CDM SMITH AUSTRALIA

1/30 Wangaratta Street
Richmond VIC 3121
australia@cdmsmith.com

Technical Report

North Star Magnetite Project Extension – Phase 2 Terrestrial GDV Risk Assessment

PREPARED FOR:

Fortescue Ltd

Level 2
87 Adelaide Terrace
East Perth WA 6004

listen. think. deliver.

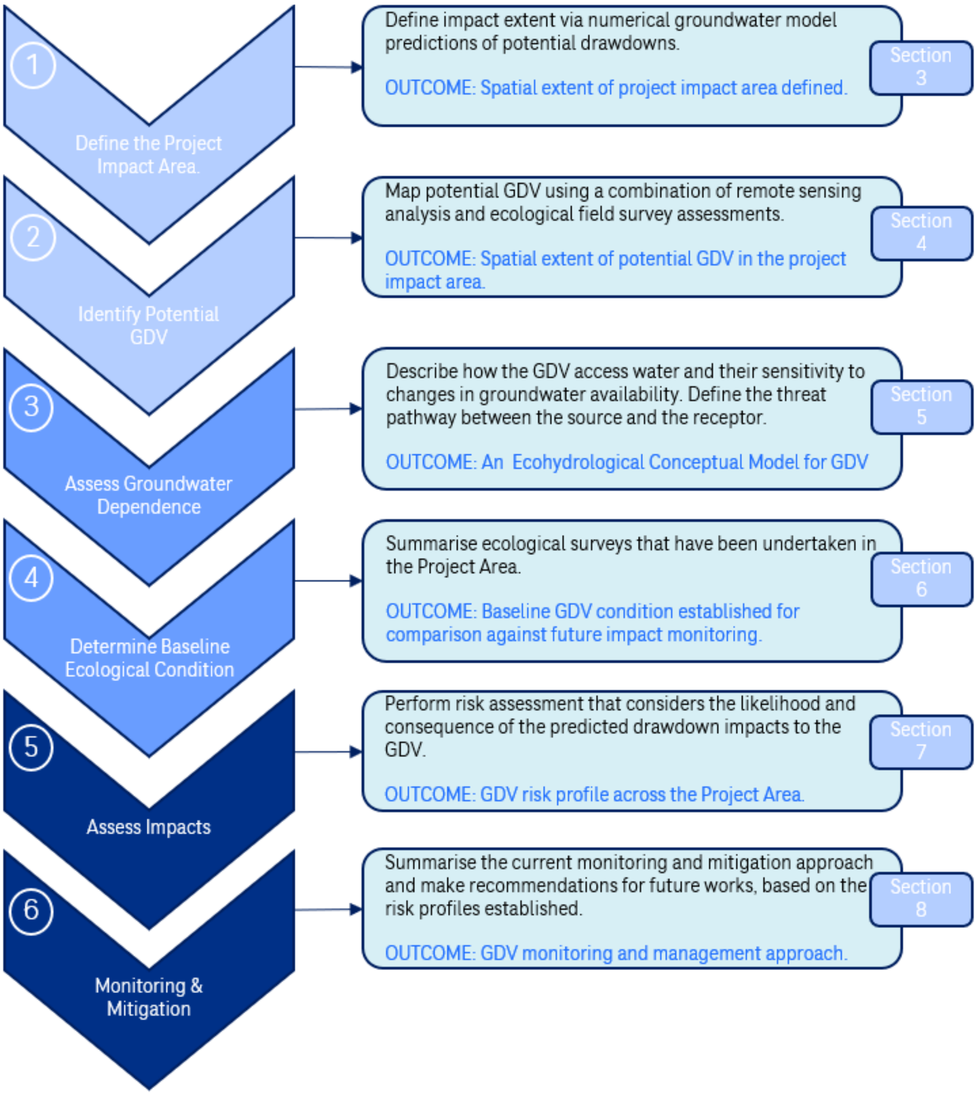
Executive Summary

This investigation addresses queries 59, 60 and 61 of the PER, that require an assessment of potential groundwater dependent vegetation (GDV), in accordance with the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (the IESC) Information Guidelines Explanatory Note – Assessing groundwater dependent ecosystems (IESC.gov.au).

The results of the assessment are consistent with previous risk categorisation of the GDV by FMG IB. (2023c), with Medium to High risks to potential GDV associated with the riparian corridor broadly across the Project Area, and an Extreme risk associated with the GDV associated with Mundagoora Pool.

The High risk GDV mapped within the NSE area is associated with the drawdowns anticipated to occur under the Proposed Action, whereas the risk to GDV outside of this area is generated under the Approved Proposal (including the risks associated with GDV at the Mundagoora Pool).

The report has been structured in alignment with the assessment approach recommended by the IESC (2019), including the step-by-step GDE assessment framework (Figure 1-1) that is recommended by the IESC (2019) and has been adapted to the specifics of this project.



Define impact extent via numerical groundwater model predictions of potential drawdowns.

OUTCOME: Spatial extent of project impact area defined.

Map potential GDV using a combination of remote sensing analysis and ecological field survey assessments.

OUTCOME: Spatial extent of potential GDV in the project impact area.

Describe how the GDV access water and their sensitivity to changes in groundwater availability. Define the threat pathway between the source and the receptor.

