: The ^{16}O is the most

	common stable isotope of oxygen and ^{18}O is present in the atmosphere in amounts that are measurable. The masses of ^{16}O and ^{18}O are different enough that these isotopes are separated (or fractionated) by the process of evaporation leading to enrichment of the heavier (^{18}O) isotope. Hydrogen has two naturally occurring stable isotopes being ^{1}H (protium) and ^{2}H (deuterium) which also fractionate during evaporation, although the higher energy state of hydrogen means that the ratio between ^{1}H and ^{2}H is much more sensitive to fractionation. Further information can be obtained from USGS (2004) and Singer (2014).
Standard Wilting Point	The minimum LWP or corresponding soil moisture potential that can be tolerated before a crop plant wilts in response to negative water supply. This is accepted at -15 bars or -1.5 MPa (or -217.55 PSI)
Specific Yield	The ratio of the volume of water that a saturated rock or soil will yield by gravity to the total volume of the rock or soil.
Surface water	Movement of water above the earths' surface as runoff or in streams
Transpiration	The process of water loss from leaves, through stomata, to the atmosphere.
Terrestrial GDE	Terrestrial vegetation supported by sub-surface expression of groundwater (i.e. tree has roots in the capillary fringe of groundwater table).
Turgor Pressure	Turgor pressure is the force exerted by stored water in a leaf against a cell wall.
Unconfined aquifer	An aquifer whose upper surface is at atmospheric pressure, producing a water table, which can rise and fall in response to recharge by rainfall
Vadose zone	The unsaturated zone, above the water table in unconfined aquifers
Water Potential	The free energy potential of water as applied to soils, leaves plants and the atmosphere.
Wetting front	The boundary of soil wet by water from rainfall and dry soil as the water moves downward in the unsaturated zone.

1.0 Introduction

Comet Ridge Mahalo North Ltd (Comet Ridge) proposes to develop The Mahalo North Project (the Project), a greenfield CSG development located in the Bowen Basin, between Rolleston and Blackwater, in an area defined as Petroleum License Application (PLA) 1128 (**Figure 1**). The Project aims to produce Coal Seam Gas (CSG) from the Bandanna Formation. This requires reducing reservoir pressure to facilitate the desorption of methane gas from coal, which is achieved by pumping groundwater from the source formation via constructed wells.

CSG developments have the potential to alter natural groundwater regimes and impact groundwater quality (IESC, 2018). Therefore, an assessment of the Project's potential impacts on ecosystems reliant on groundwater resources is required, captured under the general term of groundwater-dependent ecosystems (GDEs). GDEs are currently mapped within PLA 1128 (GDE Atlas, BOM 2024), necessitating a requirement for field inspection to confirm the presence and eco-hydrological function of GDEs, which includes:

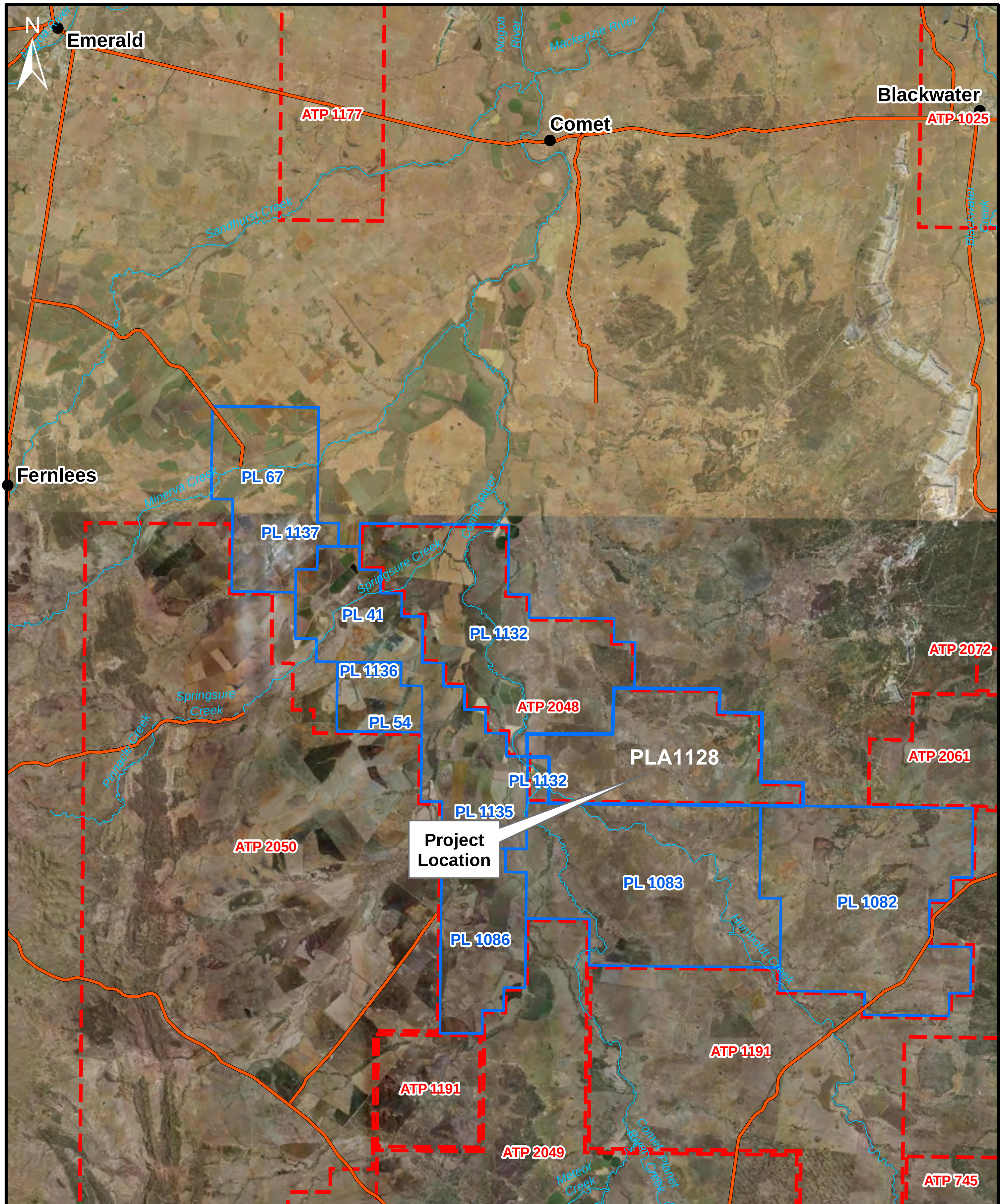
1. Terrestrial GDEs rely on groundwater's sub-surface expression (into the tree-rooting zone).
2. Aquatic GDEs are GDEs dependent on the groundwater surface expression (springs and baseflow).

Figure 2 shows mapped terrestrial and aquatic GDEs. Mapping of Aquatic GDEs represents discontinuous slivers on small-order drainage lines on the southern boundary of PLA 1128. Terrestrial GDEs occupy much broader tracts of native vegetation, often on elevated landscape portions and removed from watercourses.

2.0 Background and Objectives

A request for information (RFI) issued to the proponent by the Australian Government Department of Climate Change, Energy, the Environment and Water (DCCEEW) identified several areas where additional information is required, before an assessment of The Projects impacts can be made, allowing a decision on Project approval. The RFI included the following:

1. Conduct an investigation to determine whether any linkage between Brigalow (*Acacia harpophylla)* TEC and groundwater exists. This investigation must be done using validated, ground-truthed methods such as Doody et al. (2019). Discuss the findings of these investigations within the PD and provide supporting evidence to inform whether these linkages exist and, if so,to what extent (2.1.7).
2. An assessment of the impacts of the proposed action on Brigalow TEC with respect to changes to surface hydrology and potential decline in groundwater availability and quality and whether this may reduce the condition of the community to the extent in which it would not meet the threshold to be classed as Brigalow TEC (2.3.8).
3. Provide a discussion with supporting evidence of the occurrence of terrestrial, aquatic and subterranean GDEs within, adjacent to and downstream of the proposed action area. Groundwater dependency should be ground-truthed using a validated method, such as Doody et al. (2019) (3.3.4).



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Coordinate System: GDA 2020 MGA Zone 55 — A4

Legend

- State_controlled_roads_s...
- Watercourse
- PLA 1128
- Petroleum_leases
- Exploration permits for petroleum

Figure 1. Comet Ridge Mahalo Project Location

Client: Epic Environmental

Project: Comet Ridge Mahalo Project.

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Mobile: 0447 822 119
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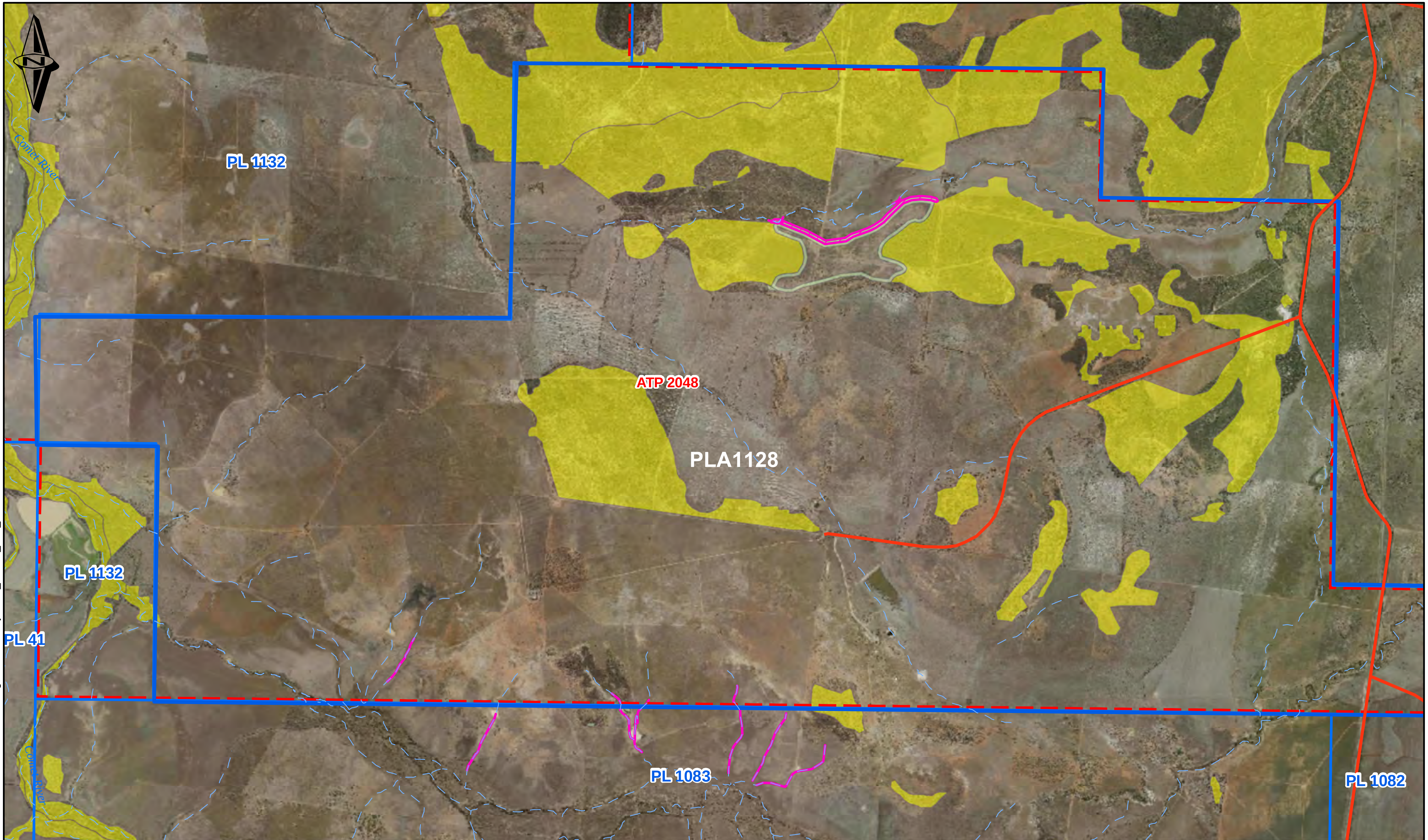
Drawn By DG — Checked DS — Date 4/12/2024



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Coordinate System: GDA 2020 MGA Zone 55 A4

Legend

- Drainage
- PLA 1128
- Petroleum_leases
- Exploration permits for petroleum

Aquatic GDE

- Moderate potential GDE - from regional studies

Terrestial GDE

- Moderate potential GDE - from regional studies
- Low potential GDE - from regional studies

Figure 2. Mapped potential GDEs from the Commonwealth assessment (BOM 2024)

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Project: Comet Ridge Mahalo Project.

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The objective of this study is to provide a detailed field-based investigation to address the RFI, assessing the presence and nature of GDEs within PLA 1128 and adjacent areas, which may be subject to an impact due to groundwater drawdown. Completion of the detailed assessment will be through:

- General field traverse of mapped Terrestrial GDE areas to identify any areas of groundwater seepage and assist in targeting field-based assessment sites.
- Biophysical assessments to characterise the physical interactions of potentially groundwater dependent trees with their edaphic controls.
- Stable isotope investigations to identify the source, or sources of moisture utilised by areas currently mapped as GDEs.

In support of the RFI, the study will focus on areas of the Brigalow TEC, although it will provide broader information on other habitats within and adjacent to PLA 1128 to allow an adequate assessment of the Project's risks to GDE function.

3.0 Survey Timing, Rainfall and Climate.

The field survey occurred over five field days between the 26th and 30th of August 2024. **Figure 3** shows the pre-survey rainfall reported in Arcturus Downs (BOM recording station 035002), approximately 20km west of PLA 1128, for four months before the field assessment. Significant rainfall occurred between the 12th and 14th of August 2024, with approximately 40 mm recorded and a more dispersed 38 mm reported between the 26th of June and the 3rd of July. The remainder of the four months was largely dry.

Analysis of SILO rainfall data (SILO 2024) expressed as Cumulative Rainfall Departure (CRD) (Weber & Stuart, 2004) is shown in **Figure 4**, indicating that the field assessment follows a strong wetting trend that occurred between April 2022 and February 2023. From that point, the climate periodically dried to September 2023, with a weaker wetting trend recorded from this point to the commencement of the field survey. The CRD data also shows significant droughts (troughs in the CRD curve) occurring between 2001 and 2007 (the Millennium drought) and between 2017 and June 2021. CRD is essential for assessing groundwater-related assets, as shallow groundwater tables will follow similar trends.

4.0 Summary of Assessment Methods

The field survey included an assessment of 15 sites, all considered to represent potential GDEs from the BOM GDE Atlas (BOM 2024). At each assessment site, sampling of up to five trees for leaf water potential (LWP) was completed, with twig samples collected to analyse xylem stable isotope composition. Five locations were subject to soil auger profiling to facilitate the collection of soil moisture potential (SMP) and stable isotope data from the soil profile. Groundwater sampling was completed as part of a dedicated quarterly groundwater sampling program. All methods are consistent with GDE assessment protocols detailed by Doody et al. (2019) and Richardson et al., (2011).

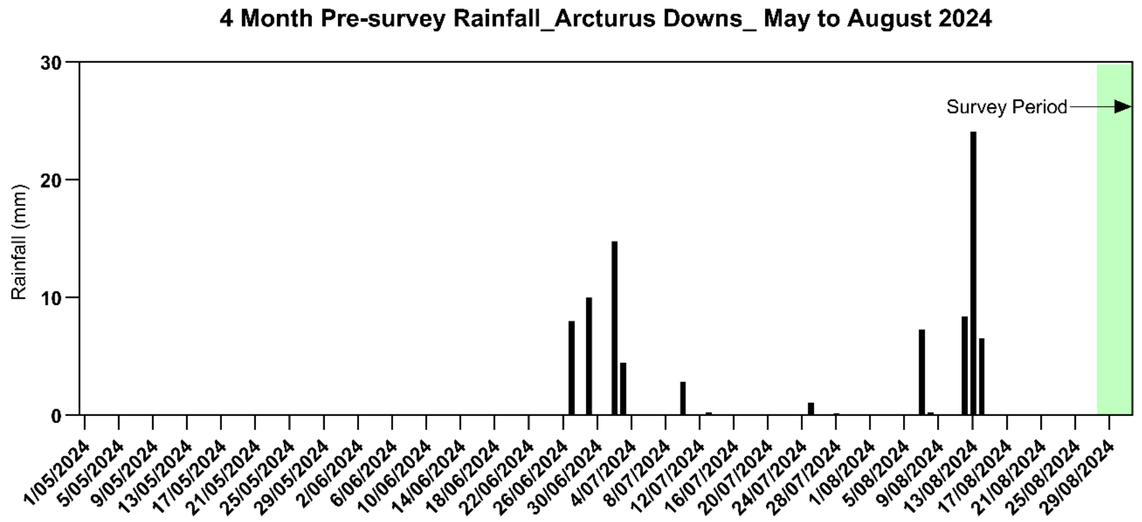


Figure 3. Pre-survey rainfall from the Clermont Airport recording station (BOM035002), the nearest reliable recording station to the assessment area from January to end Augus 2024.

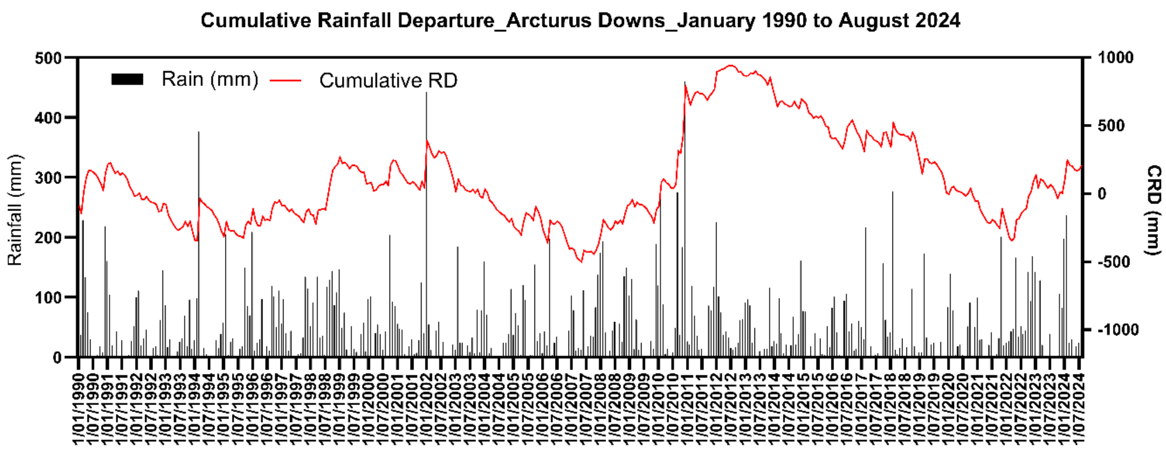


Figure 4. Rainfall trends at the Arcturus Downs expressed as Cumulative Rainfall Departure from January 1990 to 31st August 2024 (SILO 2024).

4.1 Site Selection

The survey focused on areas of the Brigalow TEC, and other areas mapped as terrestrial GDEs in the GDE Atlas, including sites where GDEs have been mapped as linear bands on the edges of residual escarpments. **Figure 5** shows sampling localities relative the mapped GDEs and TECs (from Epic, 2024) with **Table 1** providing a summary of the purpose of individual GDE assessment sites. GDE assessment sites relative to field verified regional ecosystem (RE) mapping is shown in **Figure 6.** Due to the necessity of sampling multiple sites pre-dawn, the subject sites needed to be relatively accessible with minimal foot traverse to ensure all sampling objectives could be met, hence most sites were located adjacent to access tracks.

Table 1. The location of GDE assessment sites and sampling purpose.

GDE assessment site	Landform	Purpose	Targeted RE
1, 4, 8, 12	Residual landform with loamy clay soils (often red)	Sampling of Low Potential Terrestrial GDEs associated with remnant eucalypt woodland habitats.	11.5.3
3	Residual sandy soils over clay and shallow bedrock	Sampling of Low Potential Terrestrial GDEs associated with remnant eucalypt dominant woodlands.	11.5.9
2	Residual landform with loamy clay soils	Investigation of a Moderate Potential Aquatic GDE associated with the margins of a residual escarpment.	Non-remnant
5, 6, 7	Residual clay plains with gilgai development	Sampling of Brigalow TEC patches. All sampled patches are outside mapped Terrestrial GDEs from the GDE Atlas (BOM 2024).	11.4.9 (Brigalow TEC)
9, 10, 11	Residual clay and clay loam plains over shallow basement (sedimentary) rocks.	Sampling of Low Potential Terrestrial GDEs associated remnant eucalypt woodland habitats.	11.4.8
14, 15	Alluvial clays associated with riverine floodplain.	Sampling of Low Potential Terrestrial GDEs associated with mapped occurrences of the Brigalow TEC associated with a riverine floodplain.	11.3.1 (Brigalow TEC)
13	Elevated rocky plateau with a superficial sand covering.	Sampling of Low Potential Terrestrial GDEs associated with lancewood (*Acacia shirleyi*) habitats.	11.7.2

4.2 Leaf Water Potential

Leaf Water Potential (LWP) defines the work required per unit quantity of water to transport it from the moisture held in the soil to leaf stomata. LWP balances osmotic potential, turgor pressure, and matric potential. It is a function of soil water availability, evaporative demand, and soil conductivity. LWP was measured pre-dawn (before sunrise) as per standard protocol. Due to a lack of transpiration, LWP will equilibrate with the wettest portion of the soil, which contains a significant amount of root material. LWP will shift to a lower status pre-dawn as the soil dries out seasonally (Eamus 2006a). Measurement of LWP pre-dawn thus indicates the water availability to trees at each assessment site and whether trees are tapping saturated zones of the soil profile where water is freely accessible or utilising moisture that is more tightly bound to soil particles.

Survey localities were sampled pre-dawn (first light to pre-sunrise), and leaves were collected from three to five mature canopy trees with a 9 m extension pole fitted with a lopping head. Sampling focused on both brigalow (*Acacia harpophylla)*, and other eucalypt species with potential to be a facultative phreatophyte. Collected branches were double bagged in black plastic to avoid moisture loss and sun exposure, and LWP was measured on-site within half an hour of harvest. Leaf material was trimmed with a fine blade and inserted into an appropriate grommet for sealing within a Model 3115 Plant Water Status Console (Soil Moisture Equipment Corp, 2007). The chamber was sealed and gradually pressurised with nitrogen until the first drop of leaf water emerged from the petiole with values represented in millipascals (MPa) for direct comparison to Soil Moisture Potential (SMP) measurements. In total, 32 trees were assessed for LWP across the fifteen assessment sites, with the location of these trees detailed in Section 4.2. The following categories were applied as a measure of relative water availability:

- Extremely High: LWP >-0.276 MPa
- Very High: LWP -0.276 to -0.580 MPa
- High: LWP <-0.580 to -0.896 MPa
- Moderate: LWP <-0.896 to -1.21 MPa
- Low: LWP <-1.21 to -1.72 MPa
- Very Low: LWP <-1.72 to -2.21 MPa
- Extremely Low: LWP <-2.21 MPa

While the defining values of these categories are arbitrary, they indicate the likely degree and nature of groundwater dependence or interaction. The ‘Extremely High’ category would indicate the potential for interaction with a highly fresh groundwater source, with the degree of groundwater interaction decreasing to the ‘Moderate’ category, which may indicate either utilisation of soil moisture from the vadose zone or interaction with saline groundwater. Categories of ‘Low’ to ‘Extremely Low’ are considered unlikely to utilise groundwater to any degree, regardless of salinity. It should also be noted that soil moisture in the ‘Extremely High’ category can be supplied directly from unsaturated portions of the soil profile depending on moisture availability, which can be assessed by measuring SMP.