OUTCOME: An Ecohydrological Conceptual Model for GDV

Summarise ecological surveys that have been undertaken in the Project Area.

OUTCOME: Baseline GDV condition established for comparison against future impact monitoring.

Perform risk assessment that considers the likelihood and consequence of the predicted drawdown impacts to the GDV.

OUTCOME: GDV risk profile across the Project Area.

Summarise the current monitoring and mitigation approach and make recommendations for future works, based on the risk profiles established.

OUTCOME: GDV monitoring and management approach.

Figure 1-1 GDV risk assessment approach, adapted from IESC (2019)

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Document history & status

Revision	Date issued	Reviewed by	Approved by	Date approved	Revision type
A	14/11/2024	J Fawcett	J Fawcett	14/11/2024	PD Review
A	14/11/2024	F Dean	F Dean	14/11/2024	Editorial Review
1	31/01/2025	E Wiltshire	E Wiltshire	31/01/2025	Tech Review
2	13/02/2025	J Fawcett	J Fawcett	13/02/2025	PD Review
3	20/03/2025	J Fawcett	J Fawcett	20/03/2025	PD Review
4	28/03/2025	E Wiltshire	E Wiltshire	28/03/2025	Tech Review
5	08/04/2025	E Wiltshire	E Wiltshire	08/04/2025	Tech Review

Distribution of copies

Version	Date issued	Quantity	Electronic	Issued to
0	14/11/2024	1	1	V Rios Vera
2	13/02/2024	1	1	V Rios Vera
3	20/03/2025	1	1	V Rios Vera
4	28/03/2025	1	1	V Rios Vera
5	08/04/2025	1	1	V Rios Vera

Last Saved:	8 April 2025
File Name:	RPT-1001816-FMG-GDV Phase 2 Risk Assessment_Rev5
Author:	E Wiltshire, J Fawcett, W Wyche, C Pelizaro
Project Manager:	E Wiltshire
Client:	Fortescue Ltd
Document Title:	**North Star Magnetite Project Extension – Phase 2 Terrestrial GDV Risk Assessment**
Document Version:	5
Project Number:	1001816

Section 1 Introduction

1.1 Background

Fortescue Metals Group (FMG) Iron Bridge (Aust) Pty Ltd proposes to construct and operate a mine extension at the existing FMG Iron Bridge (Aust) North Star Magnetite project (the proposed action). The mine extension will include mine pits, waste rock dump, and associated mine infrastructure. The proposed action is located approximately 110 km southeast of Port Hedland, in the Pilbara region of Western Australia (WA).

The North Star Extension (NSE) is anticipated to disturb 606.9 hectares (ha), on unallocated crown land on the Wallareenya Pastoral Lease.

The NSE was referred under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) to the Minister for the Environment (the Minister) in January 2023. In November 2023 the Minister concluded that the project has the potential to cause significant impacts on matters of national environmental significance (MNES) that are protected in the EPBC Act.

The NSE will be assessed by a Public Environment Report (PER). The PER will address 99 queries/considerations outlined in EPBC ref: 2023/09466.

1.2 Objective

FMG has engaged CDM Smith to assist with query 59, 60 and 61 of the PER specifically:

- *59) The PER must include an assessment of vegetation classified as potentially groundwater dependent. This assessment should follow recommendations made by the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (the IESC) Information Guidelines Explanatory Note – Assessing groundwater dependent ecosystems (IESC.gov.au).*
- *60) The PER should provide information relating to the characterisation of groundwater dependent vegetation. With specific reference to key indicator species for vegetation groundwater dependence (Eucalyptus victrix), which has been identified in the area.*
- *61) Vegetation fringing the Mundagoora Pool is considered groundwater dependent vegetation (FMGIB, 2023a, p. 110), a risk assessment of the potential impacts to this resource as it applies to relevant EPBC listed threatened species and communities and their habitats is required.*

Section 2 Regional Setting

The ‘Project Area’ is shown in Figure 2-2 and encompasses the NSE and a much broader surrounding area, described in more detail in Section 3 as capturing the extent of potential impact. The Project Area is located approximately 110 km southeast of Port Hedland in the Pilbara region of Western Australia.

2.1 Climate

The climate of the Pilbara bioregion is characterised by two distinct seasons; hot, wet summers and mild, dry winters. Annual rainfall in the Pilbara is highly variable and generally low, ranging from 300-350 mm in the northeast to less than 250 mm in the west (Sudmeyer, 2016). Rainfall is typically highest during summer and autumn, and lowest during winter and spring. The drivers of rainfall also vary spatially; tropical and monsoonal influences are more prominent in the east during summer and autumn, while southern mid-latitude drivers, including frontal systems, are prevalent in the west during autumn and winter (Sudmeyer, 2016).

The cumulative deviation from mean rainfall (CDFM rainfall) plot (Figure 2-1) for the NSE area illustrates long-term rainfall trends. The positive gradient from 1995-2020 for example, indicates higher rainfall conidtions relative to the average, while negative gradients (such as from 1910-1970) indicate lower than average rainfall conditions.

Currently, this area is in a relatively dry period, with below average rainfall conditions from 2020 to present.

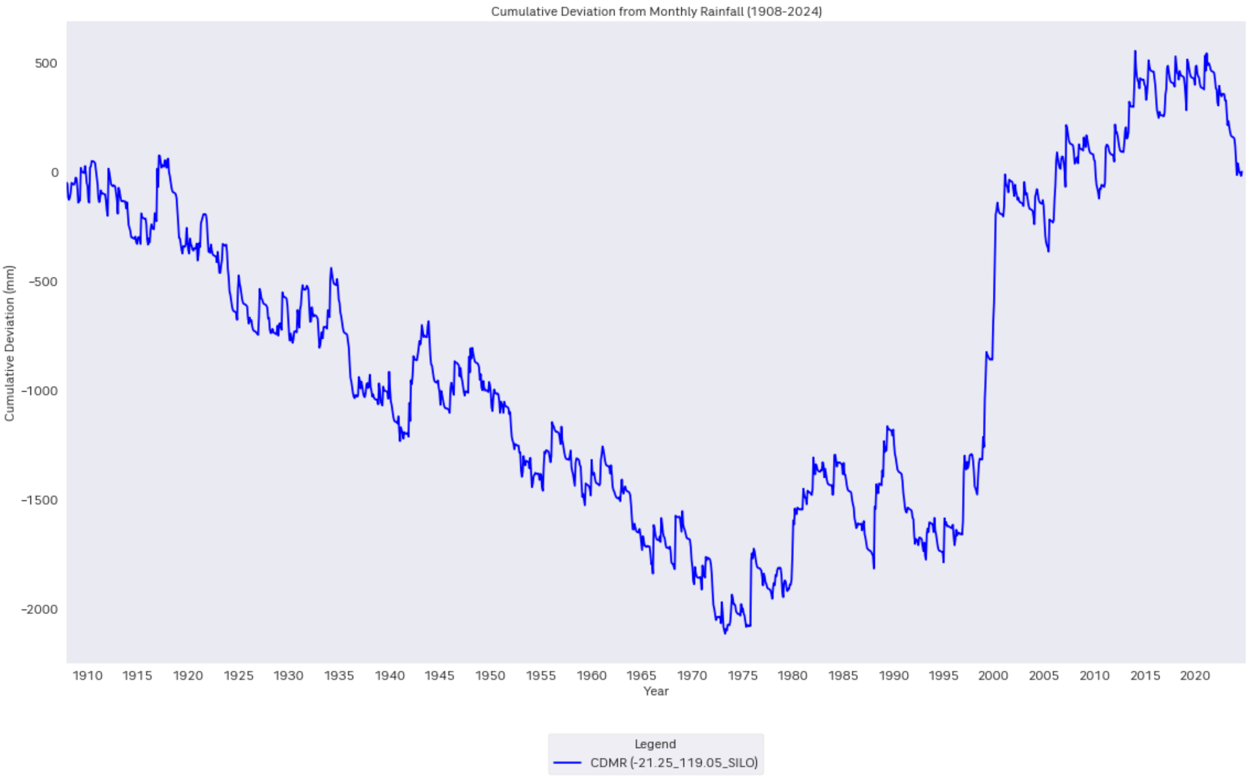


Figure 2-1 CDFM rainfall for the NSE area from 1908 to 2024 (data derived from SILO database)

2.2 Topography and Hydrology

The topography of the project area is dominated by a significant ridge feature of around 430 m AHD, that runs in a north-south orientation through the NSE and also delineates a catchment divide (Figure 2-2). To the east of the ridge are the Shaw River and Strelley River catchments. Small ephemeral creeks drain in an easterly direction towards the

Shaw River, which is approximately 18 km from the NSE. To the west of the ridge is the Turner River catchment. A number of small ephemeral tributaries flow from the NSE in a westerly direction to eventually feed into the larger Turner River, located about 15 km from the NSE.

There are multiple pools in and around the NSE that range from permanent to ephemeral. Four pools that have groundwater contributions are included on Figure 2-2 and include Mundagoora Pool, Cow Spring, Fig Pool and Site 12 Pool. Only Mundagoora Pool is considered in this assessment as it has fringing vegetation that is groundwater dependent.