4.3 Soil Moisture Potential

A hand auger was utilised to collect shallow soil samples at regular depths down the soil profile at selected sites and opportunistic sampling of groundwater where intersected. Selection of sites for auger placement considered:

1. Whether LWP measurements indicated a higher degree of water availability in the soil profile than other assessment localities, suggesting that shallow groundwater or a soil zone of higher matric potential exists at depth (i.e. a sand lens may be present in the soil profile).
2. The representativeness of a particular chosen site as a means to provide information that applies to other assessment localities.

At each site chosen for auger sampling, the aim was to collect soil samples to the maximum depth of the auger of penetration, with penetration often arrested by coarse gravel / cobble substrates, large tree roots, or refusal at relatively shallow depths in the soil profile due to a high density of root material. Observations taken for each auger hole included:

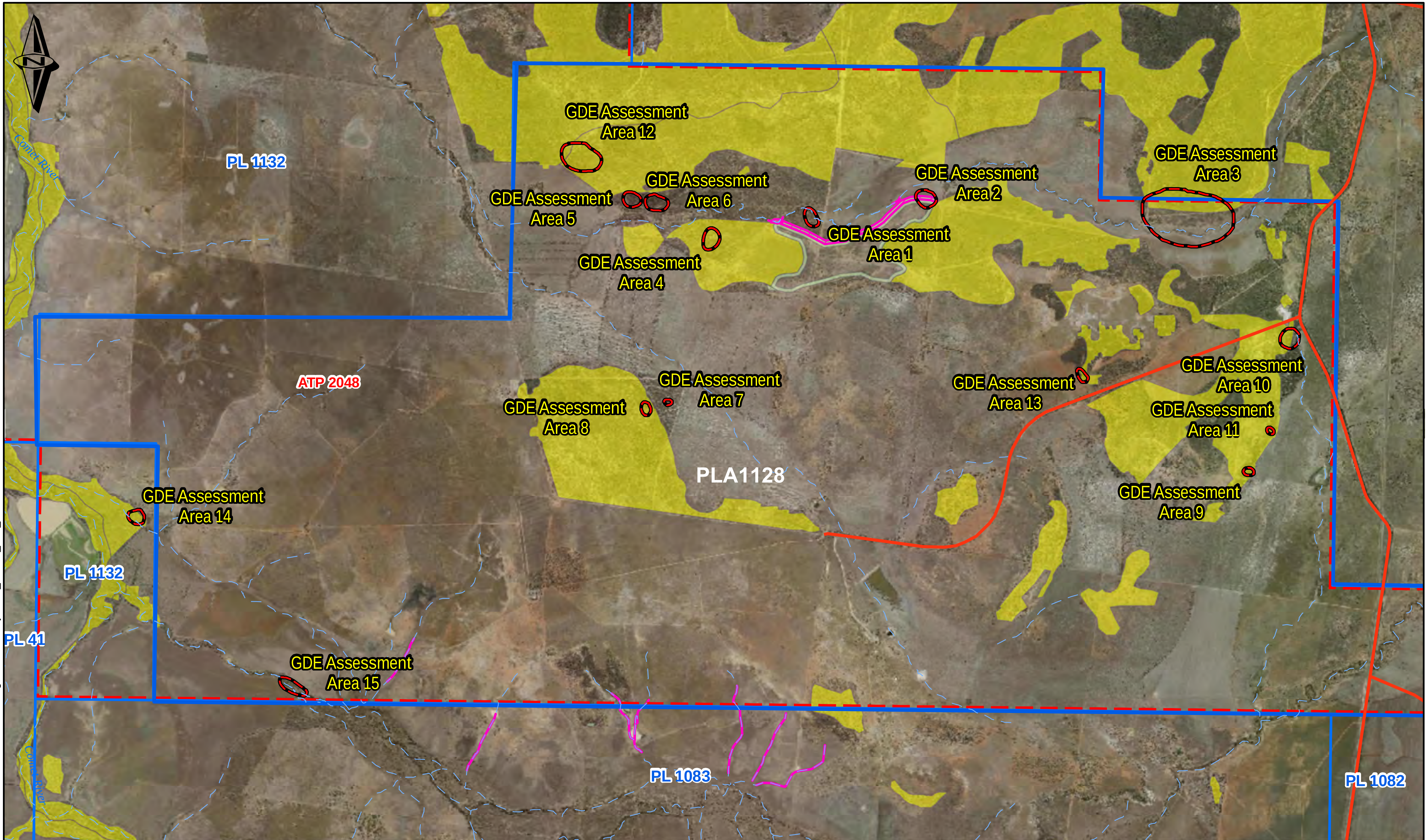
1. Soil structure, colour, and texture.
2. Presence of root matter.
3. Soil moisture/water and areas of saturation.

Soil sampling was undertaken at regular intervals down the soil profile for analysis of stable isotopes of oxygen ($\delta^{18}O$) and deuterium ($\delta^{2}H$), and duplicate samples were retained for analysis of SMP.

Sample collection was generally spaced at 0.5 m down the auger profile, with additional samples taken where changes in soil structure/texture, moisture content, or zones of tree roots were intersected. Samples were sealed in airtight plastic vials and placed on ice for later measurement of SMP.

SMP, which includes the matric (water availability) and osmotic (saltiness) potential, measures the energy required to extract moisture from the soil. Water can only move down a hydraulic gradient from soil to root (Gardner, 1960). Areas in the soil profile with a less negative SMP than measured pre-dawn LWP will be accessible as a source of moisture. Large, mature trees are unable to extract moisture from regions in the soil profile where the total SMP is significantly below LWP measured in pre-dawn leaf material (Feikema et al., 2010; Lamontagne et al., 2005; Thorburn et al., 1994; Mensforth et al., 1994; Holland et al., 2009 and Doody et al., 2015). The maximum suction roots for crops can apply to soil/rock before a plant wilts due to a negative water supply is approximately -15 bars or -1.5 MPa (or -217.55 psi). This wilting point is relatively consistent between all plant species. However, many Australian plants have adapted to conditions of low water availability and can persist strongly in soil conditions where moisture potential is below standard wilting point (Eamus, 2006a). As a general measure, however, where measured LWP is below the standard wilting point, it indicates plant water deficit, and the tree is unlikely to be supported by a saturated water source regardless of groundwater salinity.

Soils were sampled at regular intervals down a soil profile for measurement of SMP, with sampling intervals dependent on the degree of structural and lithological heterogeneity. The measurement of SMP was completed in the laboratory with a portable Dew Point Potentiometer (WP4C) (Meter et al., 2021). The WP4C meter uses the chilled mirror dew point technique with the sample equilibrated within the headspace of a sealed chamber that contains a mirror and a means of detecting condensation on the mirror. Soil moisture potential samples were measured in millipascals (mPa). A 7 ml soil sample was inserted into the WP4C meter using a stainless-steel measuring tray.



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Coordinate System: GDA 2020 MGA Zone 55 A4

Legend

- Drainage
- GDE Assessment Areas
- PLA 1128
- Petroleum_leases
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Aquatic GDE

- Moderate potential GDE - from regional studies

Terrestial GDE

- Moderate potential GDE - from regional studies
- Low potential GDE - from regional studies

Figure 5. GDE areas targeted for field assessment.

Client: Epic Environmental

Project: Comet Ridge Mahalo Project.

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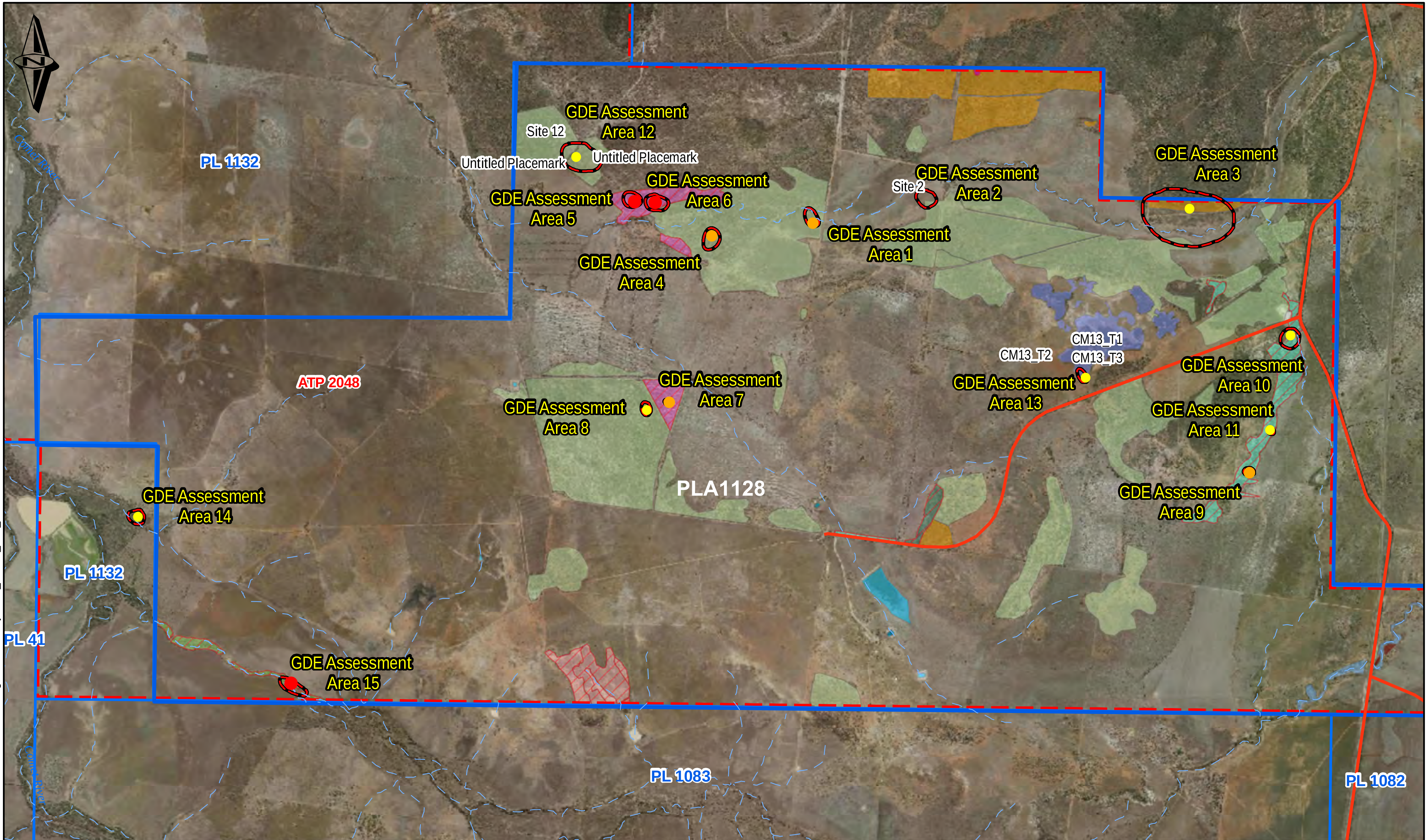

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0 0.5 1 1.5 2 KM

Coordinate System: GDA 2020 MGA Zone 55 A4

Legend

Water Availability		Threatened Ecological Community	Ground-truthed regional ecosystems		
Low	Drainage	Brigalow	11.3.1	11.4.8	11.5.3
Very low	GDE Assessment Areas		11.3.25	11.4.9	11.5.9a
Extremely low	PLA 1128		11.3.4	11.4.9a	11.7.2
	Petroleum_leases		11.4.7	11.5.16	water
	Exploration permits for petroleum				

Figure 6. Field verified RE mapping relative to GDE Assessment Areas

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4.4 Stable Isotope Sampling and Analyses

Trees may utilise water from various sources including the phreatic zone (saturated zone), the vadose zone (unsaturated zone) and surface water. The stable isotopes of water, oxygen 18 ($\delta^{18}O$), and deuterium ($\delta^{2}H$) are valuable tools to help define terrestrial vegetation's predominant water source. The method relies on a comparison between the stable isotope ratios of water contained in plant xylem (from a twig or xylem core) with stable isotope ratios found in the various sources of water, including a shallow groundwater table, potential sub-artesian aquifer water sources or shallow soil moisture. Methods used to assess stable isotopes are detailed below.

4.4.1 Local Meteoric Water Line

Data interpretation is supported by incorporating isotopic data from rainfall collected in the Bowen Basin between 2018 and 2022, which is applied to construct a best-fit Local Meteoric Water Line (LMWL) using simple linear regression (Craig, 1961). The constructed LMWL defines a slope of 6.852 and d-excess of 9.776 (Y = 6.852*X + 9.776), which is shallower than the Brisbane Meteoric Water, which defines a slope of 7.6 and d-excess of 12.8 (Y = 7.6*X + 12.8) (Crosbie et al., 2012). While construction of the LMWL is based on a limited number of samples (5 in total as per **Appendix D**), the data provides sufficient utility to support the development of a preliminary LMWL for the Clermont region.

4.4.2 Soil Moisture Isotopes

Sampling was undertaken regularly in auger holes to capture isotopic signatures from a range of potential plant moisture sources from the upper soil surface to the top of the phreatic zone in shallow water tables. The sampling intervals for soil moisture isotope analyses depended on auger yield and soil variation. In general, the initial soil sample was taken within the top 0.2 m of the soil profile, and subsequent samples were taken at 0.5 m intervals down the soil profile to the end of the hole, mirroring the interval for SMP. Approximately 200 milligrams (mg) of soil was collected for isotope analysis, sealed in airtight plastic sampling containers, double-sleeved in click-seal plastic bags, and placed on ice for storage prior to dispatch to the Australian National University (ANU) Stable Isotope Laboratory for analysis where they were snap frozen until analysis was complete.

Soil intervals selected for stable isotope analysis include where tree roots were recorded, exceptionally moist intervals, or at the base of the auger hole where high soil moisture/groundwater was recorded. In some localities, isotopic sampling of complete profiles was undertaken to aid data interpretation.

4.4.3 Xylem Water Isotopes

Twigs were collected from the outer canopy branches of target trees used to sample LWP. The following sampling procedure was applied:

1. Harvesting of outer branches of trees of the target tree at the GDE assessment site was completed, with two duplicate samples prepared from each branch for analysis.
2. The position of trees subject to assessment was marked with a GPS, and structural measurements, including height and diameter at breast height (dbh), were recorded.
3. Outer branches from each tree were harvested with an extendable aluminium pole.

4. Stem material approximately 5 cm in length was sourced with stainless-steel secateurs.
5. The bark was immediately removed, and stems were sealed in wide-mouth sample containers with leakproof polypropylene closures (approx. 125 ml volume). They were immediately labelled with the tree number and placed in an iced storage vessel prior to dispatch to the ANU Stable Isotope Laboratory.
6. Upon receipt of samples at the ANU Stable Isotope Laboratory, samples were snap-frozen (-18 degrees Celsius) until analysis.
7. Samples were taken from the xylem to be as close to the centre of the twig as possible. Extracted water was analysed using a Picarro L2140i cavity ring-down spectrometer for both xylem and soil samples.

Multiple samples were taken from a single branch sample at all sampling localities for xylem water analysis. From each branch sampled, the twig samples returning the lowest degree of isotopic enrichment were used as the reference because there may be considerable partitioning of isotope ratios across a twig cross-section (moving from the xylem to the phloem). It is only sometimes possible to consistently sample the same region of a twig when multiple samples are submitted for analysis. There is also potential for fractionation of stable isotope values, particularly δ^2H, during water movement through the xylem from roots to leaves (Evaristo et al., 2017; Petit & Froend, 2018). As fractionation will likely result in isotopic enrichment rather than depletion, the least enriched sample from each tree is considered most likely to be representative of the soil moisture or groundwater source.

4.4.4 Water Sampling

To compare the isotopic signature of groundwater to that of vegetation, water samples were collected from various sources including:

- Shallow groundwater intercepted in soil augers (if present).
- Surface waters.
- Selected developed groundwater monitoring bores (sampled by RDM Hydro) including those specifically installed as GDE monitoring bores.

All samples were dispatched to ANU to analyse stable isotope composition. Six dedicated GDE monitoring bores were installed to measure standing water levels (SWLs), water quality, and seasonal variation, as provided in **Table 2**. The location of all groundwater bores, including DNRM Registered bores, is shown in **Figure 7** relative to mapped GDEs. SWLs for the various formations. Data from bore construction reports indicates:

- The shallowest groundwater levels reported are 7.97 metres below ground level (mbgl) at monitoring well MN-MB1-a, southwest of PLA 1128. The groundwater salinity reported for this monitoring well is 33 400 µS/cm.
- More typical groundwater depths range from 20 to 22 mbgl, with groundwater associated with sandstone intervals in the Rewan Formation. Groundwater is typically saline with reported salinities from 30 000 to 51 900 µS/cm (MN-MB6-b and MN-MB5-R).
- Three installed monitoring wells were dry or produced insufficient water to draw a sample.

Table 2. Bore target formation, standing water level (SWL), and general water quality for installed dedicated GDE monitoring bores.

GDE Monitoring Bore Temp ID	Y	X	Constructed Depth (m)	Screen Depth(mbgl)	Formation/Screened Interval	SWL (mbgl)	Field EC (µS/cm)
MN-MB6-b	-24.02003	148.62113	30	23.0 – 23.9	Sandstone – Mudstone (Rewan Formation)	21.36	30 000
MN-MB4-b	-24.03918	148.61745	20	16 - 19	Clay – siltone – sandstone (Rewan Formation)	19.98	Insufficient water to sample
MN-MB5-R	-24.03926	148.61826	35	34.1	Silstone – sandstone (Rewan Formation)	21.46	51 900
MN-MB3-a	-24.0671	148.71576	25.1	18.3-24.3	Mudstone – Rewan Formation	Dry	-
MN-MB1-a	-24.06602	148.55875	17.1	10.1 - 16.1	Interface between alluvium and siltstone (Rewan Formation)	7.97	33 400
MN-MB2-b	-24.06597	148.55866	24	-	Hole abandoned due to adverse locations. Dry to drilled depth.	Dry	-

4.5 Data Reconciliation and Interpretation

Data interpretation followed a structured approach by filtering multiple lines of evidence to assess groundwater dependence. The biophysical measurement of LWP formed the primary assessment, followed by the adjunct comparison with SMP, with stable isotope data used to provide supplementary evidence where ambiguity remained. In addition, an overview of the depth of the groundwater table and groundwater salinity was completed as a final filter to determine the accessibility of groundwater and suitability as a source of moisture to support transpiration at each assessment locality.

Step 1. LWP: An initial comparison of individual trees' LWP values within the expected range for known terrestrial GDEs subject to various salinity regimes, assuming complete saturation of sediments in the groundwater table and minimal influence of soil matric potential, is applied. This data is derived from a range of published sources, including Jones et al. (2020), Holland et al., (2009), and Mensforth et al., (1994):

- Expected LWP for trees in equilibrium with a fresh to brackish saturated source of moisture (EC<1500 µS/cm) = >-0.2MPa.
- Expected LWP for trees in equilibrium with a moderately saline soil moisture source (EC>1500 to 10 000 µS /cm) =-0.2MPa to -0.55MPa.
- Expected LWP for trees in equilibrium with a saline soil moisture source (EC>10 000 to 30 000 µS /cm) = -0.55MPa to -1.5MPa.

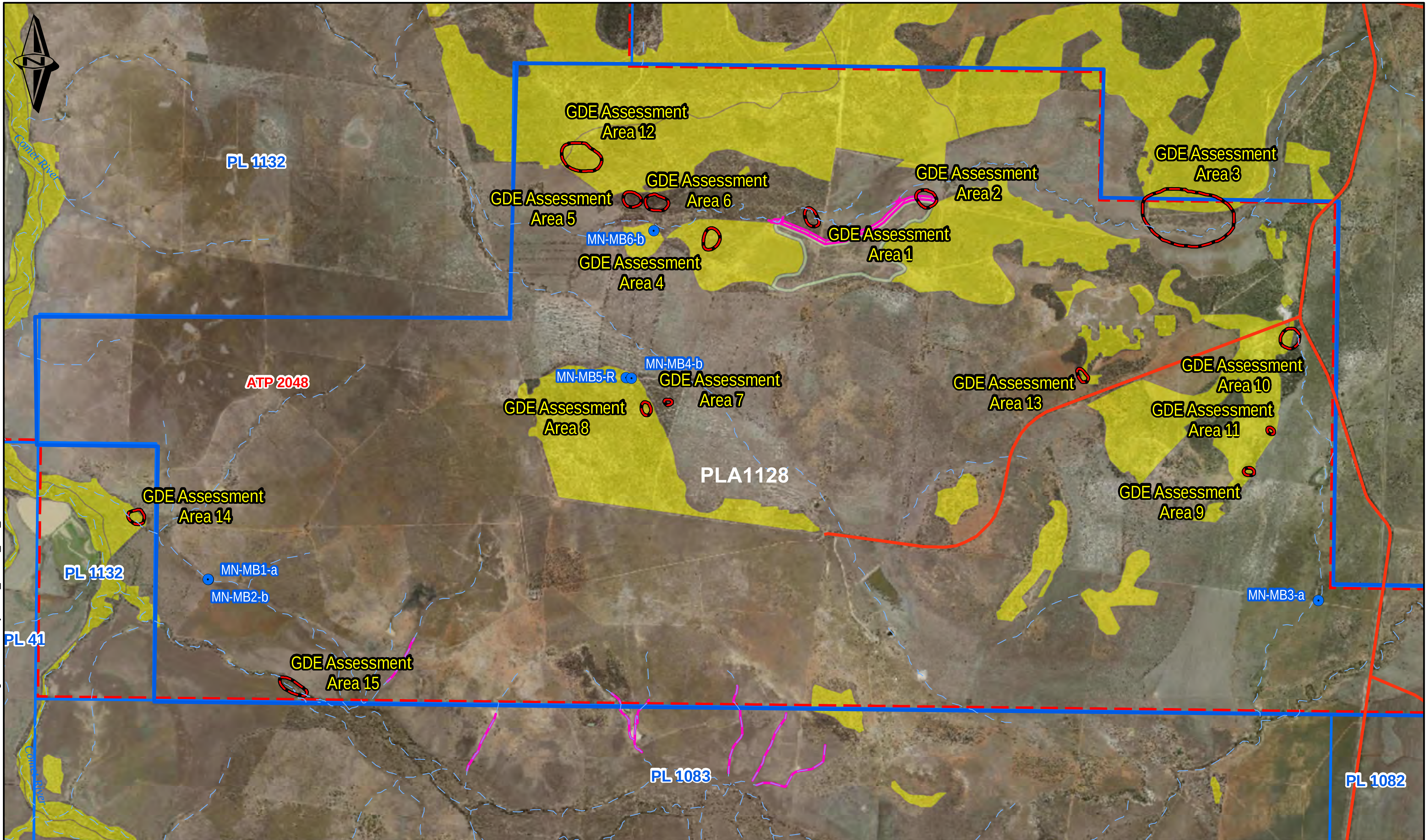
Where groundwater regimes exhibit varying salinity regimes, this greatly increases the complexity and uncertainty of LWP assessments, meaning much greater reliance on other analytical tools, such as stable isotopes. However, trees that demonstrate LWP values that are considerably more negative than expected ranges for the local groundwater salinity regimes are assumed not to exhibit any significant degree of groundwater dependence. From the range of groundwater salinities recorded from monitoring bores, sites with average LWP <-1.5 MPa (standard wilting point) were not subject to further scrutiny other than for comparative purposes. Groundwater with salinity > 30 000 µS /cm is considered an unsuitable source of moisture for most trees and unlikely to be utilised by deep rooted vegetation.

Step 2. Soil Augering and SMP: Soil augering is helpful for a) direct observation of soil physical properties including depth to bedrock; b) physical observation of distribution of tree roots down within the soil profile; c) identification and sampling of shallow groundwater tables; and d) measurement of soil biophysical properties including SMP. For trees where LWP was within the expected range of values for GDEs under specific local salinity regimes, soil augering allowed the direct observation of the physical features of the soil profile, as well as facilitated measurement of SMP to identify the likelihood that moisture for transpiration was being supplied from the upper soil profile, or whether deeper sources of moisture may exist. As described in **Section 3.3**, water can only move down a hydraulic gradient from soil to root, meaning that only those portions of the soil profile with an SMP that is less negative than measured pre-dawn LWP will be accessible as a source of moisture (Gardner, 1960). This does not provide an absolute assessment of groundwater dependence, though it identifies potential sources of moisture to give context to evaluating stable isotopes (Step 3). SMP data is only available at some sites, increasing the reliance on stable isotopes during data reconciliation.

Step 3. Stable Isotope Signatures: For trees that demonstrate potential groundwater dependence from LWP measurements, stable isotope signatures from the xylem samples were compared to signatures from groundwater, surface water from residual and permanent pools, and soil moisture (where this data was available) to provide a fingerprint for the source of moisture being utilised. Where three lines of evidence indicated utilisation of a groundwater source, the tree was generally accepted as being groundwater dependent. Where ambiguity remained in the assessment, additional features were considered, including site-specific geology, geomorphology, soil physical properties, groundwater salinity, and depth to the water table at the location to inform the final assessment of groundwater dependence for any tree or site.

4.6 Limitations and Other Information Relevant to the Assessment

This assessment provides a snapshot of ecohydrological process at each of the fifteen GDE assessment sites identified during the pre-survey desktop assessment. Due to the intensive nature of the data collection process, representative areas were chosen for GDE sampling which were used as a basis for extrapolation over broader areas considered to present similar ecohydrological function. The data collection process aimed to conceptualise the ecohydrological characteristics of any GDEs confirmed to be present in the Study Area and their general distribution.



Legend

- GDE Monitoring Bores
- Drainage
- GDE Assessment Areas
- PLA 1128
- Petroleum_leases
- Exploration permits for petroleum

Aquatic GDE

- Moderate potential GDE - from regional studies

Terrestial GDE

- Moderate potential GDE - from regional studies
- Low potential GDE - from regional studies

Figure 7. Groundwater monitoring bores relative to mapped GDEs

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5.0 Site Level Ecohydrology

The following section provides an overview of the ecohydrological characteristics of the major tree species associated with REs 11.3.1, 11.4.8, 11.4.9, 11.5.3, 11.5.9a and RE11.7.2, which were sampled during the field assessment due to their representation as potential GDEs in the GDE Atlas (BOM, 2024).

5.1 Eucalypts

Four eucalypt species were sampled during the GDE assessment, being poplar box (*Eucalyptus populnea*) in RE11.5.3, coolabah (*Eucalyptus coolabah)* as a canopy emergent within RE11.3.1, Dawson gum *(Eucalyptus cambageana)* as a canopy dominant in RE11.4.8 and a canopy emergent within RE11.4.9, and silver-leafed ironbark (*Eucalyptus melanophloia)* as a dominant canopy tree in RE11.5.9.

Coolabah: *Eucalyptus coolabah* favours sites with heavier clay soils, typically close to drainage lines and requires flooding for regeneration (Roberts 1993). There are few studies that attempt to detail the moisture sources and usage strategies of *Eucalyptus coolabah.* Costelloe et al., (2008) suggest that coolabah avoids using saline groundwater via the following mechanisms:

1. Growing at sites that maximise the frequency of soil moisture replenishment (i.e. on drainage lines and overflow channels).
2. Having extremely low transpiration rates.
3. Strong capacity to extract moisture from soils with extremely low osmotic / matric potentials.

Costelloe et al., (2008) concluded that coolabah avoided using hypersaline groundwater (71 000 mg/L[Cl] or 70 290 µs/cm), instead favouring the use of low salinity soil moisture in the vadose zone above the groundwater table. Coolabah can however continue to extract moisture at Cl concentrations up to 30 000 mg/L (~27 800 µS/cm) in soils where matric potential in the upper soil profile is extremely low due to a combination of extreme drying coupled with a clayey substrate.

The heavy clay soils that support the Brigalow TEC place a physical limitation on tree root penetration. Clay substrates are an unsuitable medium for development of a deep tap root system that would be necessary to penetrate to the groundwater table (Dupuy et al., 2005) and soils with low hydraulic conductivities, such as clays, greatly limit the ability of trees to utilise groundwater (Feikema et al., 2010). Hence it is not expected that coolabah would have the same capacity to develop the deeper tap roots that characterise river red gum, and maximum rooting depth would be considerably shallower, most likely considerably less than 10 m.

Other Eucalyptus Species: All eucalyptus species are potential users of groundwater (Cook et al 2007) although few studies demonstrating this dependence exist. Fensham and Fairfax (2007) consider poplar box, and silver leaf ironbark (*Eucalyptus melanophloia)* to possess a shallow rooting system with limited investment in deep root architecture, rendering them susceptible to droughting. Poplar box is more typically associated with upper terraces that are elevated above the river channel requiring a deeper rooting system to access groundwater. Silver leaf ironbark generally occupies more elevated portions of the landscape, away from drainage lines where depth to groundwater would be greatest. For Dawson gum (*Eucalyptus cambageana)*, the general association of the species with heavy clay soils and brigalow suggests that there will be limited development of deeper sinker roots. It is expected that species ecology will be similar to poplar box and coolabah, with a strong association with heavy clay soils, presenting a physical limitation on tree root penetration (Dupuy et al., 2005).

5.2 Acacia's

Brigalow (*Acacia harpophylla)* habitats and individual trees regularly occur adjacent to the floodplain of the major drainage systems and generally occupy heavy clay soils (vertosols) with well-developed gilgai microtopography in the upper soil profile (0.6 m to surface) where the bulk of nutrient recycling occurs. The subsoil components are however typically strongly cohesive clays with high levels of salinity, sodicity, acidity and phytotoxic concentrations of chloride which may reduce the effective rooting depth in these soils (Dang et al., 2012). Johnson et al., (2016) describe brigalow as *'a clonal species with stems arising from horizontal roots which draw resources from a substantial area around the plant'*. The concentration of the brigalow root mass in the upper soil profile enables the species to resprout profusely from horizontal roots after physical disturbance and limits the capacity for other woody species to compete for moisture and nutrients. Brigalow's shallow rooting habit is evident with the tendency of mature trees to topple because of churning in the upper soil profile with fallen trees universally exposing a well-developed lateral root system with little evidence for development of deeper sinker roots that would have capacity to propagate to deeper groundwater tables. Brigalow is not considered to represent groundwater dependent vegetation.

Unlike brigalow, lancewood (*Acacia shirleyi*) is associated with rocky substates with skeletal soils, typically on lateritic plateaus and outcrops. There is no evidence that lancewood has capacity to utilise groundwater to any degree.

5.3 Summary - Depth of Tree Rooting and Salinity Tolerances

As described in previous sections, tree rooting depth is a difficult parameter to predict and measure as it depends on several factors including tree species, substrate, edaphic conditions, as well as depth to groundwater. Tree root penetration is typically arrested at the capillary fringe (Eamus et al 2006b). DNRME (2013) considers 20 m to represent the maximum potential rooting depth of river red gum (*Eucalyptus camaldulensis)*, the species where the most information on tree rooting depth has been obtained, although this would likely only occur under optimal conditions with favourable soil types and moisture unencumbered by salinity. As previously discussed, other authors have suggested much shallower maximum rooting depths including Jones et al (2020) at 8.1 mbgl based on physical observation and Horner et al. (2009) at 12–15 mbgl and Doody et al., (2019) suggests that vegetation will only consistently utilise groundwater where it occurs at depths of <10 m below the land surface. Based on these observations, it is unlikely that river red gum would be utilising a groundwater table deeper than 15 mbgl, and for other species including coolabah, poplar box, silver leaf ironbark, Dawson gum and brigalow, the groundwater depth threshold would be considerably shallower (<10 m).

Based on evidence from published literature (Costelloe et al., 2008; Thorburn et al., 1994, Mensforth et al., 1994) and the Watermark Eco's experience, it is unlikely that the terrestrial woody vegetation that characterises the study area would have capacity to utilise groundwater that has salinity greater than 30 000 µS/cm, instead relying on whatever fresh moisture that can be extracted from the vadose zone. It is also unlikely that any tree would invest in the development of a deep root system to tap water from a saline water table, where the benefits in terms of increased water availability would be very marginal.

6.0 Results

6.1. Leaf Water Potential

Figure 8 shows the average LWP values for the fifteen GDE assessment sites, **Figure 9** represents the LWP values for individual trees, and **Figure 10** provides a spatial representation of average values. The data demonstrates that average LWP values at most sites lie below the standard wilting point, spanning Low to Extremely Low moisture availability ranges.

- Assessment sites associated with the Brigalow TEC, including RE11.4.9 (Sites CM_S5, CM_S6 & CM_S7), RE11.4.8 (CM_S4, CM_S9, CM_S10 & CM_S11), and RE11.3.1 (CMS_14 & CMS_15), have LWP values that fall within the Very Low to Extremely Low range (-1.65 to -3.4 MPa). These sites are unlikely to be associated with any degree of groundwater dependence. **Figure 10** demonstrates that brigalow consistently has the lowest moisture availability of all trees, particularly at Sites CM_S5 and CM_S6, indicating the species' tolerance to extremely dry edaphic conditions. Coolabah and Dawson gum, growing in association with brigalow, demonstrate a similar range of LWP values across all assessment sites, generally falling close to or below standard wilting point.
- CM_S3 and CM_S13, associated with silver leaf ironbark (RE11.5.9) and lancewood (RE11.7.2), record the highest (least negative) average LWP values, implying the highest moisture availability at -1.13 (Moderate moisture availability) and -1.38 MPa (Low moisture availability) respectively.
- Poplar box woodlands at Sites CM_S1 and CM_S12 fall mostly below standard wilting point, consistent with values reported for coolabah and Dawson gum. However, values for poplar box are slightly higher at CM_S8 (-1.1 to -1.2 MPa as per **Figure 10**).
- Site CM_S2 was visited on the ground. As there were no mature trees at this assessment site, LWP sampling was not completed. There was no observed seepage or surface water expression in the vicinity, as might be inferred from mapping presented in the GDE Atlas (BOM 2024).

Overall, the data indicates low moisture availability across most, if not all, habitats, suggesting that the potential for groundwater reliance is extremely low across PLA 1128, and brigalow is reliant on soil moisture held within characteristically tight clay soils. **Section**

5.2 examines edaphic controls on moisture availability, which may account for the significantly higher moisture status demonstrated for silver leaf ironbark (CM_S3) and lancewood (CM_S13).

Table 3 provides an initial assessment of the likelihood of groundwater utilisation for all sites at the time of assessment. The potential for those trees with LWP values <-0.55 to utilise groundwater becomes increasingly unlikely as LWP values become more negative, although saline groundwater may complicate this. Based on this data, however, any degree of groundwater dependence for brigalow dominant and co-dominant habitats, including trees associated with RE11.3.1, 11.4.8, and 11.4.9, seems extremely unlikely. **Appendix A** provides a structural summary of all trees assessed for LWP.

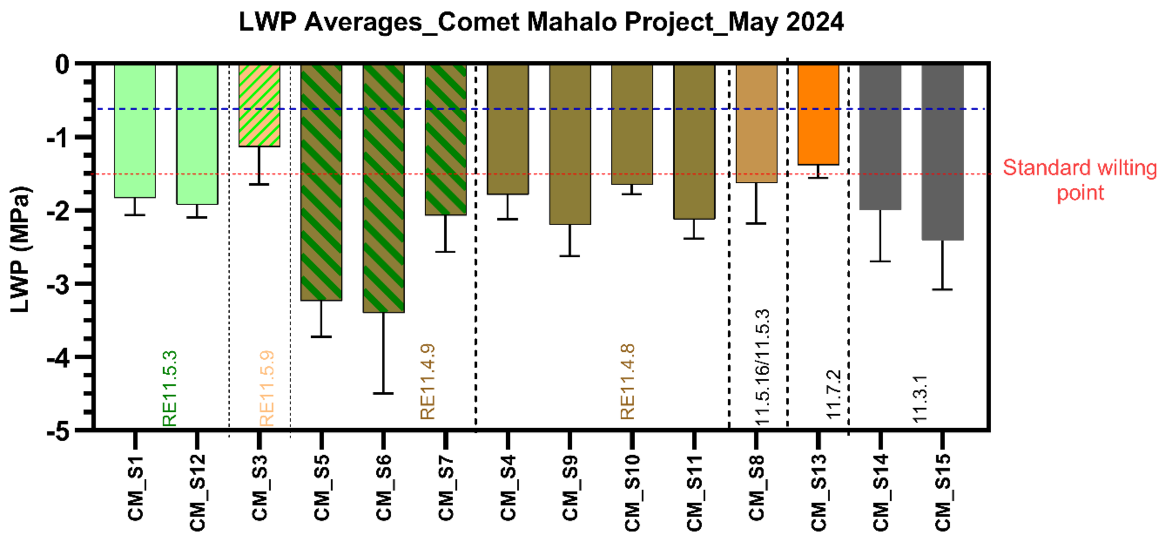


Figure 8. Average LWP values for all assessment sites with the blue dashed line indicating extremely high moisture availability, and the red dashed line indicating Standard Wilting Point (for reference).

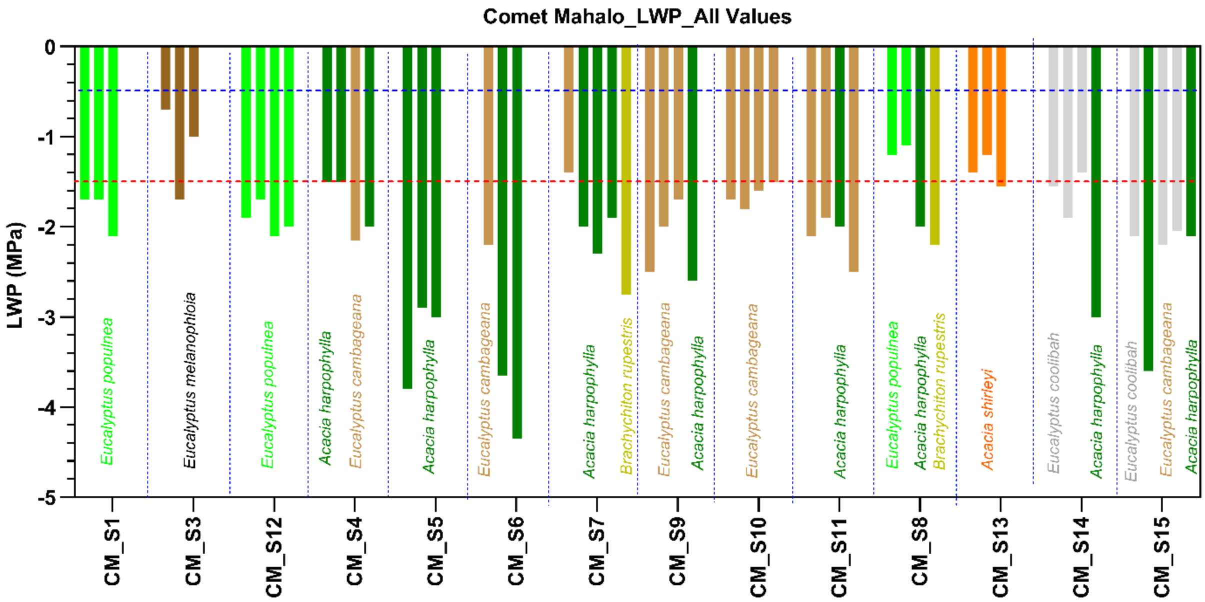
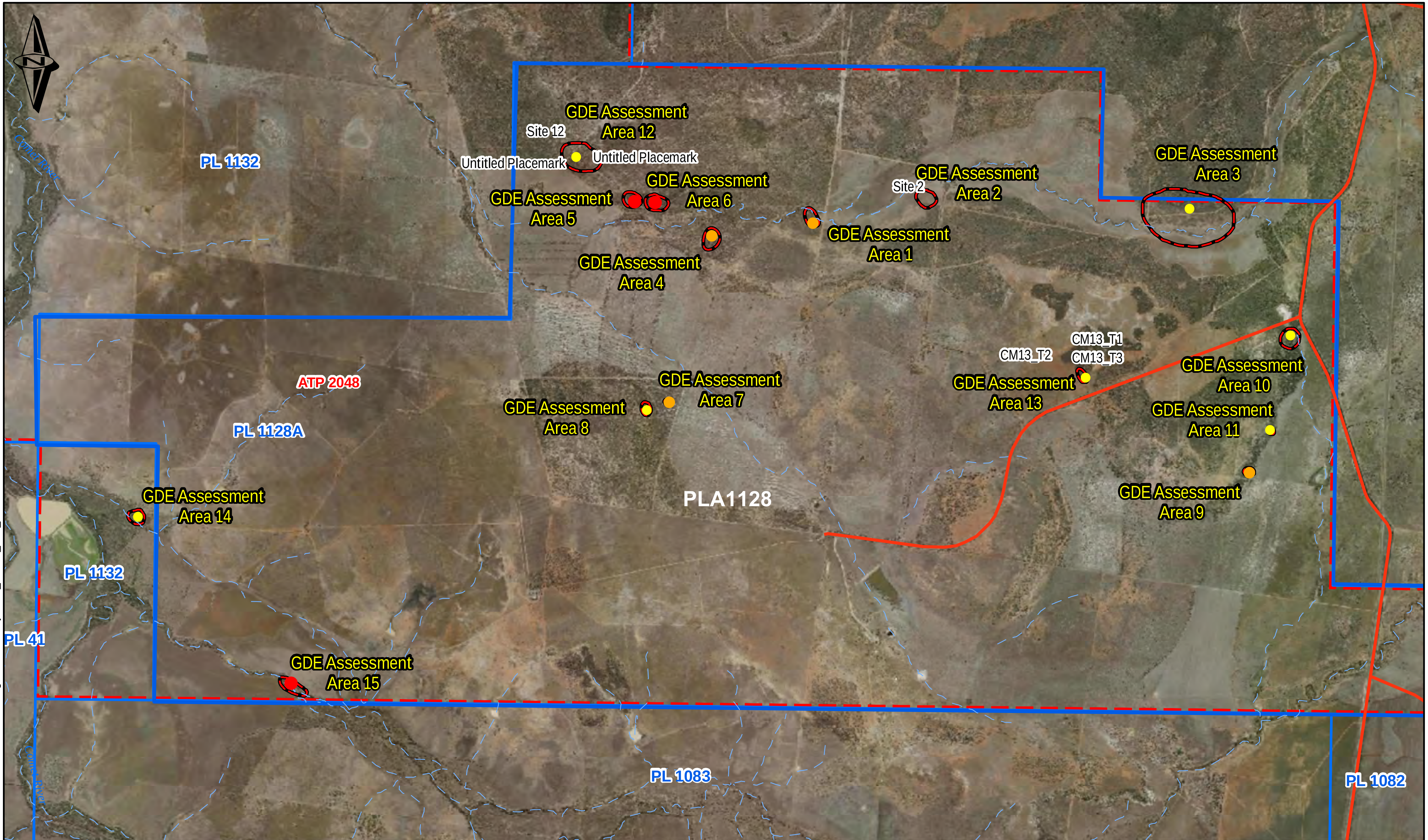


Figure 9. LWP values for individual trees across all assessment sites with the with the blue dashed line indicating extremely high moisture availability, and the red dashed line indicating Standard Wilting Point (for reference).



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0 0.5 1 1.5 2 KM

Coordinate System: GDA 2020 MGA Zone 55 A4

Legend

Water Availability
- Low
- Very low
- Extremely low

- Drainage
- GDE Assessment Areas
- PLA 1128
- Petroleum_leases
- Exploration permits for petroleum

Figure 9. Average LWP values for GDE assessment sites.

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Table 3. Summary details and results of LWP assessment for each GDE assessment site.

Site	Average LWP (MPa)	Water Availability	Comments
RE11.5.9 – *Eucalyptus melanophloia*			
CM_S3	-0.7 to -1.7 MPa	High to Low	The highest LWP value (-0.7MPa) suggests some potential for groundwater usage, though LWPs at the site are highly variable, indicating mixed moisture sources. The shallow root system of silver leaf ironbark (Fensham & Fairfax. 2007) suggests that trees are most likely accessing moisture in the shallow soil profile rather than deeper groundwater sources. Further evidence from soil moisture profiling and stable isotopes is required to confirm moisture sources at this GDE assessment site.
RE11.5.3 – *Eucalyptus populnea*			
Site CMS_1, CMS_8, CMS_12	-1.1 to -2.1 MPa	Moderate to Extremely Low	The sampled poplar box at sites CM_S1 and CM_S12 have LWP values in the Low (-1.7 MPa) to Extremely Low (-2.1) range indicating limited moisture availability. For Site CM_S8, the slightly higher LWP values for the poplar box suggest some potential for utilising saline groundwater, although the shallow rooting systems of poplar box suggest that these trees are more likely utilising soil moisture from unsaturated regions of the soil profile. The most relevant groundwater monitoring bores for these ecosystems are MN-MB4-b, MN-MB5-R, and MN-MB6-b, which have SWLs ~ of 21.5mbgl and salinities ranging from 30 000 to 51 900 µS/cm. Neither of these values renders groundwater a suitable source of moisture to support transpiration. No indication of groundwater utilisation at any of these assessment sites is given based on highly negative LWP values and unsuitable groundwater sources. Stable isotope analysis will provide further context.
RE11.3.1 (Brigalow TEC) – *Acacia harpophylla / Eucalyptus coolabah*			
Site CM_S14, CM_S15.	-1.4 to -3.1 MPa	Low to Extremely Low	RE11.3.1 comprises a mix of brigalow with larger emergent coolabah. The coolabah's LWP values range from -1.4 to -2.2 MPa, in the Low to Extremely Low range, suggesting limited potential for groundwater usage. This is consistent with the coolabah's inferred shallow rooting system and its edaphic preference for clay soils. Brigalow sampled at these sites demonstrate Extremely Low water potentials (<2.1 MPa), which precludes groundwater usage, consistent with Brigalow's shallow root system concentrated in the upper portions of a heavy clay soil profile. The most applicable groundwater monitoring bore for these sites is MN-MB1-a, which reported a SWL of 7.9mbgl and a groundwater salinity of 33 400 µS/cm. While the SWL may be at the lower limits of tree rooting depth, the high salinity of the groundwater means that it provides an unsuitable source of moisture to support transpiration.