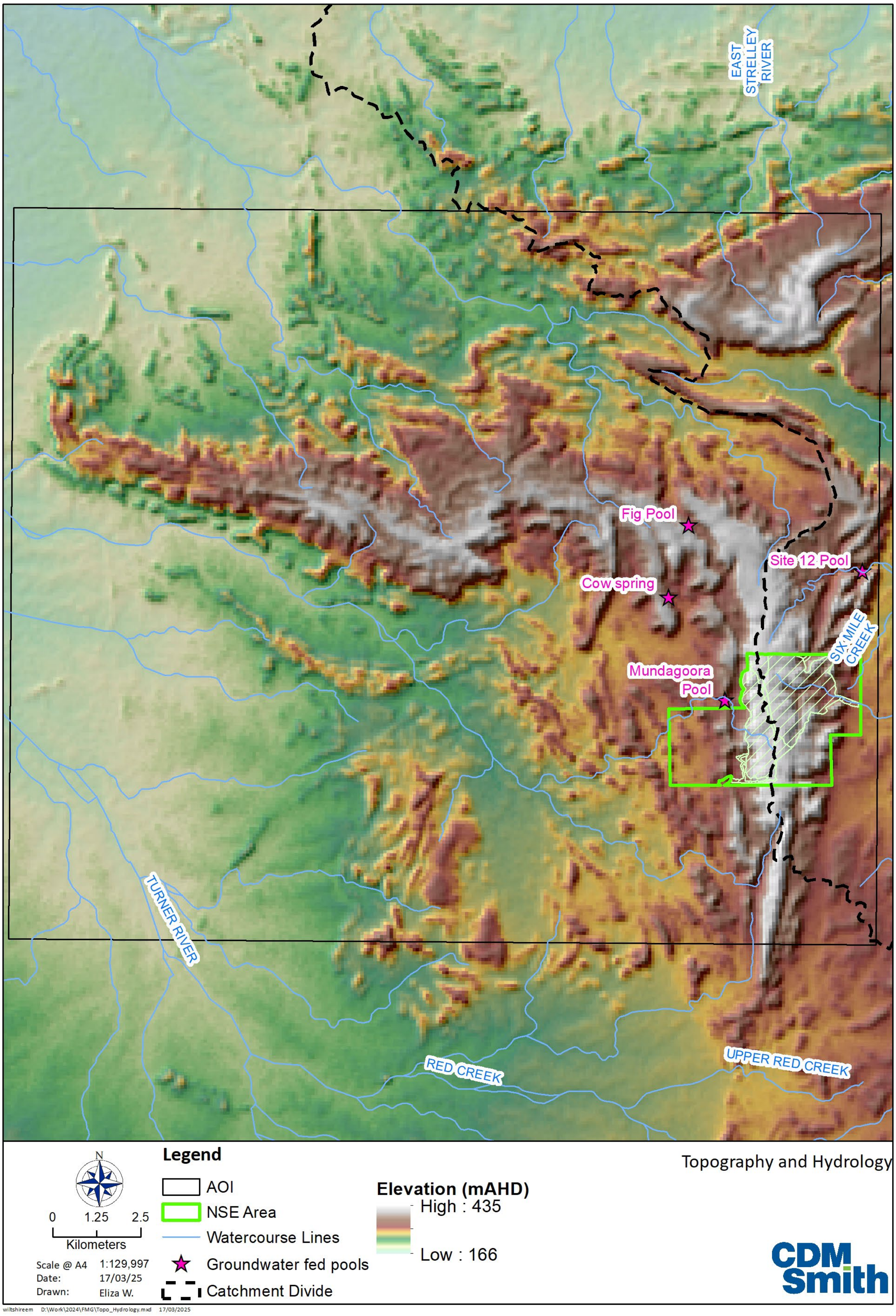


Figure 2-2 Project area topography and hydrological features

2.3 Geology

The iron ore deposit underlying the NSE is hosted within the Paleoarchean Pincunah Banded-iron Member of the Sulphur Springs Group (FMG IB, 2022). The Sulphur Springs Group is inconsistently overlain by the Gorge Creek Group, which is comprised of sandstone and conglomerate.

The Sulphur Springs Group is comprised from base to top of; Leilira Formation, Kunagunarrina Formation, Kangaroo Caves Formation and the Pincunah Banded-iron Member.

The Southern and Northern Borefields of the Iron Bridge project are located within the Sulphur Springs Group, while the Eastern Borefield is located within the Gorge Creek Group.

2.4 Mining Landuse and Groundwater Abstraction

FMG IB North Star (NS) was referred under the Environmental Protection Act (1986) in 2012 and was approved in early 2015. The project commenced construction in 2019, and first ore was shipped from NS in 2022, with approximately 20 MTPA of high-grade magnetite concentrate product for export.

Groundwater abstraction data provided by FMG is presented in Figure 2-3 and indicates that approximately 11 GL of groundwater has been extracted from production bores for NS operations to date. Major periods of extraction occurred during the following dates:

- 2014-2016, with annual abstraction rates reaching 150 ML/year;
- 2020-2021, with annual abstraction rates reaching 215 ML/year; and
- 2023-current, with annual abstraction rates exceeding 250 ML/year.

As part of a numerical groundwater modelling exercise, Groundwater Consulting Pty Ltd (FMG IB, 2023b) simulated the following future water supply borefield abstraction rates associated with the NSE;

- Borefield abstraction of 3.5 GL/year from July 2022 – December 2024;
- A reduction in borefield abstraction to 3 GL/yr until December 2031; and
- A further reduction in borefield abstraction to 2 GL/year until June 2044.

An analysis of the dewatering impacts on the watertable according to the monitoring bore network is discussed further in Section 3 (Extent of Potential Impact).