Site	Average LWP (MPa)	Water Availability	Comments
			Based on evidence from LWP sampling and information on groundwater depth and salinity, groundwater utilisation for these brigalow ecosystems is unlikely. Soil moisture profiling and stable isotope analysis will provide further context.
RE11.4.9 and RE11.4.8 (Brigalow TEC) – *Eucalyptus cambageana / Acacia harpophylla / Brachychiton rupestris*			
Site CM_S4, CM_S5, CM_S6, CM_S7, CM_S9, CM_S10, CM_S11	-1.4 to -4.3MPa	Low to Extremely Low	These habitats mix Dawson gum and brigalow, with both species demonstrating Low to Extremely Low moisture availability. Some extreme LWP values are reported for brigalow (- 4 MPa), which indicates the species' tolerance of dry clay soils. The most relevant groundwater monitoring bores for these ecosystems are MN-MB4-b, MN-MB5-R, and MN-MB6-b, which have SWLs ~ of 21.5mbgl and salinities ranging from 30 000 to 51 900 µS/cm. Neither of these factors render groundwater a suitable source of moisture to support transpiration. No indication of groundwater utilisation at any of these assessment sites is given based on highly negative LWP values and unsuitable groundwater sources.
RE11.7.2 – *Acacia shirleyi*			
CM_S13	-1.2 to -1.55 MPa	Low	The Lancewood habitat sampled at CM_S13 consistently has higher LWP values than brigalow sites. This is more likely associated with higher moisture availability in the supporting substrate rather than an indication of groundwater usage. The clay soils associated with brigalow have significantly more negative matric potentials than sandy or stony soils, which can host freely available moisture in pore spaces or fractures after a moisture recharge event.

6.2 Soil Auger Sampling

The survey program included the sampling of five soil auger holes, focusing specifically on habitats associated with the Brigalow TEC and at other locations where LWP values suggested increased moisture availability. **Table 4** summarises auger location, target ecosystem, target geology, and depth, with auger logs representing the significant elements of the soil profile, including soil intervals, the depth of the groundwater table, and the presence of tree roots. Collection of soil samples occurred at each significant change in soil texture/moisture to measure SMP and stable isotope analysis. Soil moisture potential (SMP) was measured for each soil sample, and the results of these analyses were plotted directly on the auger logs. Appendix A shows the location of auger holes relative to sampled trees at each GDE assessment site. **Appendix C** provides a summary of SMP values.

Table 4. The location, depth and target of shallow auger holes sampled during the assessment.

Auger Hole	Y	X	Ecosystem Sampled (RE)	Auger Target	Total Auger Depth (m)
CM3_AU1	-24.016563	148.69681	11.5.9	Base of sandy residual soils at their interface with either tight clays or weathered bedrock.	1.25
CM7_AU1	-24.042292	148.62364	11.4.9	Base of the clay soil profile, at its intersection with weathered basement rock.	2.80
CM10_AU1	-24.032721	148.71131	11.4.8	Weathered bedrock at the base of loamy surface sediments	0.7
CM14_AU1	-24.058316	148.54832	11.3.1	Weathered bedrock at the base of the alluvial clay profile	1.6
CM15_AU1	-24.080332	148.57195	11.3.1	Weathered bedrock at the base of the alluvial clay profile	2.75

6.2.1 RE11.3.1 (Auger CM14_AU1 and CM15_AU1)

Augers CM14_AU1 and CM15_AU1 were placed into alluvial clays associated with the Brigalow TEC. Auger CM14_AU1 encountered 1.6 m of heavy alluvial clay (black soil) before being arrested in an indurated calcrete layer overlying hard grey clay / weathered sediment. Coarse tree roots were intersected at 1.0 mbgl and at 1.5 mbgl at the base of the alluvial clay horizon (**Figure 11** and **Photograph 1**). Downhole profiling indicates an intersection between LWP and SMP values at 0.75 to 1.0 mbgl and a depth of 1.6 mbgl at the clay base, suggesting that the LWP values can be accounted for by moisture in the shallow soil profile. Auger CM_S14 did not intersect groundwater, and the soil profile remained dry to full depth.

Compared to CM14_AU1, a similar, much deeper alluvial clay profile was intersected in CM15_AU1 (**Figure 12**). The profile demonstrated a hardened grey-brown clay loam down to depths of 2.0 mbgl before passing into a more heterogeneous orange-brown mottled clay layer, with weathered sedimentary rock intersected at 2.75 mbgl. Tree roots from a large coolabah located on the margins of a residual pool (**Photograph 2**) were intersected at 0.3 mbgl, demonstrating a surface root system indicative of reactive utilisation of soil moisture from rainfall recharge. A significant intersection exists between LWP and downhole SMP values deeper than 1.5 mbgl and at the surface, indicating that the shallow soil profile can account for tree moisture sources. As per auger CM_S14, CM_S15 remained dry for its full depth.

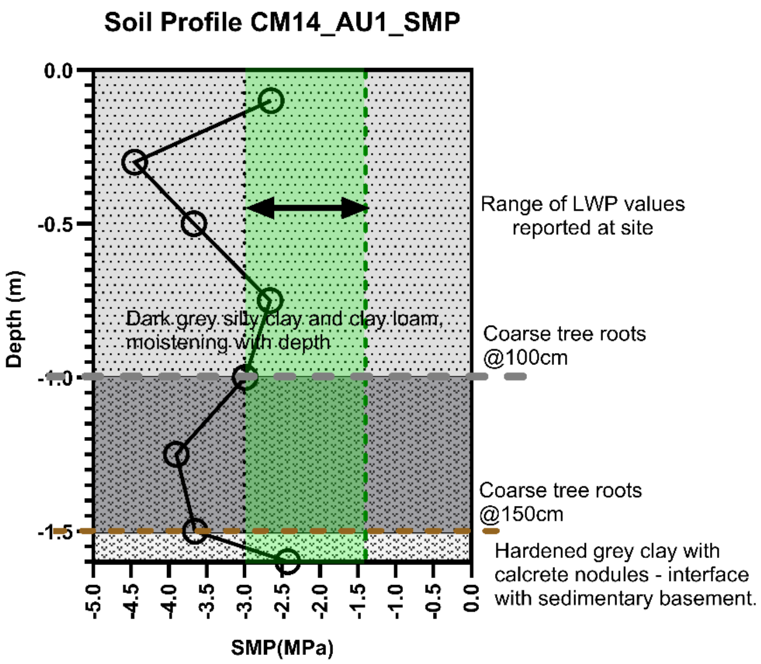

Figure 11. Auger profile for CM14_AU1 demonstrating the intersection of LWP and SMP values between 0.75 and 1.0mbgl, and also at 1.5mbgl.

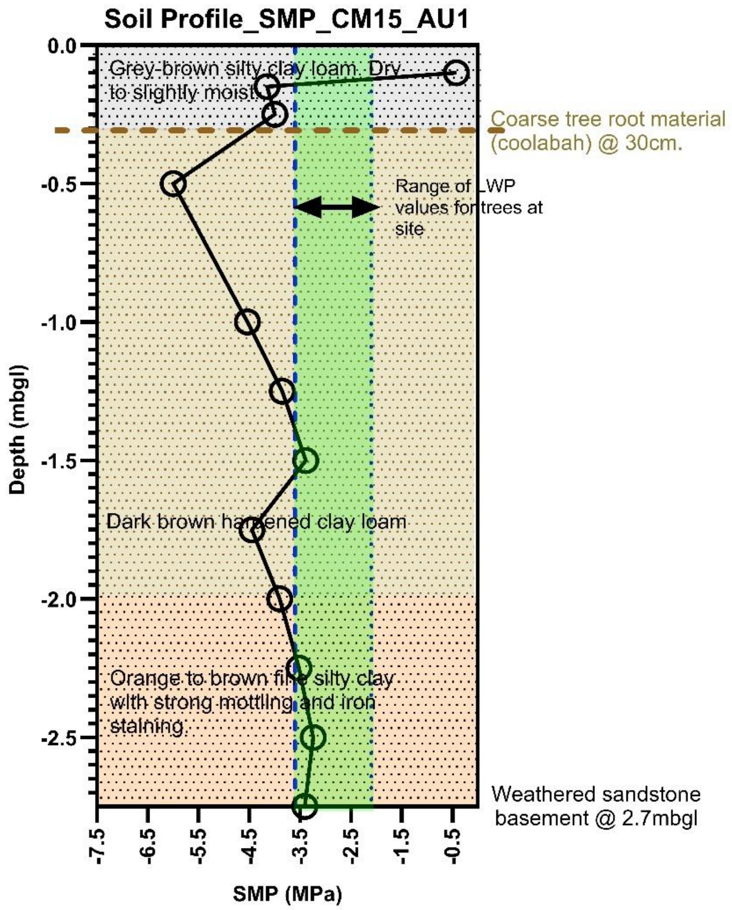

Figure 12. Auger profile for CM15_AU1 demonstrating the intersection of LWP and SMP values at the surface, and also at depths >1.5 mbgl. Moisture sources for vegetation can be readily accounted for in the shallow soil profile.

Photograph 1. Coarse tree roots of coolabah intersected in auger CM14_AU1 at the interface between alluvial clays and weathered sediments (1.6 mbgl), evident in the grey clay nodules.

Photograph 2. The location of auger CM15_AU1, at Site CM_S15, with a large coolabah spreading surface roots into a residual pool.

6.2.2 RE11.4.9 (Auger CM7_AU1)

The location of Auger CM7_AU1 was an elevated clay plain that hosted a well-developed woodland of brigalow and Dawson gum (RE11.4.8) as shown in **Photograph 3**. The auger intersected a relatively massive clay to clayey sand profile terminated in hard, dry clay with coarse gravel fragments at 2.8 mbgl. Intersection of coarse tree roots occurred at various depths, including 1.5 and 2.4 mbgl, and at the surface. The variability in tree root intervals suggests that trees can utilise moisture opportunistically/reactively at various depths in the soil profile, including reactivity to rainfall recharge at shallow depths. SMP values become progressively drier at depth in the profile, recording extremely negative SMP values as low as -5.5 MPa at 2.8 mbgl. The intersection of SMP and LWP values occurred at shallow depths (0.3 mbgl), indicating that vegetation was likely to utilise moisture from the shallow part of the soil profile (**Figure 13**), possibly residual moisture recharge from recent rainfall. The data indicates that unsaturated regions of the soil profile account for the moisture sources of woodland vegetation at the site at the time of the assessment.

Photograph 3. Brigalow woodland (RE11.4.9) at site CM_S7 at the location of auger CM7_AU1, noting the numerous brigalow stags.

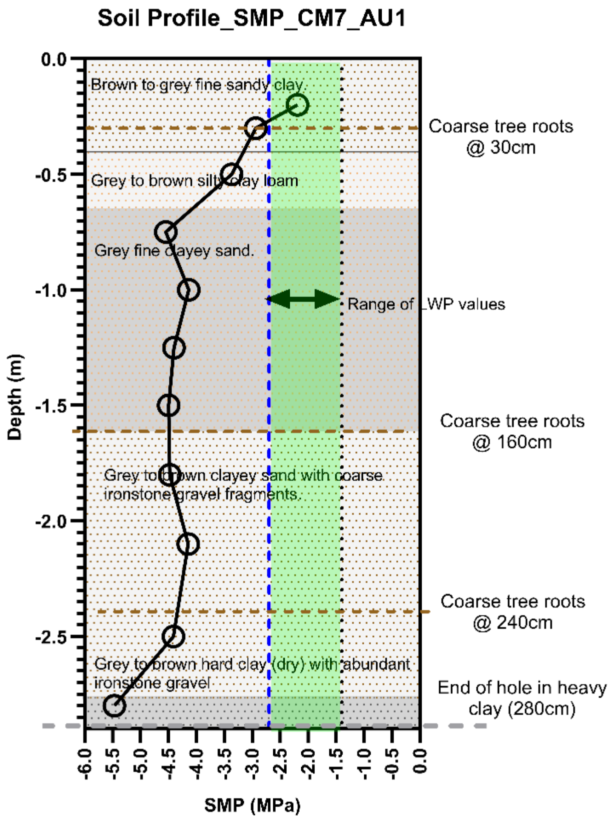

Figure 13. Auger profile for ML7_AU1 demonstrating the intersection of LWP and SMP values at shallow depths in the soil profile and regular intersection of tree roots to a depth of 2.4 mbgl.

6.2.3 RE11.4.8 (Auger ML10_AU1)

Auger ML10_AU1 intersected 0.7 m of silty loam before intersected weathered sedimentary rock, with sedimentary basement (Rewan Formation) surface outcrop visible nearby. No deeper auger profiling could be completed.

6.2.4 RE11.5.9 (Auger CM3_AU1)

Installation of auger CM3_AU1 occurred in sandy residual soils supporting a silver leaf ironbark dominant habitat (RE11.5.9). The purpose of the auger was to determine if moisture availability in the shallow soil profile could explain the relatively high LWP values reported for trees at this site. The auger encountered uniform red-brown sandy soils in the upper 1.2 mbgl before intersecting heavy clays mixed with large ironstone gravel fragments. The heavy clays limited deeper auger penetration at 1.25 mbgl, confirming only superficial sandy soil cover. LWP values for the silver leaf ironbark sampled at the site and SMP values intersect at a depth of approximately 0.75 mbgl. The high moisture availability in the upper 0.5m of the soil profile is also notable, most likely residual moisture from the rainfall two weeks before the survey. The data indicates that the high to moderate LWP values reported for trees at the site could be readily reconciled with soil moisture available in the shallow soil profile (see **Figure 14**).

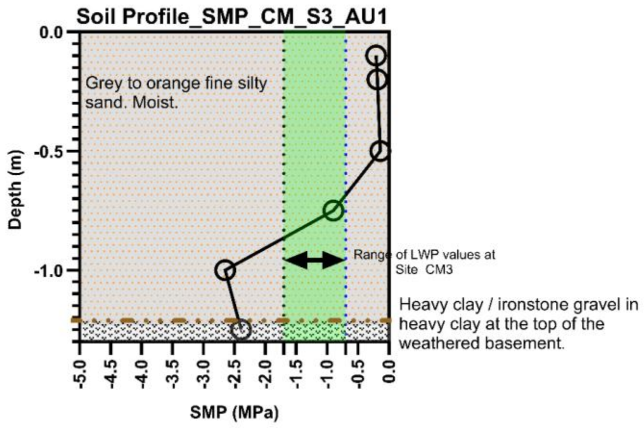

Figure 14. Auger profile for CM3_AU1 installed into sandy residual soils, demonstrating a shallow superficial cover of sand and intersection of LWP and SMP values at depths of approximately 0.75m.

6.3 Stable Isotope Sampling and Analyses

Section 6.3 presents an analysis of stable isotope data collected from soils, twig xylem, groundwater and surface water during the assessment. The data is applied as an additional line of evidence to support biophysical measurements, which may assist data interpretation where any ambiguity in interpretation exists.

6.3.1 Stable isotope biplots and Lc-excess values

Figures 15 to **17** provide biplots representing stable isotope values ($\delta^{18}O$ and $\delta^{2}H$) for soil, twig xylem, groundwater, and surface water for sampling points within Brigalow TEC habitats RE11.3.1 (**Figure 15**), RE11.4.8 and 11.4.9 (**Figure 16**), and the eucalypt woodland habitats RE11.5.3 and 11.5.9 (**Figure 17**). **Figure 18** shows Lc-excess values represented as box and whisker plots for all sites and sample types.

Notably, the three groundwater values form a discrete cluster of values that are isotopically lighter than those formed by the twig samples from all habitats (further to the left along the LMWL and enriched in ^{16}O compared to ^{18}O). The groundwater samples are also generally isotopically lighter than the soil samples, with some minor, though insignificant, overlap. Interestingly, the shallowest groundwater bore (MN-MB1-a) has a much lighter isotopic signature than the two deeper bores, which indicates differences in recharge mechanisms and the type of rainfall event responsible for recharge of the two groundwater systems.

For all three vegetation groupings, scatter of twig xylem isotope values strongly overlaps with the broad scatter of soil isotope values (**Figures 15** to **17**). While this indicates isotopic heterogeneity of the soil moisture source, it also indicates that moisture from unsaturated regions of the soil profile is supporting tree moisture requirements across all habitats in the study area. Soils demonstrate considerable isotopic spread compared to the groundwater values, with samples from shallow portions of the soil profile subject to evaporative enrichment and deeper soil samples, recharged through deep infiltration of rainfall, having lighter isotopic signatures. For all habitat types, clusters of isotope values from twig xylem overlap with soil values without substantial evidence for groundwater interaction.

The lc-excess data (**Figure 18**) indicates that the three groundwater samples are the most evaporatively evolved of any of the measured moisture sources, offset considerably below the LMWL, indicative of significant ^{2}H depletion relative to meteoric values. Lc-excess for the soil samples presents a much greater range of values, with some analyses close to a meteoric source indicative of direct infiltration of recent rainfall into the soil profile. Twig xylem samples all fall within the range of values associated with soils, and only CM11 (RE11.4.9), and CM15 (11.3.1) to a lesser extent, directly overlap with groundwater values. This overlap between groundwater and twig xylem values at CM11/CM15 is not an indication of groundwater usage but rather the use of a moisture source that has coincidentally undergone a similar degree of isotopic evolution. The persistent overlap between twig xylem and soil moisture values does, however, confirm that soil moisture predominantly supports vegetation transpiration across the broader tenement.

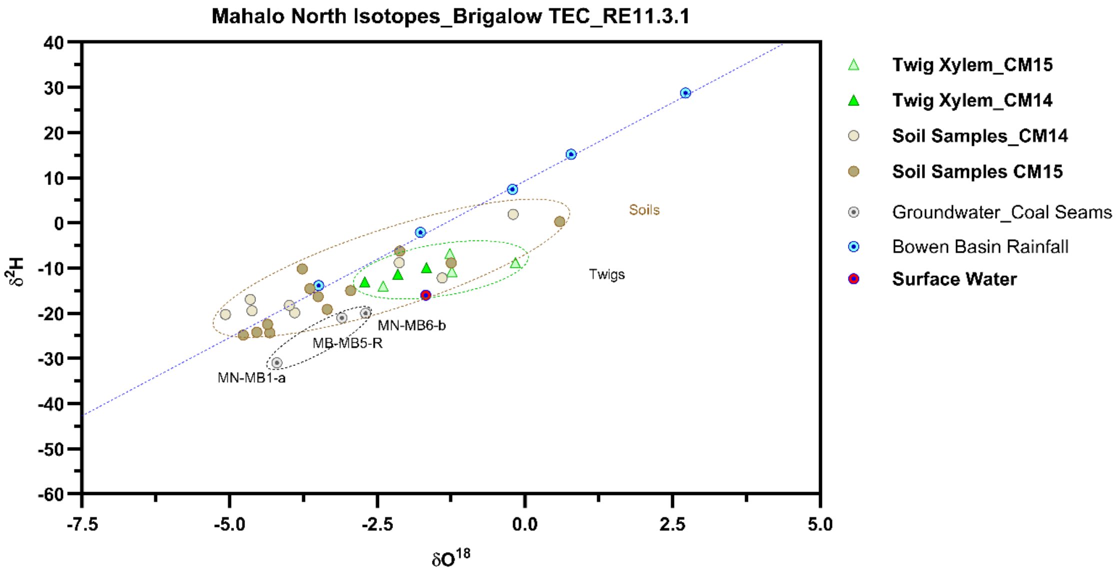

Figure 15. Stable isotope scatter for sites within RE11.3.1 (CM14 and CM15) showing overlap between isotopic compositions of xylem and soil samples, and clear lack of overlap between xylem and groundwater samples. The LMWL is indicated by the black dashed line.

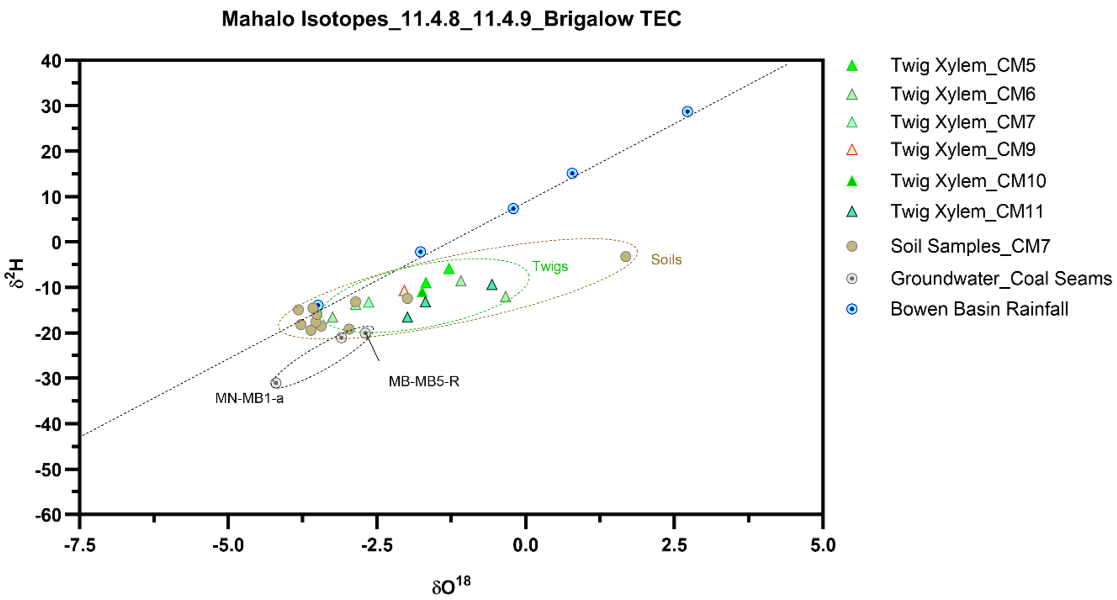

Figure 16. Stable isotope scatter for sites within RE11.4.8/11.4.9 showing overlap between isotopic compositions of xylem and soil samples, and clear lack of overlap between xylem and groundwater samples.