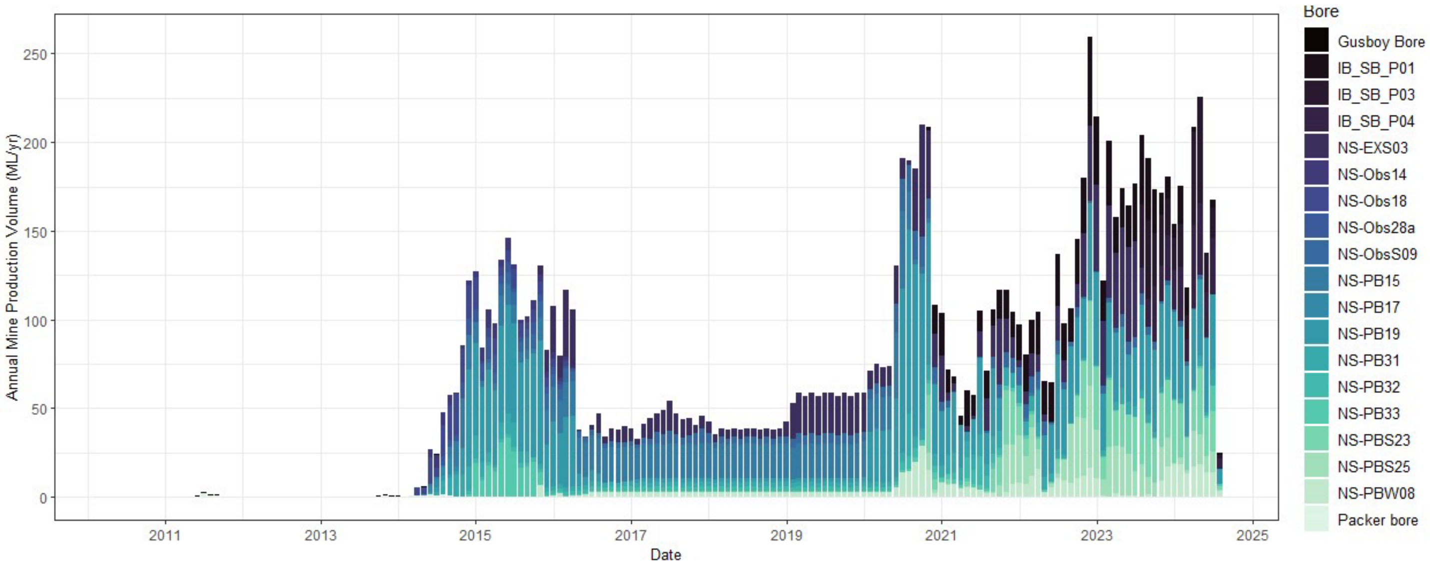


Figure 2-3 FMG IB North Star annual dewatering from production bores

2.5 Hydrogeology

2.5.1 Hydrostratigraphy

The regional hydrogeology is defined by four key hydrostratigraphic units (FMG IB, 2022):

- Alluvial sand and gravel deposits adjacent to some creeks that are a few metres thick, mostly restricted to the immediate stream channel area, and intermittently saturated following major rainfall events.
- The weathered and oxide/fresh transition zone that is up to 60-70 m deep. Fractured rock aquifers within the weathered profile present transmissivity values that can be locally high, but generally low. The transition zone is considered a poor aquifer in terms of storage and transmissivity and is highly reliant on rainfall recharge.
- The deep fractured bedrock that consists of various greenstone rocks of mainly igneous basalt, ultramafic and andesitic tuff, and sedimentary rocks of sandstone, siltstone, shale, chert and banded iron-formation (i.e. Corboy Formation, Pincunah Hill Formation and Kangaroo Caves Formation).
- The shale units that structurally sandwich the host BIF in a syncline (i.e. western shale of the Kangaroo Formation and Eastern inter-bedded shales of the Corboy Formation), form a poorly developed aquifer(s).

The hydrostratigraphic profile can be generalised as a weathered and fractured basement overlain by unconsolidated alluvium in the vicinity of the creek lines. Groundwater is found predominantly within the weathered rock mass and fractured bedrock. The four hydrostratigraphic units are connected, with some compartmentalisation by local faults (FMG IB, 2023b). Transmissivity is highly variable, ranging from 1.9 – 2,000 m^2/day.

2.5.2 Groundwater recharge

Groundwater recharge is primarily driven by infiltration of rainfall associated with cyclonic events and the interaction with intermittent stream flows occurring during the wet season.

Groundwater levels fluctuate seasonally, typically peaking during the wet season from summer to autumn and declining in the dry season from winter to spring. Shallow bores in the Western Borefield reflect these seasonal recharge events, as seen in Figure 2-4, with water level trends closely aligning with rainfall (CDMR from SILO rainfall data in the NSE). Significant wet season rainfall events, when they occur, correspond with up to 7.5 m of groundwater recovery. Notably, there is a consistent decline in groundwater levels since 2021 and this corresponds with the negative CDMR trend, indicating that the lower than average rainfall characteristic of the recent period can be considered as a driver of declining groundwater levels.

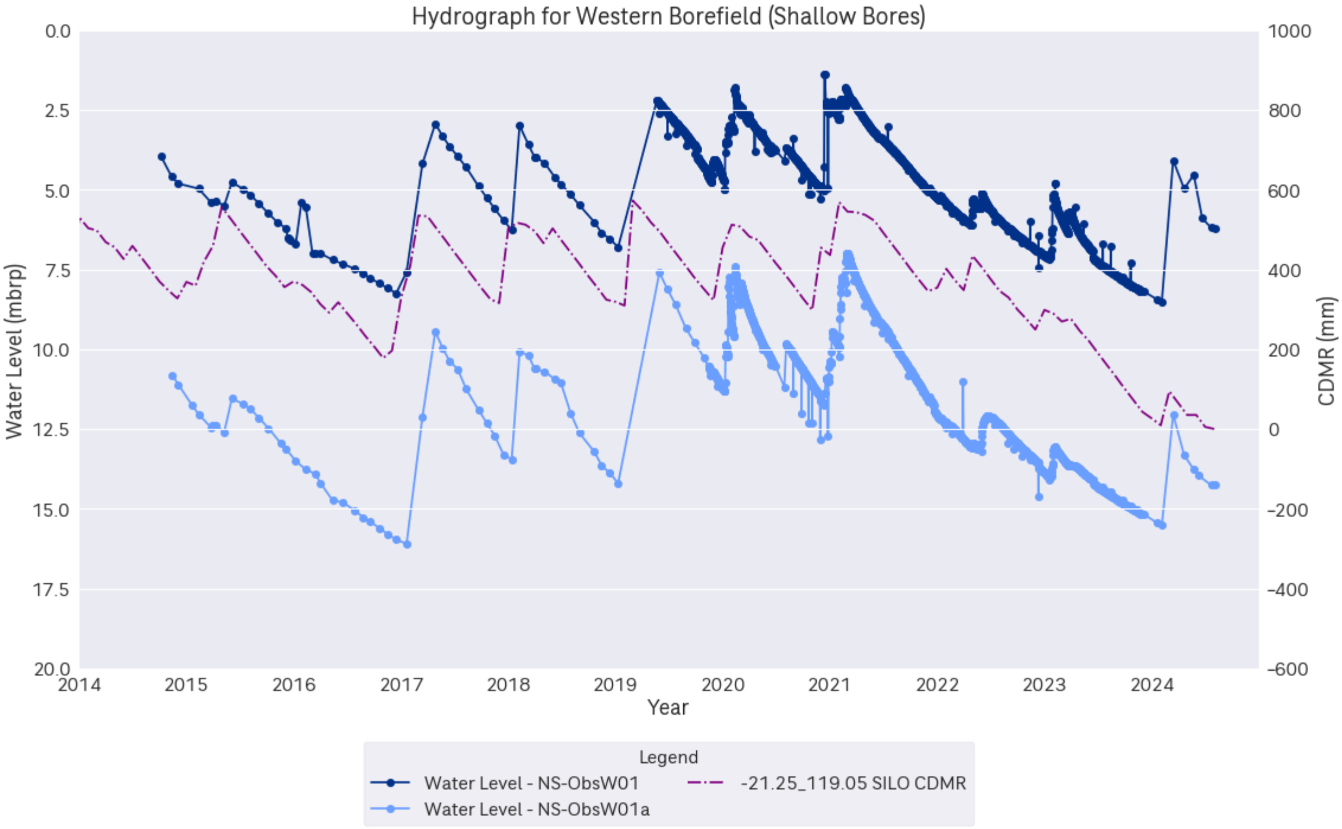


Figure 2-4 Seasonal recharge events at shallow Western Borefield bores

2.5.3 Groundwater level data

FMG manage a large network of groundwater abstraction and monitoring bores that generally have groundwater data from 2014. The information for a selection of these bores that reside within a 200 m buffer of potential GDV (locations included in Figure 2-5) has been plotted in spatially related groups. The hydrographs are included in Figure 2-6 and a high level summary of the watertable characteristics observed by the hydrographs is provided in Table 2-1. This indicates that there are a number of areas that are characterised by shallow watertables (<10 m deep) and that where there is sufficient data (frequency and duration), a seasonal watertable recharge response can be observed, with groundwater levels fluctuating by up to 7 m in some cases. Most monitoring bores also show a gradual decline in watertable between 2021-2024, correlating to below average rainfall conditions (although the additional influence of groundwater abstraction in the area cannot be ruled out as another driver of the trend). There are two areas where groundwater abstraction is currently impacting the watertable (the Southern Borefield and Northern Borefield), with around 40 meters of decline in groundwater levels observed in some bores.

Trend analysis of the groundwater hydrographs has been undertaken using Mann-Kendall to statistically assess if there is an upward or downward trend and a simple linear regression (Theil-Sen) that calculates the rate of change (i.e. meters per year decline in groundwater level). These results are included in Appendix A.

Table 2-1 High level summary of watertable characteristics in zones considered in this assessment.

	Shallow Watertable (<10m)	Moderate Watertable (10-20m)	Deep Watertable (>20m)	Watertable shows Seasonal Response	Watertable shows Dewatering Impact (currently)
Western Borefield	Yes	Yes	No	Yes	No

	Shallow Watertable (<10m)	Moderate Watertable (10-20m)	Deep Watertable (>20m)	Watertable shows Seasonal Response	Watertable shows Dewatering Impact (currently)
Waste Rock Dump 1 Area	Yes	Yes	No	Yes	No
Mundagoora	No	Yes	No	No (but limited data)	No
Northern Valley	No	Yes	No	No (but limited data)	No
Southern Borefield	Yes	No	No	No (but limited data)	Yes
Northern Borefield	Yes	No	No	No (but limited data)	Yes
Glacier Valley Pit Area	No	No	Yes	No	No (deep WLs but no production bores)
North Star Pit Area	Yes	Yes	Yes	Yes	No (historic impact observed in one abstraction bore)
TSF & WRP Area	Yes	No	Yes	Yes	No (historic impact observed in one abstraction bore)