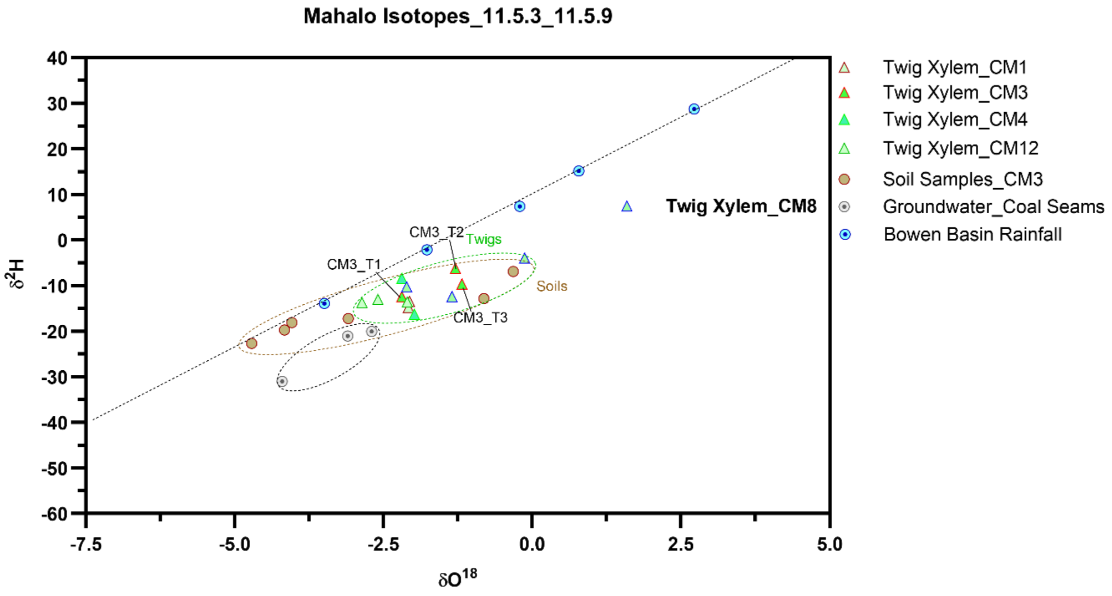

Figure 17. Stable isotope scatter for sites associated with REs 11.5.3 and 11.5.9 showing overlap between isotopic compositions of xylem and soil samples, and clear lack of overlap between xylem and groundwater samples.

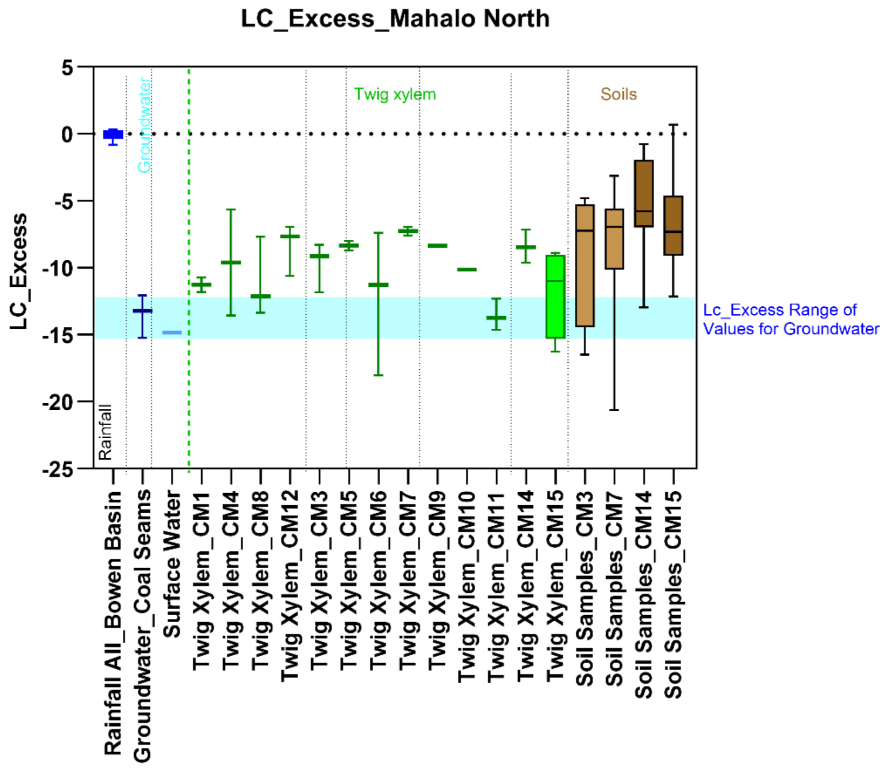

Figure 18. Lc-excess values for all sites including water sources soils and twigs. The most evaporatively enriched are groundwater and surface water sources, with soil samples presenting some values which are closer to meteoric origin.

6.3.2 Downhole δ18O soil profiles

The data below reconciles downhole $\delta^{18}O$ values for all auger holes with the range of values reported for twig xylem. Reconciliation with biophysical data from **Section 6.3.2** and **6.3.3** is also provided where required.

RE11.3.1 (CM14_AU1 & CM15_AU1): Figure 19 illustrates the downhole δ18O values for the two augers in RE11.3.1. For CM14 (CM14_AU1), the data demonstrates an overlap between soil and twig xylem values in the upper 30cm of the soil profile and again at 1.25 mbgl. A similar pattern is evident for CM15_AU1, with an overlap between twig xylem and soil moisture δ18O values at depths between the surface and 0.3 mbgl and again at 2.0 mbgl. Moisture utilisation from these regions of the soil profile broadly supports the biophysical data presented in **Figure 11** and **Figure 12**, suggesting a shallow soil moisture source supporting transpiration rather than groundwater.

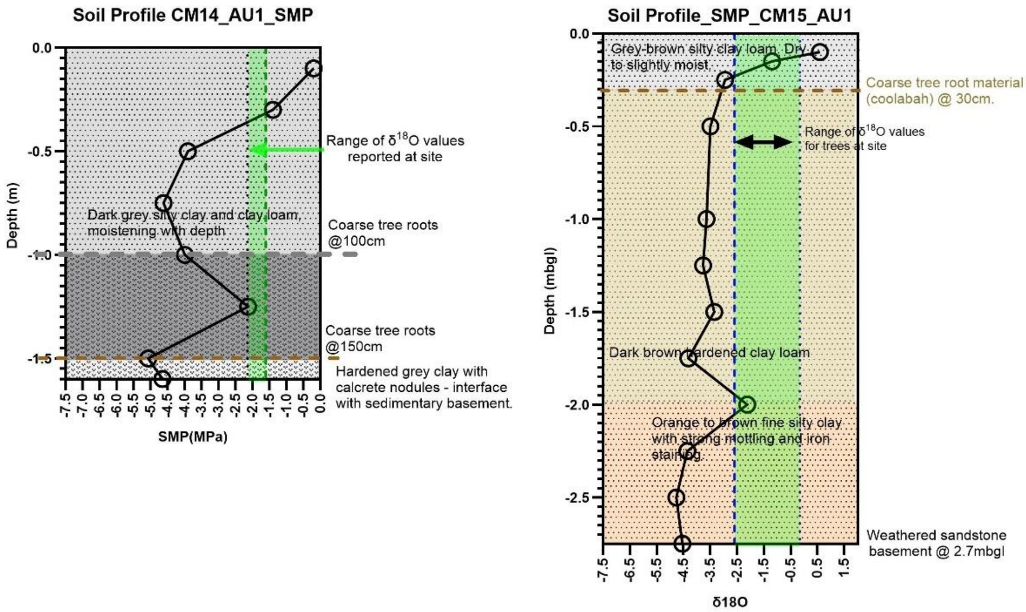

Figure 19. Downhole $\delta^{18}O$ values for augers CM14_AU1 (left) and CM15_AU1 (right) showing the intersection of isotopic values for twig xylem and soil moisture in the upper 0.3m of the soil profile for both augers, and at depths of 1.25 mbgl and 2.0 mbgl for CM14 and CM15 respectively.

RE11.4.8 & 11.4.9 (CM7_AU1): Figure 20 illustrates the downhole $\delta^{18}O$ values for augers CM7_AU1 sited in RE11.4.9 at Site CM7. Similar to the results for RE11.3.1, the data illustrates isotopic overlap between twig xylem and soil moisture at depths <0.5 mbgl and also at 1.5 mbgl, coincident with the intersection of coarse tree roots. Combined with the biophysical data from auger CM7_AU1 shown in **Figure 13**, this suggests that at the time of the assessment, vegetation was utilising moisture predominantly from shallow depths (<0.50 m) in the soil profile.

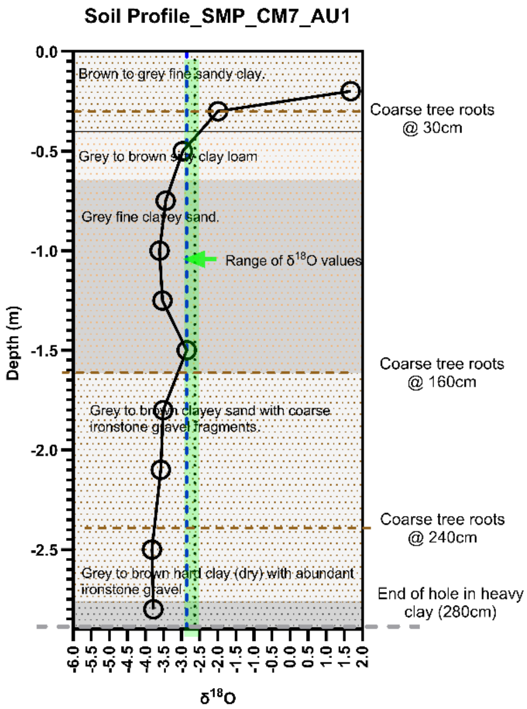

Figure 20. Downhole $\delta^{18}O$ values for auger CM7_AU1 in RE11.4.9, showing the intersection between twig xylem and soil moisture in the upper 0.3m of the soil profile and also at 1.5 mbgl.

RE11.5.9 (CM3_AU1): Figure 21 illustrates the downhole $\delta^{18}O$ values for shallow auger CM3_AU1 in RE11.5.9 at Site CM3, which presented the lowest LWP values for any site during the assessment. The data illustrates the isotopic overlap between twig xylem and soil moisture at shallow depths (<0.5 mbgl), presenting a slight mismatch with the biophysical data, which suggests slightly deeper moisture utilisation from 0.75 mbgl (**Figure 14**). While the cause of this mismatch cannot be easily explained, the two datasets (biophysical and isotopic) do indicate a shallow source of moisture is driving transpiration at this locality, and the high LWP values reported from the site are associated with recently infiltrated rainfall.

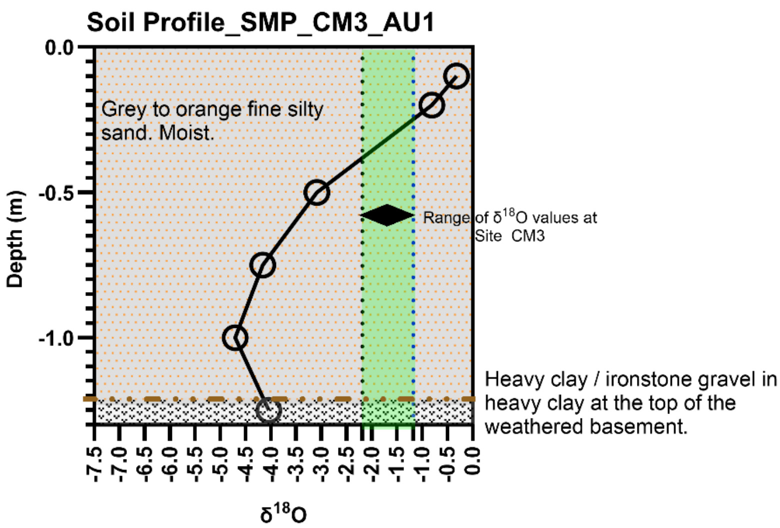

Figure 21. Downhole $\delta^{18}O$ values for auger CM3_AU1 (RE11.5.9) showing the intersection of isotopic values for twig xylem and soil moisture at shallow depths, <0.5 m from the soil surface.

7.0 Discussion and Conceptualisation of Tree Moisture Sources

Several factors indicate that woody vegetation within PLA 1128 does not rely on groundwater to support transpiration:

- LWP values for all trees sampled from a range of habitats, including both brigalow and eucalypt woodlands, are consistently strongly negative, suggesting that woody vegetation is either reliant on soil moisture from unsaturated portions of the soil profile that is held tightly in a clay matrix, or trees are using a highly saline groundwater source.
- SMP values for the four deeper augers sampled during the field assessment overlap with LWP values reported for trees sampled at the individual assessment sites, implying that moisture in the soil profile's unsaturated regions supported transpiration at the time of sampling.
- Analysis of stable isotope trends confirm that the unsaturated zone is the dominant moisture source supporting transpiration across PLA1128. There is no overlap between the isotopic composition of sampled xylem moisture and groundwater samples, while strong isotopic overlap exists between twigs and soils. Downhole $\delta^{18}O$ profiles also support a source of moisture from shallow regions in the soil profile.
- Groundwater within the tenement, confirmed by dedicated GDE monitoring bores, is both too deep (>19m) and too saline (>30 000µS/cm) to provide a functional source of moisture for deep-rooted woody vegetation.

CM_S3 was the only site that presented LWP values that might indicate potential for groundwater usage, where silver leaf ironbark reported LWP values as high as -0.7MPa, compared to general values for most trees of <-1.5MPa. Auger profiling indicates that moisture in the shallow soil profile at this site has sufficient moisture availability to account for this anomaly due to its sandy nature, which increases both soil matric capacity and provides for efficient infiltration of rainfall into the shallow soil profile. Stable isotope analysis also indicates that xylem moisture sampled at CM_S3 strongly aligns with the isotopic trends measured in the shallow soil profile, consistent with utilisation of recently infiltrated rainfall. With the exception of CM_S3, other eucalypts sampled across the Project site, including coolabah, poplar box, and Dawson gum demonstrated LWP values that were consistently close to or below standard wilting point. In the context of eucalypts, this does not mean that the trees are necessarily stressed or in severe moisture deficit, though it does indicate that their moisture sources are likely to be tightly bound to soils in unsaturated regions of the soil profile, rather than free draining. Eucalypt species that are co-occurring with brigalow such as coolabah and Dawson gum are likely to be similarly adapted to moisture constrained clay soils.

The shallow root system of brigalow is evident from auger sampling, where tree moisture availability correlated with shallow regions in the soil profile, and 2.4 mbgl was the deepest brigalow rooting depth recorded. Strong drying of the soil profile with increasing depth is evident at site CM_S7 (auger CM7_AU1), below the rooting depth of brigalow (2.4 mbgl). The extreme dryness of the basement clays (-5.5MPa @2.8 mbgl) would impede the deeper root penetration required for brigalow trees to access groundwater. There is also substantial evidence across the Project site that brigalow is subject to episodic droughting with abundant dead stags throughout many observed brigalow habitats, which provides further evidence that groundwater does not sustain brigalow through drought periods and that the source of moisture for transpiration is from unsaturated regions of the soil profile (**see Photograph 3**). Investing significant root mass into the shallow soil profile is risky in seasonally dry clay soils due to the inherent risk posed by seasonal droughting (Fensham & Holman, 1999).

The two specimens of bottle tree (*Brachychiton rupestris*) sampled within or adjacent to brigalow habitats at CM_S7 and CM_S8 demonstrate extremely negative LWP values similar to brigalow (-2.75 and -2.2MPa, respectively). Dry vine forest species can maintain drought tolerance through several physical and physiological adaptions, including leaf fall (deciduousness) at progressively lower LWP, lower leaf surface area (LSA) reflecting a greater degree of sclerophylly (Eamus, 1999; Lamont et al., 2002), and stomata closure at low LWP (Smith et al., 1997). Dry rainforest trees can also increase drought tolerance through higher vertical leaf angles, resulting in lower LSA exposure to direct sunlight during the hottest part of the day (Cowan, 1981). Bowman (2000) identifies that the extremely low LWP typical of brigalow, which often grows in association with dry rainforest species, indicates that dry rainforest trees can survive arid edaphic conditions. Therefore, there is no requirement to infer dry rainforest species growing within brigalow habitats is an indication of increased moisture availability or groundwater reliance.

8.0 Conclusions

The major conclusions drawn from this assessment are:

- Brigalow predominantly draws moisture from the shallow soil profile down to depths of 2.4 mbgl, where extremely dry and hard clays arrest deeper penetration. This is consistent with previous studies on brigalow, which suggest a shallow rooting system.
- There is no evidence from LWP measurement recorded in brigalow that trees rely on permanent or seasonal groundwater sources, supported by the observed susceptibility of the species to droughting. SMP measurements confirm that unsaturated regions of the soil profile have capacity to support the moisture availability measured in leaves.
- Stable isotope analysis also supports brigalow deriving moisture from shallow regions in the unsaturated soil profile, with strong isotopic overlap between twig xylem and soils and limited overlap between twig xylem and groundwater sources.
- Eucalypts across the Project site are mostly shallow-rooted box species that rely on moisture from the shallow soil profile. Some species, such as Dawson gum, have a strong affinity with brigalow, suggesting that they derive moisture from similar shallow regions of the soil profile. Based on LWP values, there is no indication of any substantial groundwater utilisations for any eucalypt species on the Project site. The lack of evidence for groundwater usage is further supported by stable isotope analysis demonstrating a strong affinity between soil and twig xylem moisture sources and limited interaction between twig xylem moisture and groundwater sources.

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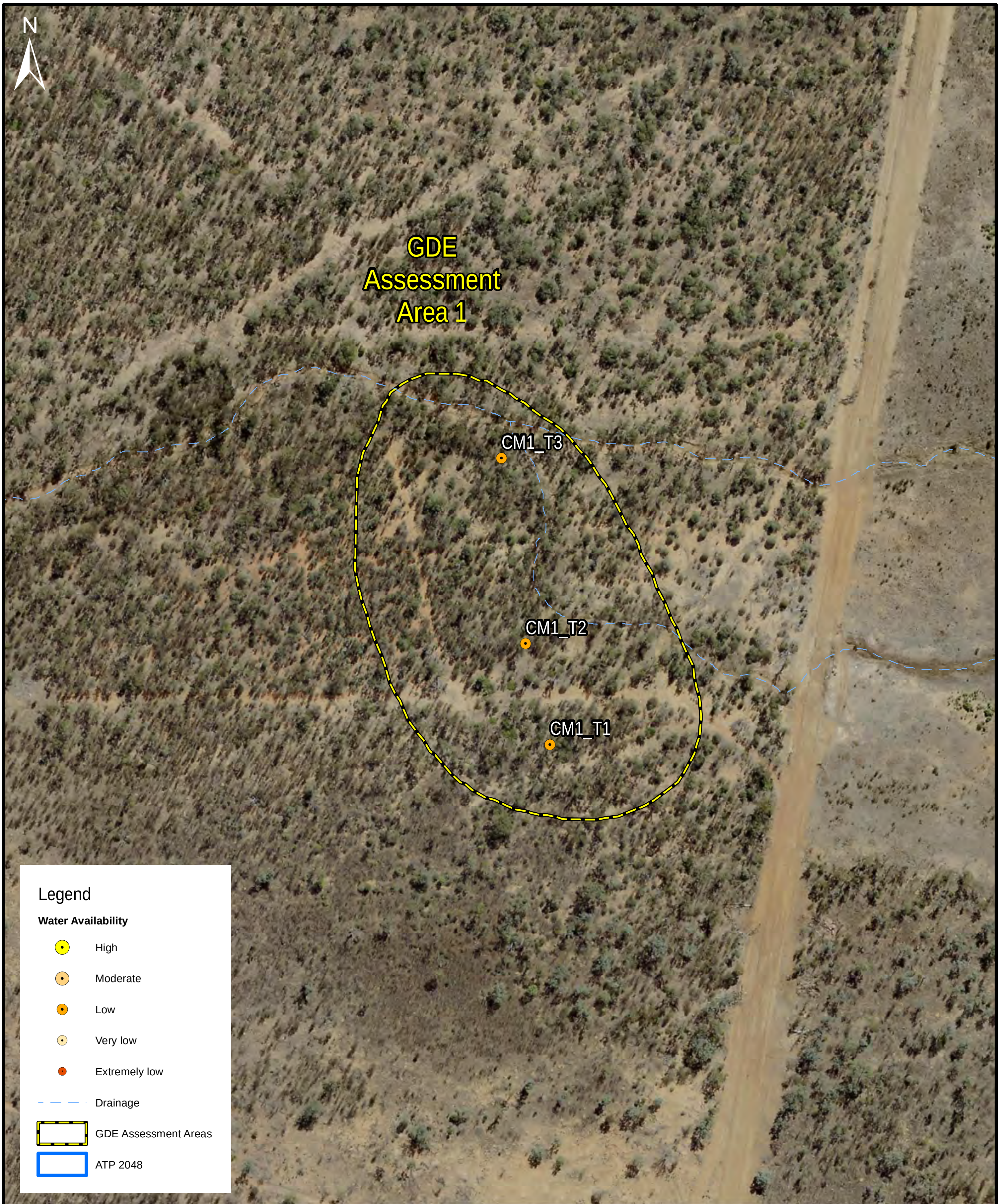
10. Appendix

Appendix A. Tree Structural Measurements

Tree_Number	Y	X	Type	Species	DBH (cm)	Height (m)	LWP (MPA)	Water Availability
CM1_T1	-24.018869	148.64363	Twig Xylem	*Eucalyptus populnea*	42	17	-1.7	Low
CM1_T2	-24.01832602	148.64348	Twig Xylem	*Eucalyptus populnea*	35	13	-1.7	Low
CM1_T3	-24.01732598	148.643325	Twig Xylem	*Eucalyptus populnea*	40	18	-2.1	Low
CM10_T1	-24.03236101	148.711353	Twig Xylem	*Eucalyptus camabageana*	50	17	-1.7	Low
CM10_T2	-24.03271196	148.711348	Twig Xylem	*Eucalyptus camabageana*	70	15	-1.8	Low
CM10_T3	-24.03295303	148.711327	Twig Xylem	*Eucalyptus camabageana*	90	20	-1.6	Low
CM10_T4	-24.03283702	148.711077	Twig Xylem	*Eucalyptus camabageana*	75	20	-1.5	Low
CM11_T1	-24.04491702	148.708579	Twig Xylem	*Eucalyptus camabageana*	70	20	-2.1	Low
CM11_T2	-24.04505398	148.708597	Twig Xylem	*Eucalyptus camabageana*	60	18	-1.9	Low
CM11_T3	-24.04523302	148.708891	Twig Xylem	*Acacia harpophylla*	15	7	-2	Low
CM11_T4	-24.04529303	148.708941	Twig Xylem	*Eucalyptus camabageana*	45	18	-2.5	Extremely low
CM12_T1	-24.01059799	148.609897	Twig Xylem	*Eucalyptus populnea*	55	18	-1.9	Low
CM12_T2	-24.01062397	148.610086	Twig Xylem	*Eucalyptus populnea*	60	17	-1.7	Low
CM12_T3	-24.01060998	148.61044	Twig Xylem	*Eucalyptus populnea*	50	17	-2.1	Low
CM12_T4	-24.01101499	148.610554	Twig Xylem	*Eucalyptus populnea*	65	19	-2	Low
CM14_T1	-24.05799002	148.548832	Twig Xylem	*Eucalyptus coolabah*	30	10	-1.7	Low
CM14_T2	-24.05800997	148.548663	Twig Xylem	*Eucalyptus coolabah*	40	12	-1.9	Low
CM14_T3	-24.05821097	148.548325	Twig Xylem	*Eucalyptus coolabah*	50	16	-1.4	Low
CM14_T4	-24.05830904	148.548426	Twig Xylem	*Acacia harpophylla*	25	12	-3	Extremely low
CM15_T1	-24.07941299	148.570767	Twig Xylem	*Eucalyptus coolabah*	40	15	-2.1	Low
CM15_T2	-24.07934301	148.57042	Twig Xylem	*Acacia harpophylla*	20	9	-3.6	Extremely low
CM15_T3	-24.07937997	148.570583	Twig Xylem	*Eucalyptus coolabah*	45	14	-2.2	Extremely low
CM15_T4	-24.08042	148.571968	Twig Xylem	*Eucalyptus coolabah*	100	19	-2.05	Low
CM15_T5	-24.080507	148.57221	Twig Xylem	*Acacia harpophylla*	30	9	-2.1	Low
CM3_T1	-24.01661896	148.696782	Twig Xylem	*Eucalyptus melanophloia*	30	12	-0.7	High
CM3_T2	-24.01640698	148.696844	Twig Xylem	*Eucalyptus melanophloia*	25	11	-1.7	Low
CM3_T3	-24.01613298	148.69668	Twig Xylem	*Eucalyptus melanophloia*	43	16	-1	Moderate

Tree_Number	Y	X	Type	Species	DBH (cm)	Height (m)	LWP (MPA)	Water Availability
CM4_T1	-24.02187601	148.628996	Twig Xylem	*Acacia harpophylla*	27	12	-1.5	Low
CM4_T2	-24.02162497	148.629123	Twig Xylem	*Eucalyptus camabageana*	50	13	-1.5	Low
CM4_T3	-24.02066097	148.629336	Twig Xylem	*Acacia harpophylla*	25	12	-2.15	Very low
CM4_T4	-24.02010097	148.62947	Twig Xylem	*Acacia harpophylla*	25	11	-2	Very low
CM5_T1	-24.01639399	148.618259	Twig Xylem	*Acacia harpophylla*	35	14	-3.8	Extremely low
CM5_T2	-24.01631998	148.618403	Twig Xylem	*Acacia harpophylla*	30	14	-2.9	Extremely low
CM5_T3	-24.01588898	148.618515	Twig Xylem	*Acacia harpophylla*	25	12	-3	Extremely low
CM6_T1	-24.01655098	148.62131	Twig Xylem	*Eucalyptus camabageana*	40	18	-2.2	Extremely low
CM6_T2	-24.01641	148.621315	Twig Xylem	*Acacia harpophylla*	30	12	-3.65	Extremely low
CM6_T3	-24.01619098	148.621308	Twig Xylem	*Acacia harpophylla*	30	15	-4.35	Extremely low
CM7_T1	-24.04216197	148.623723	Twig Xylem	*Eucalyptus camabageana*	65	14	-1.4	Low
CM7_T2	-24.04234604	148.623611	Twig Xylem	*Acacia harpophylla*	35	13	-2	Very low
CM7_T3	-24.042426	148.623404	Twig Xylem	*Acacia harpophylla*	28	13	-2.3	Extremely low
CM7_T4	-24.04226398	148.623242	Twig Xylem	*Acacia harpophylla*	25	12	-1.9	Very low
CM7T_5A	-24.04222299	148.623192	Twig Xylem	*Brachychiton rupestris*	35	6	-2.75	Extremely low
CM8_T1	-24.04370802	148.620575	Twig Xylem	*Eucalyptus populnea*	35	13	-1.2	Moderate
CM8_T2	-24.04342001	148.620442	Twig Xylem	*Eucalyptus populnea*	30	9	-1.1	Moderate
CM8_T3	-24.04300997	148.62049	Twig Xylem	*Acacia harpophylla*	25	11	-2	Very low
CM8T_4	-24.04263798	148.620315	Twig Xylem	*Brachychiton rupestris*	120	16	-2.2	Very low
CM9_T1	-24.05061001	148.705544	Twig Xylem	*Eucalyptus camabageana*	50	15	-2.5	Extremely low
CM9_T2	-24.05061102	148.70579	Twig Xylem	*Eucalyptus camabageana*	45	15	-2	Very low
CM9_T3	-24.050565	148.70594	Twig Xylem	*Eucalyptus camabageana*	70	15	-1.7	Very low
CM9_T4	-24.05028496	148.705944	Twig Xylem	*Acacia harpophylla*	20	7	-2.6	Extremely low
CM13_T1	-24.038573	148.681972	Twig Xylem	*Acacia shirleyi*	20	12	-1.4	Low
CM13_T2	-24.038188	148.681808	Twig Xylem	*Acacia shirleyi*	15	11	-1.2	Low
CM13_T3	-24.038338	148.682127	Twig Xylem	*Acacia shirleyi*	25	11	-1.55	Low

Appendix B. Sampling locations and Moisture Availability



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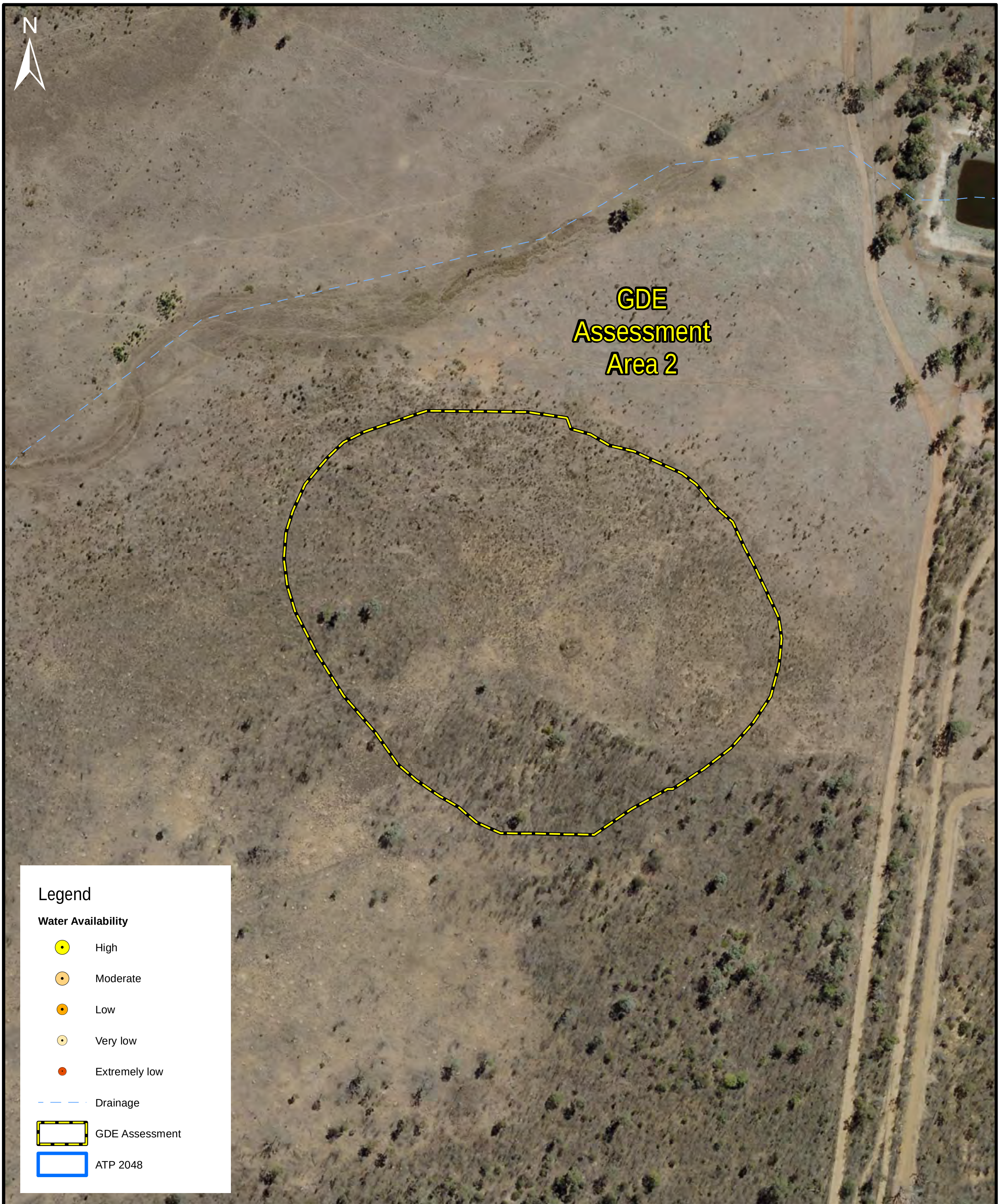
Scale 1:3,000 @ A4 0 100 200 M Coordinate System: GDA 2020 MGA Zone 55 A4

Appendix A1. Sampling detail at GDE Assessment Area 1

Client: Epic Environmental
Project: Comet Ridge Mahalo Project.

WATER MARK ECO
Kenmore, Qld 4069
Mobile: 0447 822 119
www.3denvironmental.com.au

Drawn By DG Checked DS Date 13/11/2024



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Scale 1:3,000 @ A4 0 100 200 M

Coordinate System: GDA 2020 MGA Zone 55 A4

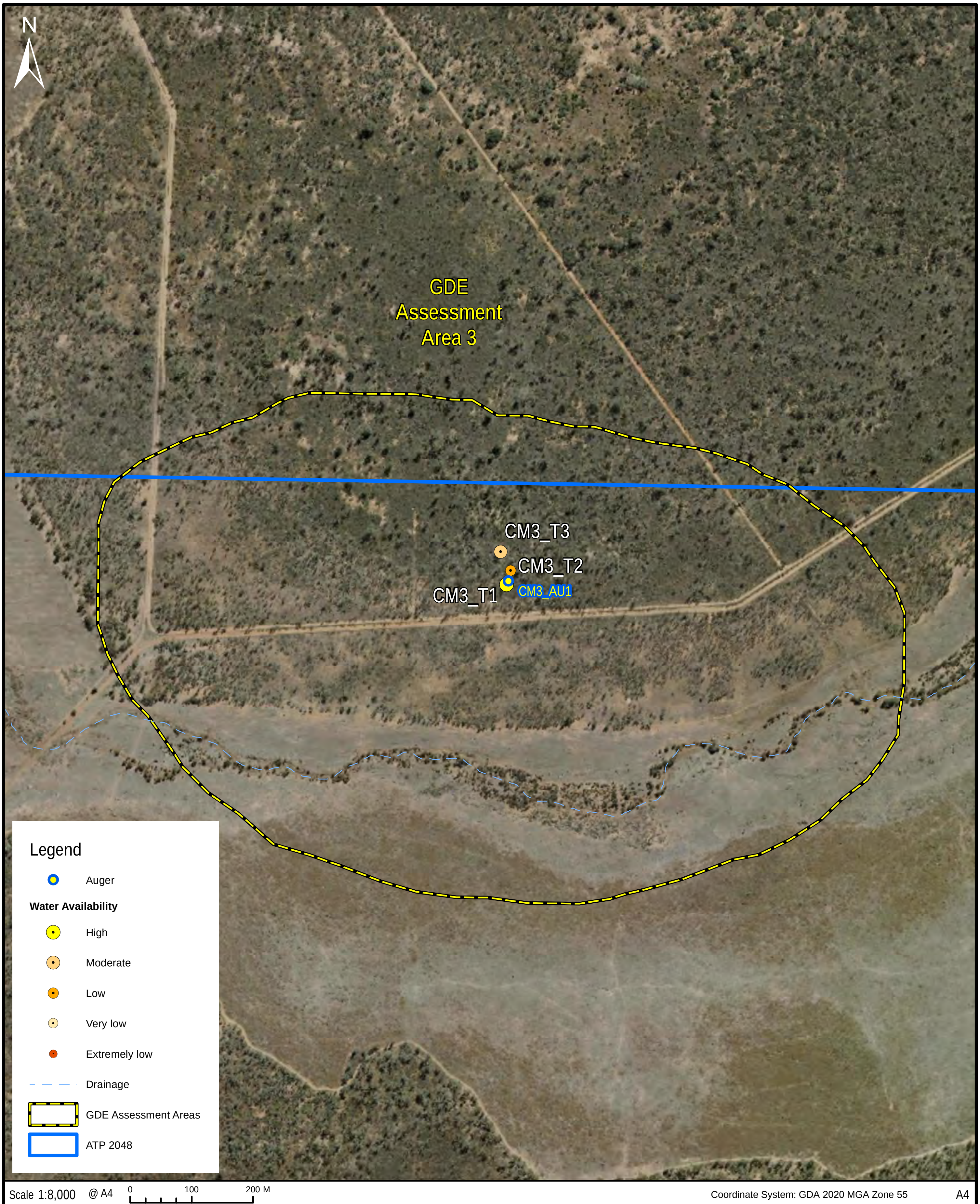
Appendix A2. Sampling detail at GDE Assessment Area 2

Client: Epic Environmental

Project: Comet Ridge Mahalo Project.

WATER MARK ECO
Kenmore, Qld 4069
Mobile: 0447 822 119
www.3denvironmental.com.au

Drawn By DG Checked DS Date 13/11/2024



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Appendix A3. Sampling detail at GDE Assessment Area 3

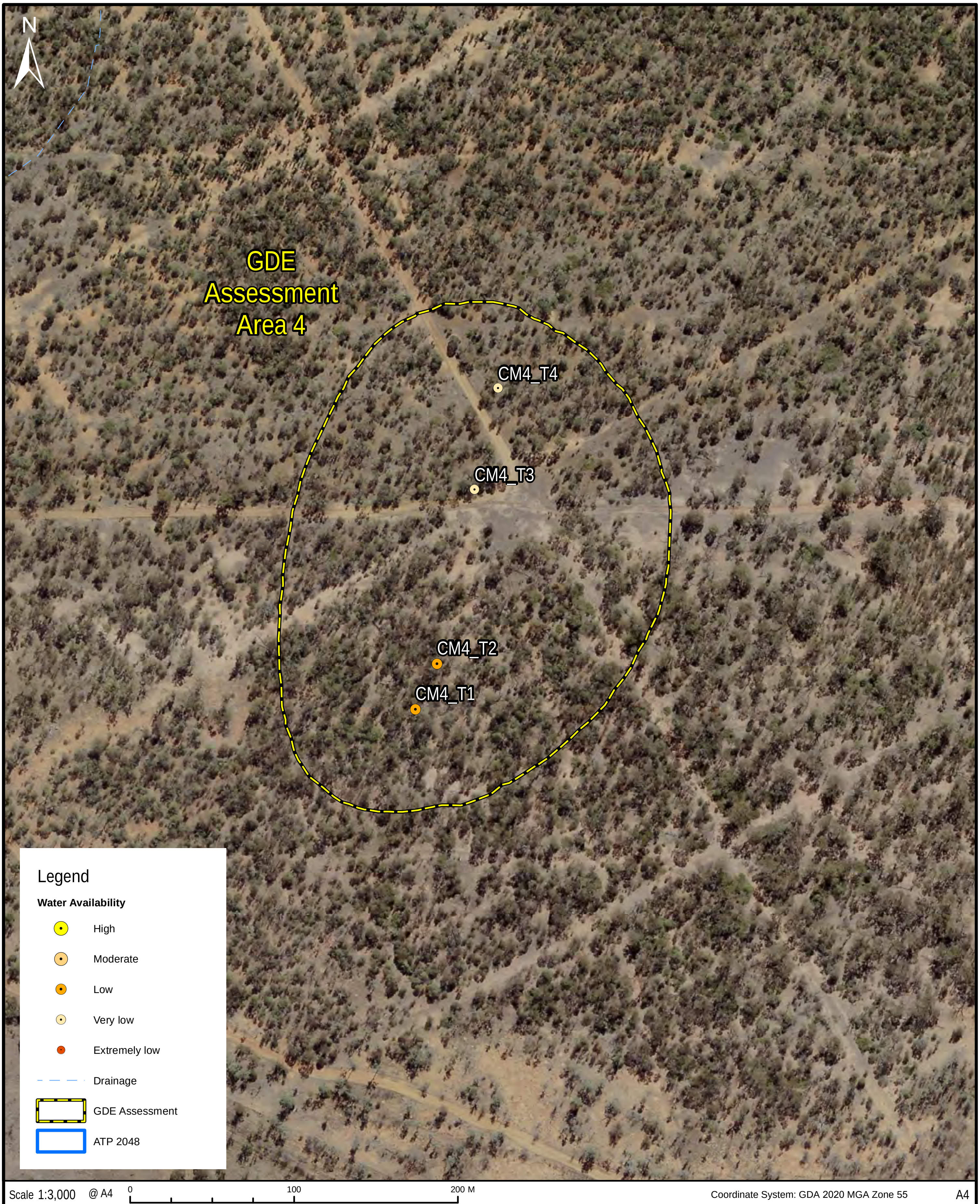
WATER MARK ECO

Kenmore, Qld 4069
Mobile: 0447 822 119
www.3denvironmental.com.au

Client: Epic Environmental

Project: Comet Ridge Mahalo Project.

Drawn By DG Checked DS Date 13/11/2024



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Appendix A4. Sampling detail at GDE Assessment Area 4

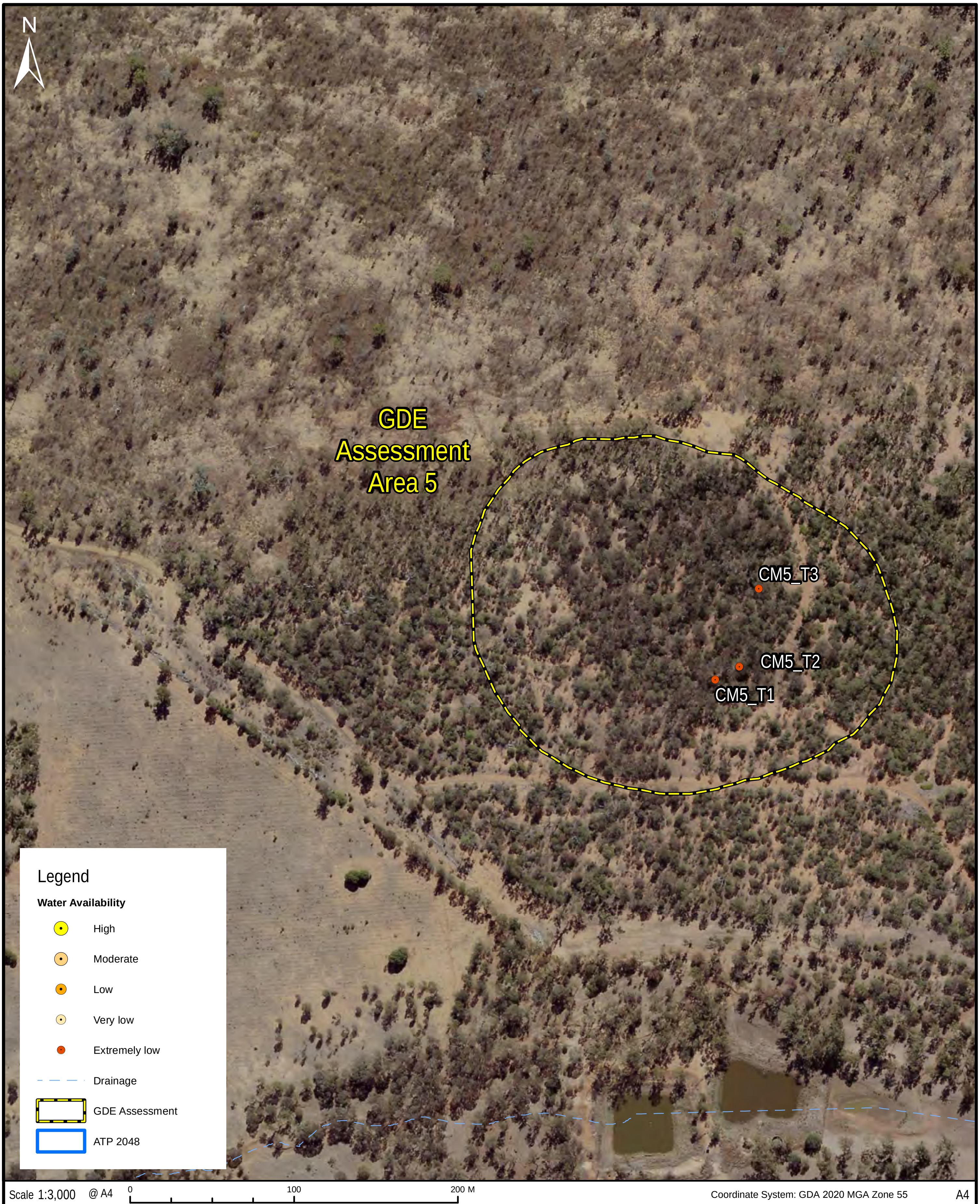
WATER MARK ECO

Kenmore, Qld 4069
Mobile: 0447 822 119
www.3denvironmental.com.au

Client: Epic Environmental

Project: Comet Ridge Mahalo Project.

Drawn By DG | Checked DS | Date 13/11/2024



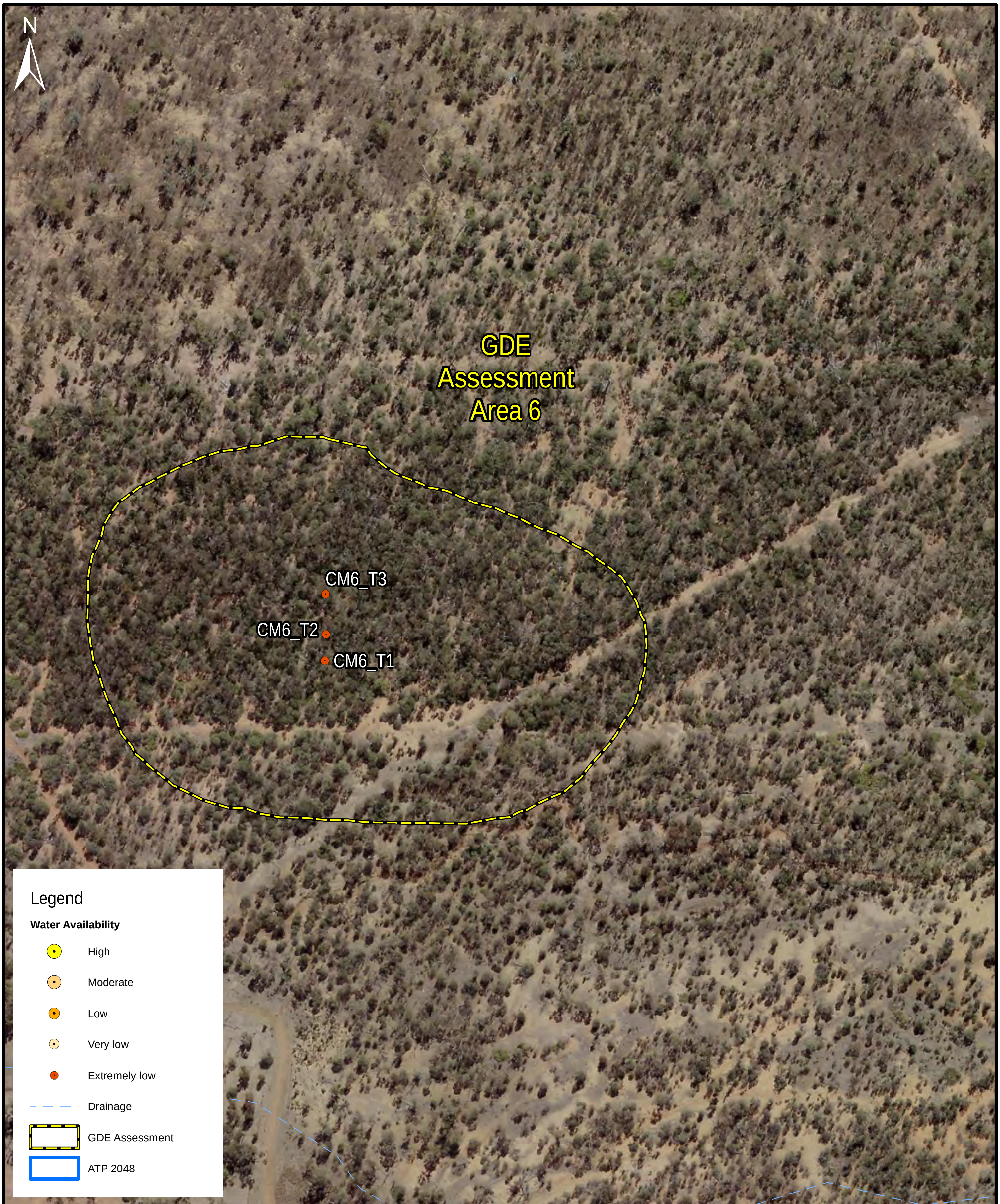
Appendix A5. Sampling detail at GDE Assessment Area 5

Client: Epic Environmental

Project: Comet Ridge Mahalo Project.