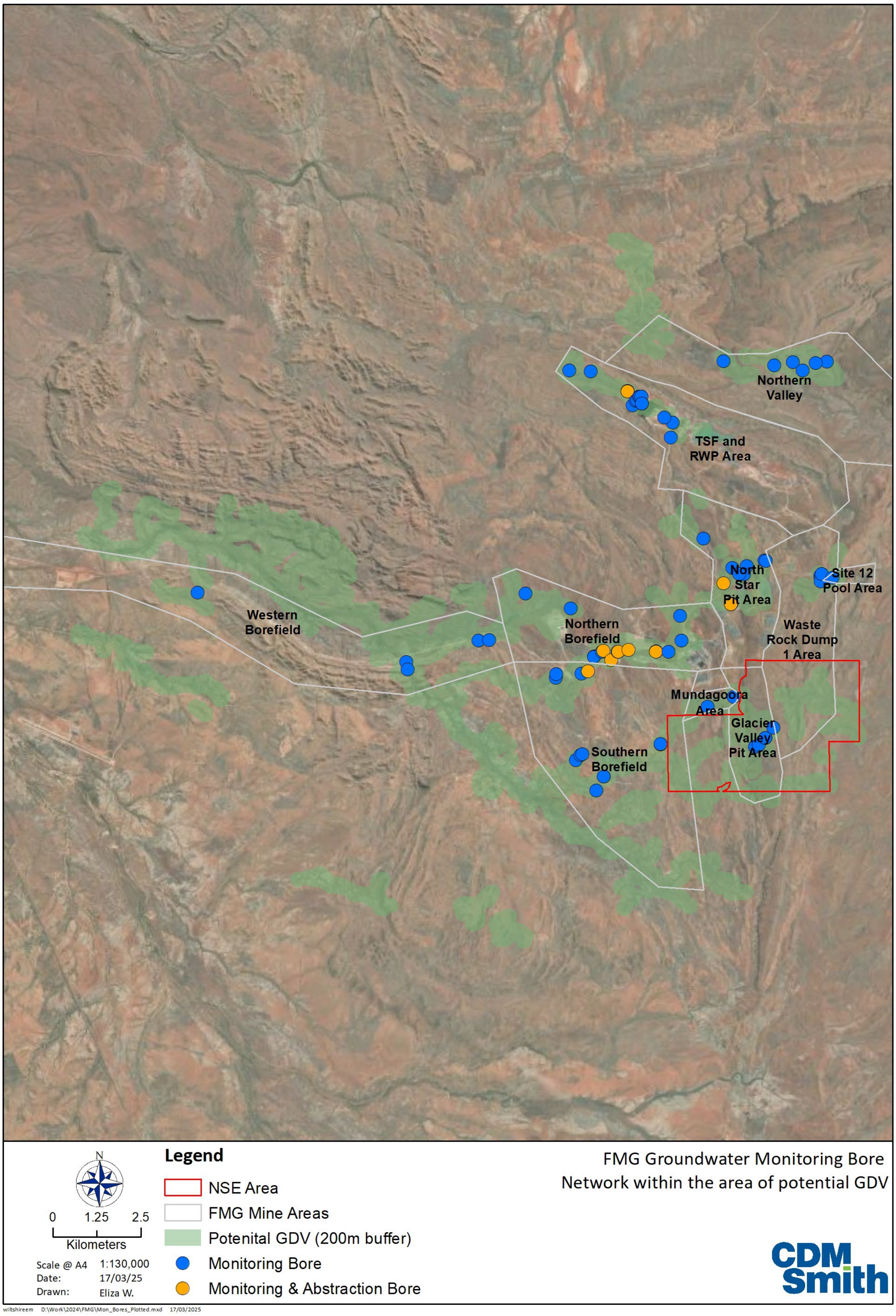
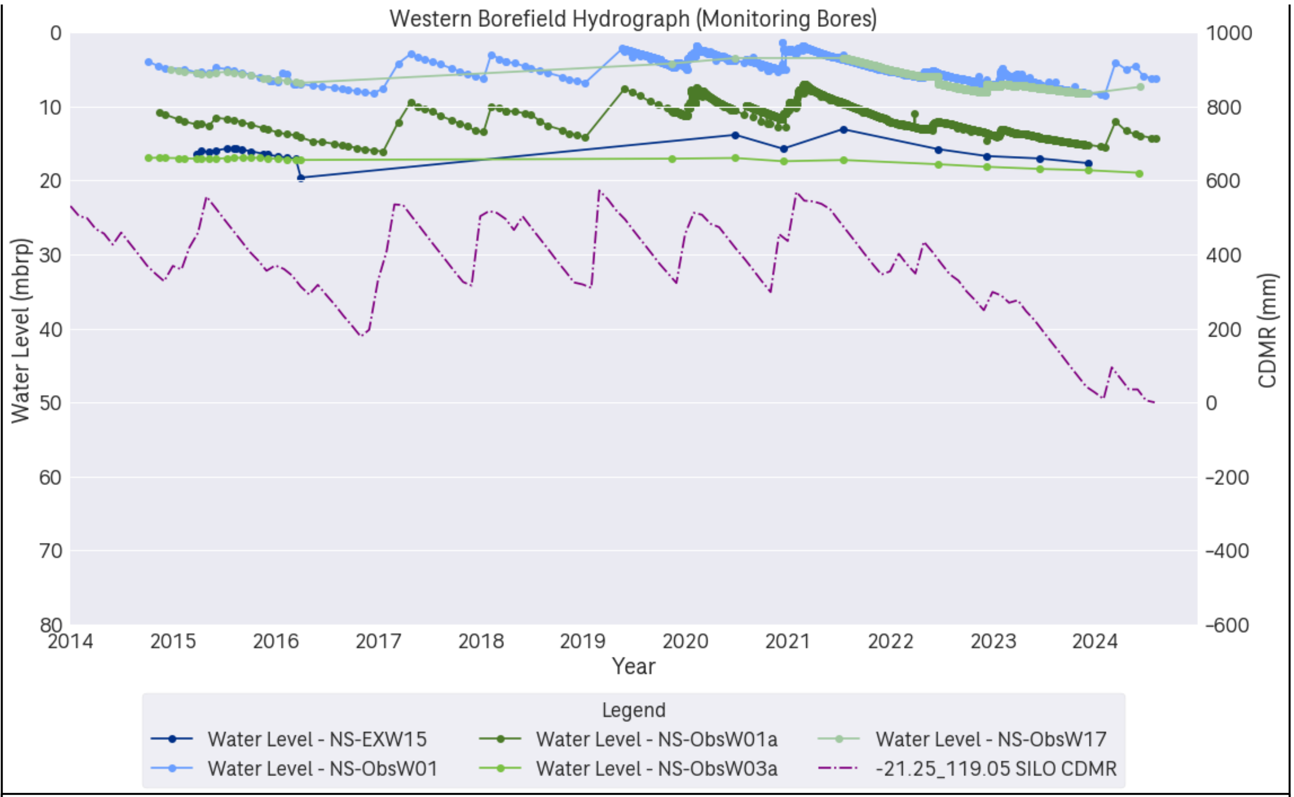