WATER MARK ECO
Kenmore, Qld 4069
Mobile: 0447 822 119
www.3denvironmental.com.au

Drawn By DG Checked DS Date 13/11/2024



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Scale 1:3,000 @ A4 0 100 200 M

Coordinate System: GDA 2020 MGA Zone 55 A4

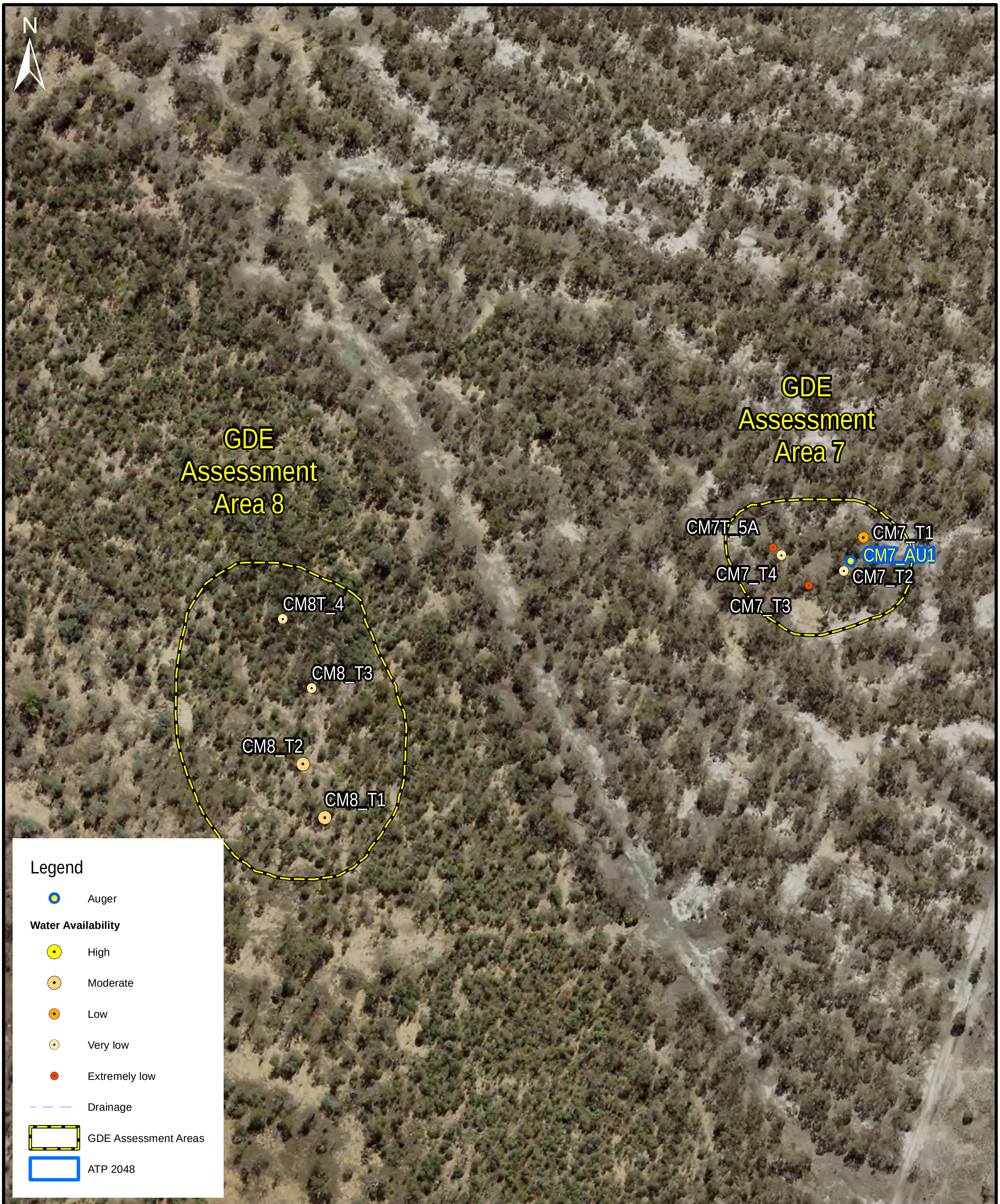
Appendix A6. Sampling detail at GDE Assessment Area 6

Client: Epic Environmental

Project: Comet Ridge Mahalo Project.

WATER MARK ECO
Kenmore, Qld 4069
Mobile: 0447 822 119
www.3denvironmental.com.au

Drawn By DG Checked DS Date 13/11/2024



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Scale 1:3,000 @ A4 0 100 200 M

Coordinate System: GDA 2020 MGA Zone 55 A4

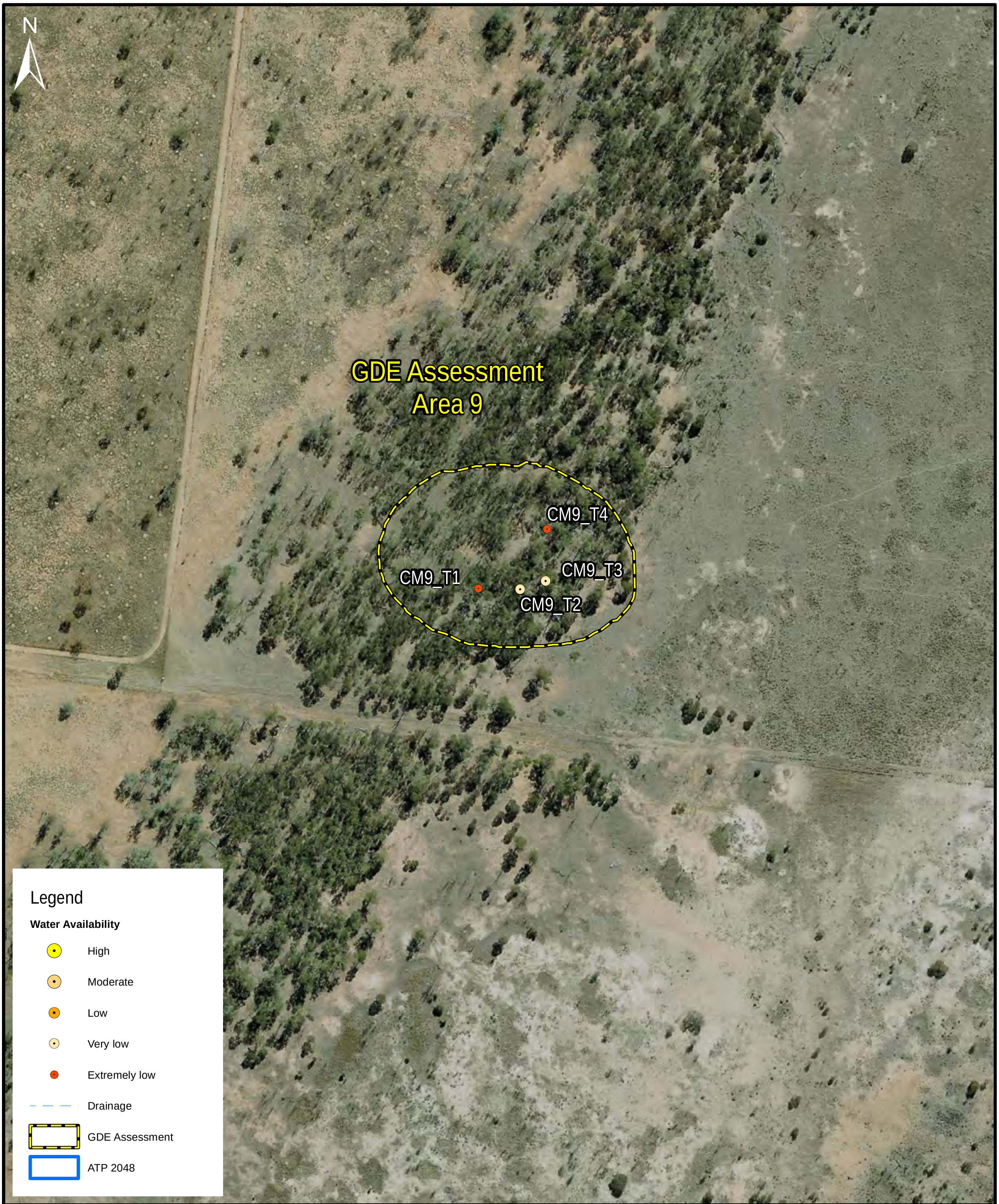
Appendix A7. Sampling detail at GDE Assessment Area 7 and GDE Assessment Area 8

WATER MARK ECO

Kenmore, Qld 4069
Mobile: 0447 822 119
www.3denvironmental.com.au

Client: Epic Environmental
Project: Comet Ridge Mahalo Project.

Drawn By DG Checked DS Date 13/11/2024



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Scale 1:3,000 @ A4 0 100 200 M

Coordinate System: GDA 2020 MGA Zone 55 A4

Appendix A8. Sampling detail at GDE Assessment Area 9

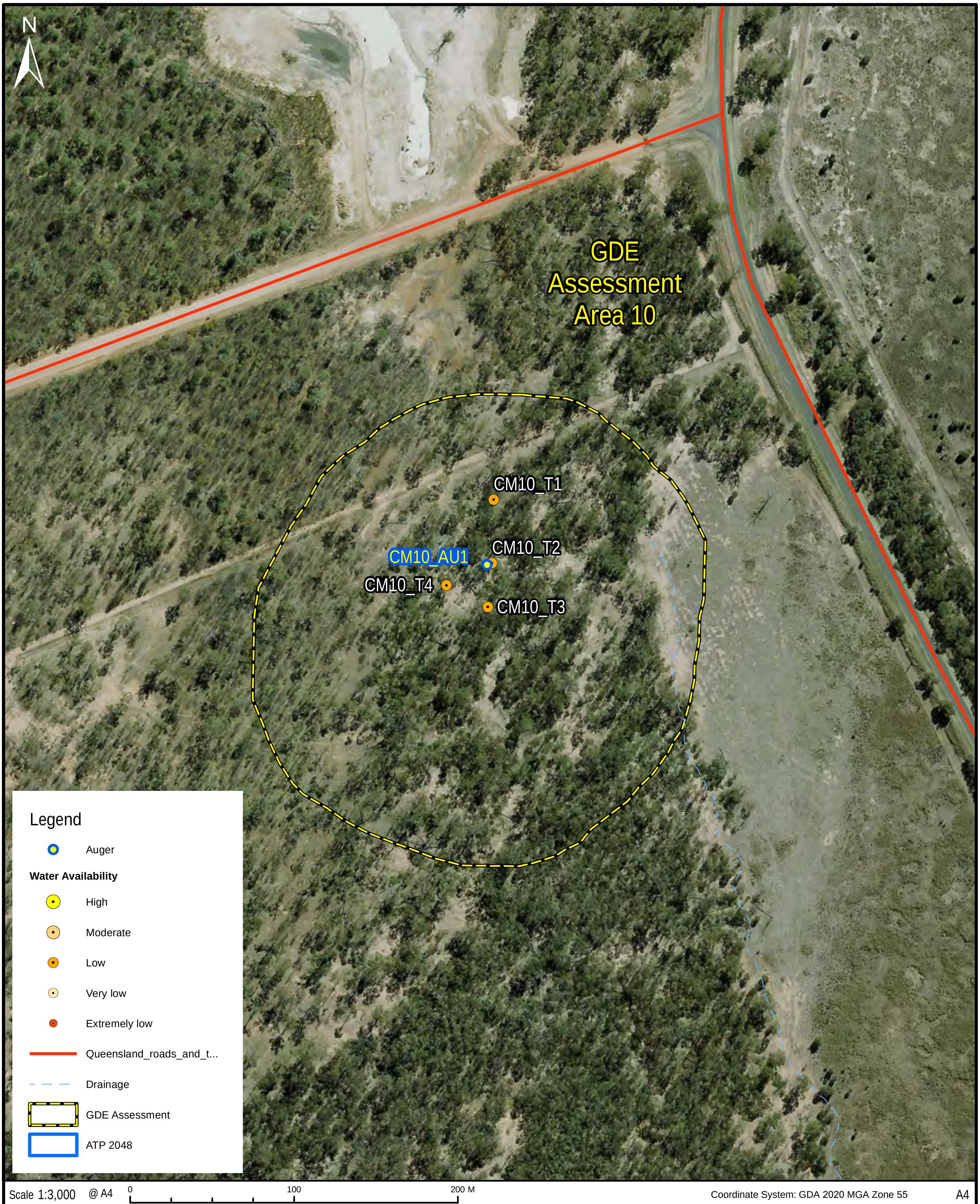
WATER MARK ECO

Kenmore, Qld 4069
Mobile: 0447 822 119
www.3denvironmental.com.au

Client: Epic Environmental

Project: Comet Ridge Mahalo Project.

Drawn By DG Checked DS Date 13/11/2024



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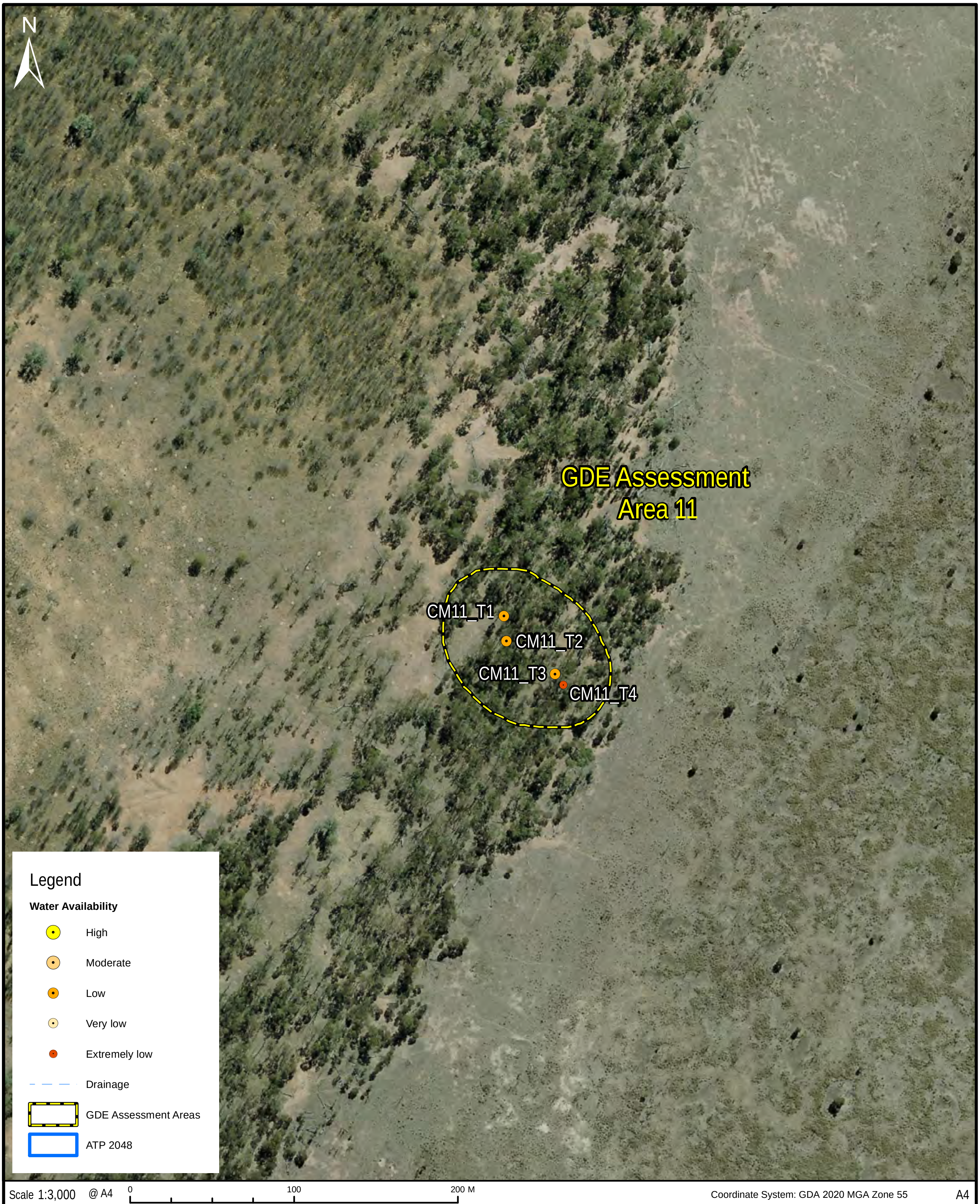
Appendix A9. Sampling detail at GDE Assessment Area 10

WATER MARK ECO
Kenmore, Qld 4069
Mobile: 0447 822 119
www.3denvironmental.com.au

Client: Epic Environmental
Project: Comet Ridge Mahalo Project.

Drawn By DG Checked DS Date 13/11/2024



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Appendix A10. Sampling detail at GDE Assessment Area 11

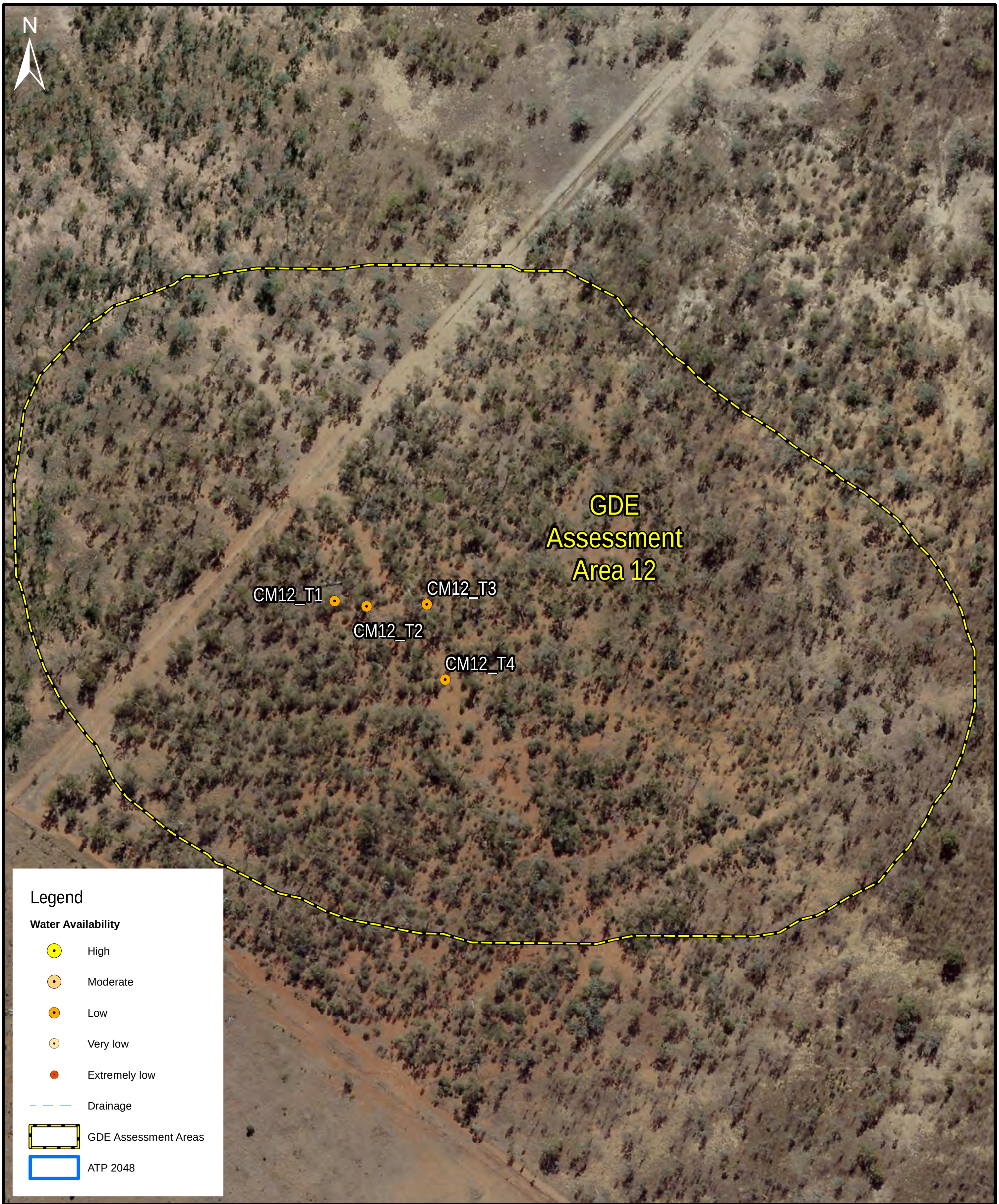
WATER MARK ECO

Kenmore, Qld 4069
Mobile: 0447 822 119
www.3denvironmental.com.au

Client: Epic Environmental

Project: Comet Ridge Mahalo Project.

Drawn By DG | Checked DS | Date 13/11/2024



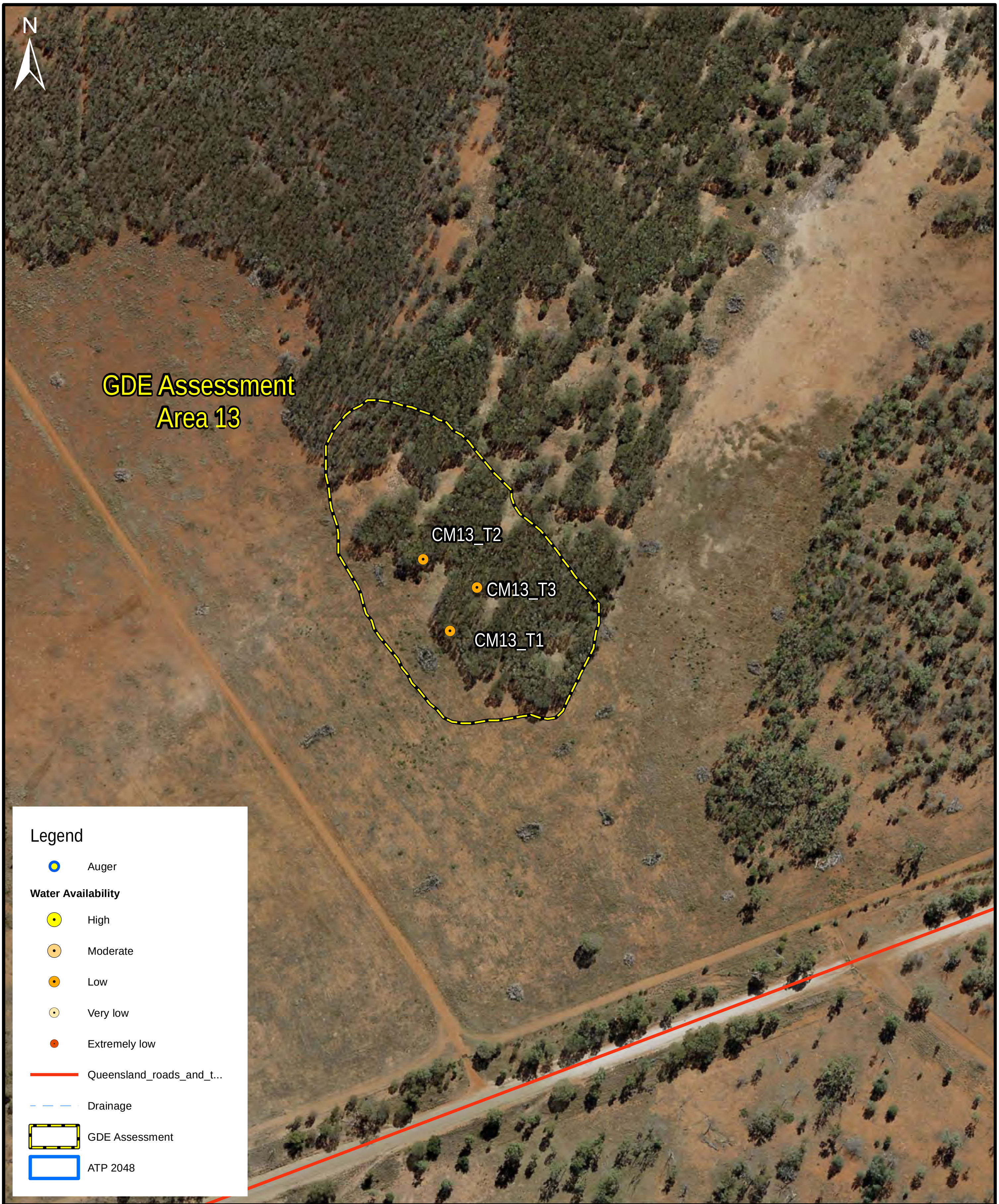
Scale 1:3,000 @ A4 0 100 200 M Coordinate System: GDA 2020 MGA Zone 55 A4

Appendix A11. Sampling detail at GDE Assessment Area 12

Client: Epic Environmental
Project: Comet Ridge Mahalo Project.

WATER MARK ECO
Kenmore, Qld 4069
Mobile: 0447 822 119
www.3denvironmental.com.au

Drawn By DG Checked DS Date 13/11/2024



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Scale 1:3,000 @ A4 0 100 200 M

Coordinate System: GDA 2020 MGA Zone 55 A4

Appendix A12. Sampling detail at GDE Assessment Area 13

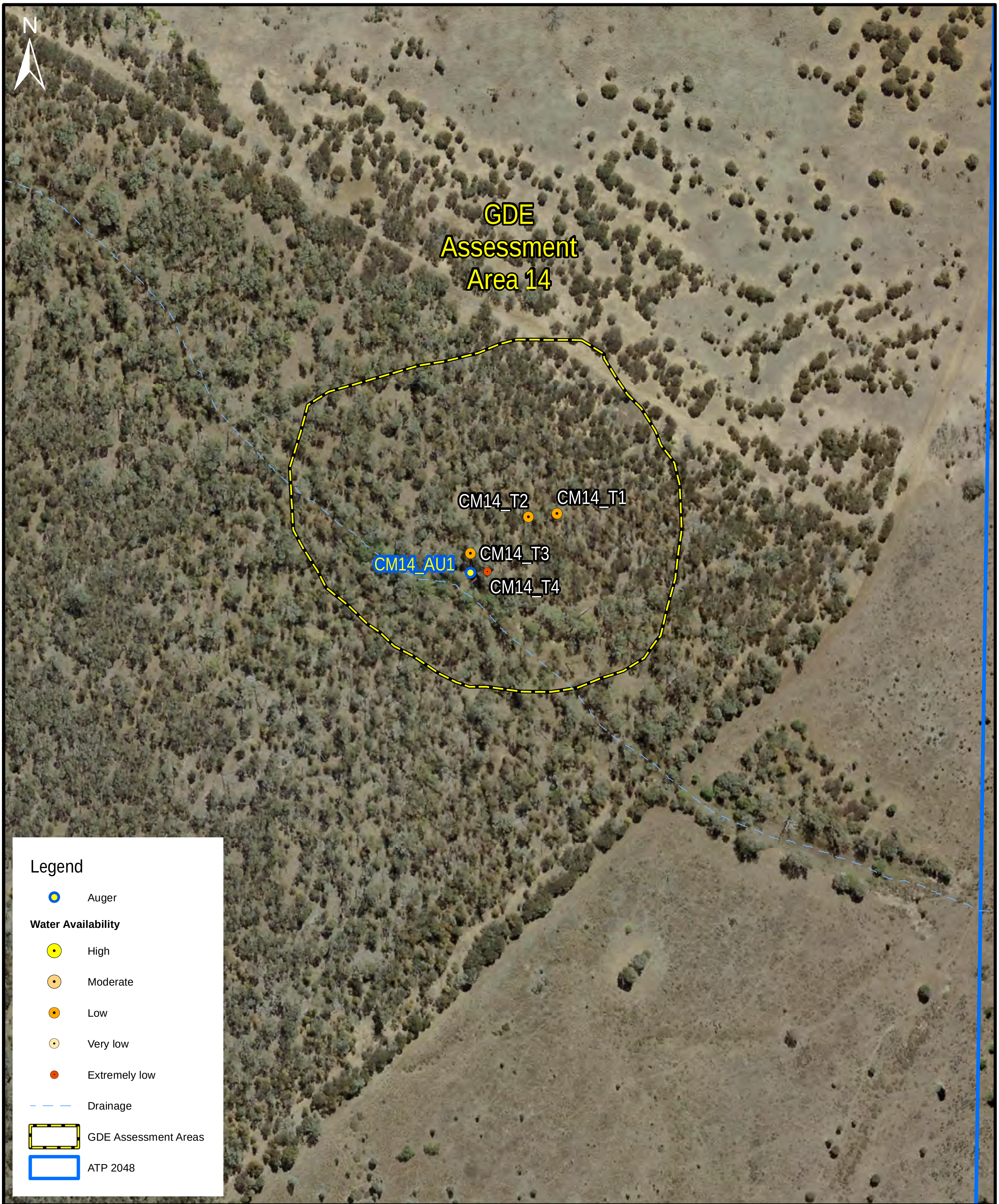
WATER MARK ECO

Kenmore, Qld 4069
Mobile: 0447 822 119
www.3denvironmental.com.au

Client: Epic Environmental

Project: Comet Ridge Mahalo Project.

Drawn By DG Checked DS Date 13/11/2024



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Scale 1:3,000 @ A4 0 100 200 M

Coordinate System: GDA 2020 MGA Zone 55 A4

Appendix A13. Sampling detail at GDE Assessment Area 14

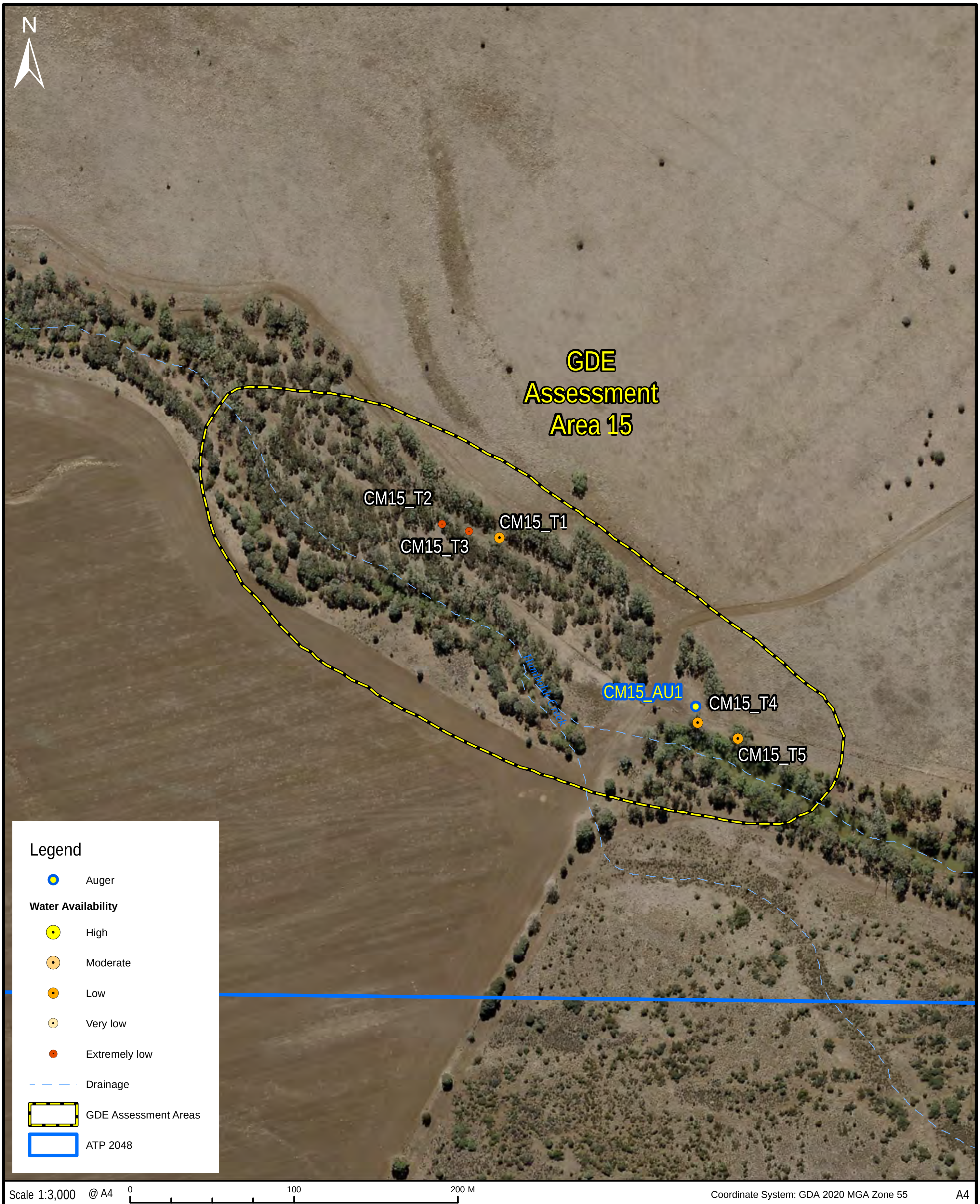
WATER MARK ECO

Kenmore, Qld 4069
Mobile: 0447 822 119
www.3denvironmental.com.au

Client: Epic Environmental

Project: Comet Ridge Mahalo Project.

Drawn By DG Checked DS Date 13/11/2024



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Appendix A14. Sampling detail at GDE Assessment Area 15

Client: Epic Environmental

Project: Comet Ridge Mahalo Project.

WATER MARK ECO
Kenmore, Qld 4069
Mobile: 0447 822 119
www.3denvironmental.com.au

Drawn By DG Checked DS Date 13/11/2024

Appendix C. Soil Moisture Potentials-Raw Data

Sample	Type	Project	Date Sampled		SMP Value
CM14_AU1_0.1	Soil	Comet Mahalo	28/08/2024	Dark grey silty clay.	-2.65
CM14_AU1_0.3	Soil	Comet Mahalo	28/08/2024	Dark grey silty clay.	-4.45
CM14_AU1_0.5	Soil	Comet Mahalo	28/08/2024	Dark grey silty clay. Slightly moist.	-3.67
CM14_AU1_0.75	Soil	Comet Mahalo	28/08/2024	Dark grey silty clay. Slightly moist.	-2.66
CM14_AU1_1.00	Soil	Comet Mahalo	28/08/2024	Dark grey silty clay. Slightly moist.	-2.99
CM14_AU1_1.25	Soil	Comet Mahalo	28/08/2024	Dark grey silty clay with calcrete nodules.	-3.9
CM14_AU1_1.5	Soil	Comet Mahalo	28/08/2024	Dark grey silty clay with calcrete nodules.	-3.65
CM14_AU1_1.6	Soil	Comet Mahalo	28/08/2024	Grey silt and clay. Hardened.	-2.43
CM15_0.1	Soil	Comet Mahalo	27/08/2024	Dark brown silty clay. Moist.	-0.42
CM15_0.15	Soil	Comet Mahalo	27/08/2024	Dark brown silty clay. Moist.	-4.15
CM15_0.25	Soil	Comet Mahalo	27/08/2024	Dark brown hardened clay loam.	-4
CM15_0.5	Soil	Comet Mahalo	27/08/2024	Dark brown hardened clay loam.	-6
CM15_1.0	Soil	Comet Mahalo	27/08/2024	Dark brown hardened clay loam.	-4.54
CM15_1.25	Soil	Comet Mahalo	27/08/2024	Dark brown hardened clay loam.	-3.85
CM15_1.5	Soil	Comet Mahalo	27/08/2024	Dark brown hardened clay loam.	-3.39
CM15_1.75	Soil	Comet Mahalo	27/08/2024	Dark brown hardened clay loam.	-4.45
CM15_2.0	Soil	Comet Mahalo	27/08/2024	Dark brown hardened clay loam.	-3.9
CM15_2.25	Soil	Comet Mahalo	27/08/2024	Dark brown hardened clay loam.	-3.52
CM15_2.5	Soil	Comet Mahalo	27/08/2024	Light brown clayey fine sand to sandy clay.	-3.24
CM15_2.75	Soil	Comet Mahalo	27/08/2024	Dark red brown hardened sandy clay loam.	-3.41
CM3_AU1_0.1	Soil	Comet Mahalo	29/08/2024	Grey fine silty sand.	-0.21
CM3_AU1_0.2	Soil	Comet Mahalo	29/08/2024	Grey-orange fine silty sand.	-0.19
CM3_AU1_0.5	Soil	Comet Mahalo	29/08/2024	Orange fine silty sand.	-0.14
CM3_AU1_0.75	Soil	Comet Mahalo	29/08/2024	Orange fine clayet sand.	-0.9
CM3_AU1_1.0	Soil	Comet Mahalo	29/08/2024	Orange fine clayey sand.	-2.65
CM3_AU1_1.25	Soil	Comet Mahalo	29/08/2024	Orange mottled sandy clayey with gravel	-2.39
CM7_AU1_0.2	Soil	Comet Mahalo	28/08/2024	Grey brown loamy clay.	-2.19
CM7_AU1_0.3	Soil	Comet Mahalo	28/08/2024	Grey fine sandy clay. Coarse tree roots observed.	-2.94
CM7_AU1_0.5	Soil	Comet Mahalo	28/08/2024	Grey clayey sand to sandy clay with some gravel.	-3.37
CM7_AU1_0.75	Soil	Comet Mahalo	28/08/2024	Grey fine sandy clay to clayey sand.	-4.55
CM7_AU1_1.0	Soil	Comet Mahalo	28/08/2024	Grey fine sandy clay with minor gravel.	-4.14
CM7_AU1_1.25	Soil	Comet Mahalo	28/08/2024	Grey clayey sand to sandy clay.	-4.4
CM7_AU1_1.5	Soil	Comet Mahalo	28/08/2024	Grey brown sandy clay.	-4.5

Sample	Type	Project	Date Sampled		SMP Value
CM7_AU1_1.8	Soil	Comet Mahalo	28/08/2024	Grey clayey sand to sandy clay.	-4.48
CM7_AU1_2.1	Soil	Comet Mahalo	28/08/2024	Grey brown clayey sand with strong mottling.	-4.15
CM7_AU1_2.5	Soil	Comet Mahalo	28/08/2024	Grey brown sandy clay to clayey sand. Mottled.	-4.41
CM7_AU1_2.8	Soil	Comet Mahalo	28/08/2024	Grey brown sandy clay to clayey sand. Mottled.	-5.47

Appendix D. Stable Isotope Results

Sample Number	Type	$d^{18}O$ VSMOW	$d^{2}H$ VSMOW	D_Excess	LC Excess
CM1_T1	Twig	-2.08	-14.79	1.85	-11.80
CM1_T2	Twig	-2.06	-13.42	3.06	-10.71
CM10_T2	Twig	-1.74	-10.91	3.01	-10.13
CM11_T1	Twig	-1.99	-16.51	-0.59	-13.74
CM11_T2	Twig	-1.69	-13.13	0.39	-12.31
CM11_T3	Twig	-0.57	-9.32	-4.76	-14.63
CM12_T1	Twig	-2.86	-13.72	9.16	-6.94
CM12_T2	Twig	-2.59	-12.98	7.74	-7.66
CM12_T4	Twig	-2.1	-13.54	3.26	-10.61
CM14_T1	Twig	-2.15	-11.37	5.83	-8.47
CM14_T2	Twig	-2.71	-13.08	8.60	-7.14
CM14_T3	Twig	-1.67	-9.91	3.45	-9.61
CM15_T1	Twig	-2.4	-13.99	5.21	-9.49
CM15_T3	Twig	-1.24	-10.73	-0.81	-12.49
CM15_T4	Twig	-1.27	-6.78	3.38	-8.90
CM15_T5	Twig	-0.16	-8.83	-7.55	-16.27
CM3_T1	Twig	-2.19	-12.37	5.15	-9.14
CM3_T2	Twig	-1.29	-6.18	4.14	-8.28
CM3_T3	Twig	-1.18	-9.64	-0.20	-11.84
CM4_T1	Twig	-1.98	-16.25	-0.41	-13.57
CM4_T3	Twig	-2.19	-8.35	9.17	-5.64
CM5_T2	Twig	-1.29	-5.83	4.49	-7.98
CM5_T4	Twig	-1.68	-8.93	4.51	-8.71
CM6_T1	Twig	-3.25	-16.49	9.51	-7.39
CM6_T2	Twig	-0.34	-11.91	-9.19	-18.04
CM6_T3	Twig	-1.09	-8.48	0.24	-11.29
CM7_T1	Twig	-2.64	-13.19	7.93	-7.59
CM7_T2	Twig	-2.86	-13.72	9.16	-6.94
CM8_T1	Twig	-1.35	-12.38	-1.58	-13.37
CM8_T3	Twig	-0.13	-3.91	-2.87	-12.14
CM8_T4	Twig	-2.11	-10.23	6.65	-7.68
CM9_T3	Twig	-2.04	-10.61	5.71	-8.36
CM14_AU1_0.1	Soil	-0.2	1.9	3.50	-6.73
CM14_AU1_0.3	Soil	-1.4	-12.21	-1.01	-12.97
CM14_AU1_0.5	Soil	-3.9	-19.89	11.31	-7.08
CM14_AU1_0.75	Soil	-4.62	-19.46	17.50	-3.09
CM14_AU1_1.00	Soil	-3.99	-18.29	13.63	-5.24
CM14_AU1_1.25	Soil	-2.13	-8.8	8.24	-6.34
CM14_AU1_1.5	Soil	-5.07	-20.28	20.28	-1.54
CM14_AU1_1.6	Soil	-4.65	-16.95	20.25	-0.76
CM15_0.1	Soil	0.59	0.24	-4.48	-12.15
CM15_0.15	Soil	-1.25	-8.89	1.11	-10.84
CM15_0.25	Soil	-2.95	-14.99	8.61	-7.60

CM15_0.5	Soil	-3.5	-16.33	11.67	-6.00
CM15_1.0	Soil	-3.64	-14.57	14.55	-3.76
CM15_1.25	Soil	-3.77	-10.21	19.95	0.68
CM15_1.5	Soil	-3.35	-19.15	7.65	-9.20
CM15_1.75	Soil	-4.32	-24.36	10.20	-8.86
CM15_2.0	Soil	-2.12	-6.23	10.73	-4.15
CM15_2.25	Soil	-4.36	-22.47	12.41	-7.01
CM15_2.5	Soil	-4.77	-24.86	13.30	-7.03
CM15_2.75	Soil	-4.54	-24.19	12.13	-7.60
CM7_AU1_0.2	Soil	1.68	-3.19	-16.63	-20.61
CM7_AU1_0.3	Soil	-1.99	-12.38	3.54	-10.15
CM7_AU1_0.5	Soil	-2.97	-19.14	4.62	-11.10
CM7_AU1_0.75	Soil	-3.44	-18.46	9.06	-8.15
CM7_AU1_1.0	Soil	-3.61	-19.41	9.47	-8.12
CM7_AU1_1.25	Soil	-3.53	-17.59	10.65	-6.94
CM7_AU1_1.5	Soil	-2.86	-13.15	9.73	-6.45
CM7_AU1_1.8	Soil	-3.51	-15.89	12.19	-5.56
CM7_AU1_2.1	Soil	-3.58	-14.51	14.13	-4.01
CM7_AU1_2.5	Soil	-3.82	-14.89	15.67	-3.14
CM7_AU1_2.8	Soil	-3.78	-18.11	12.13	-6.14
CM3_AU1_0.1	Soil	-0.32	-6.89	-4.33	-13.77
CM3_AU1_0.2	Soil	-0.81	-12.83	-6.35	-16.48
CM3_AU1_0.5	Soil	-3.09	-17.19	7.53	-8.81
CM3_AU1_0.75	Soil	-4.16	-19.73	13.55	-5.64
CM3_AU1_1.0	Soil	-4.71	-22.64	15.04	-5.40
CM3_AU1_1.25	Soil	-4.04	-18.09	14.23	-4.81
RAIN MOR_171121_1806	Rainfall	0.78	-10.65	-16.89	-22.57
RAIN MOR_181121_0806	Rainfall	2.72	-8.05	-29.81	-30.06
Clermont Mar-Apr-08	Rainfall	-1.77	-10.61	3.55	-9.72
Clermont Mar-Apr-08	Rainfall	-3.49	-10.76	17.16	-1.20
RAIN MOR 19-11	Rainfall	-0.21	-13.32	-11.64	-19.92
CM15_SW1	Surface Water	-1.68	-15.99	-2.55	-14.85
MN-MB1-a	Ground Water	-4.2	-31	2.60	-15.23
MB-MB5-R	Ground Water	-2.7	-20	1.60	-13.21
MN-MB6-b	Ground Water	-3.1	-21	3.80	-12.07