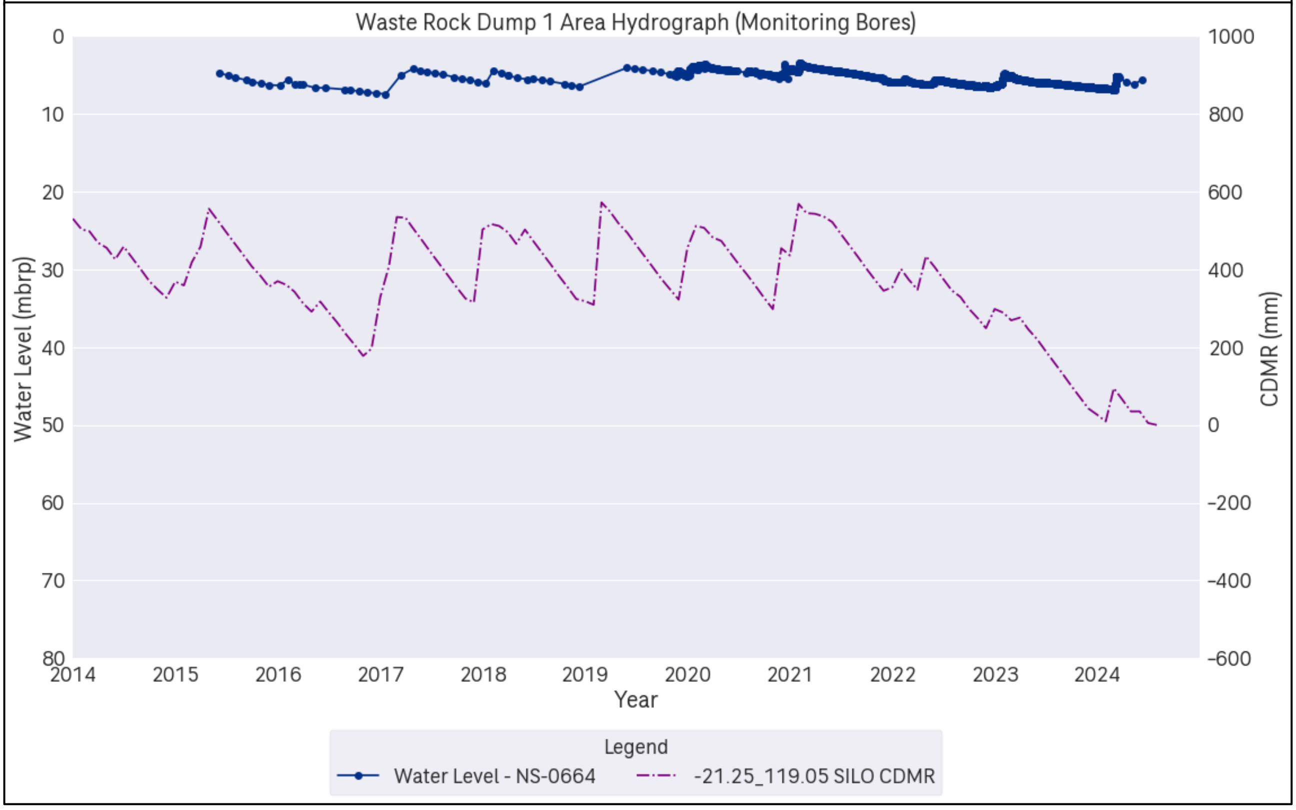
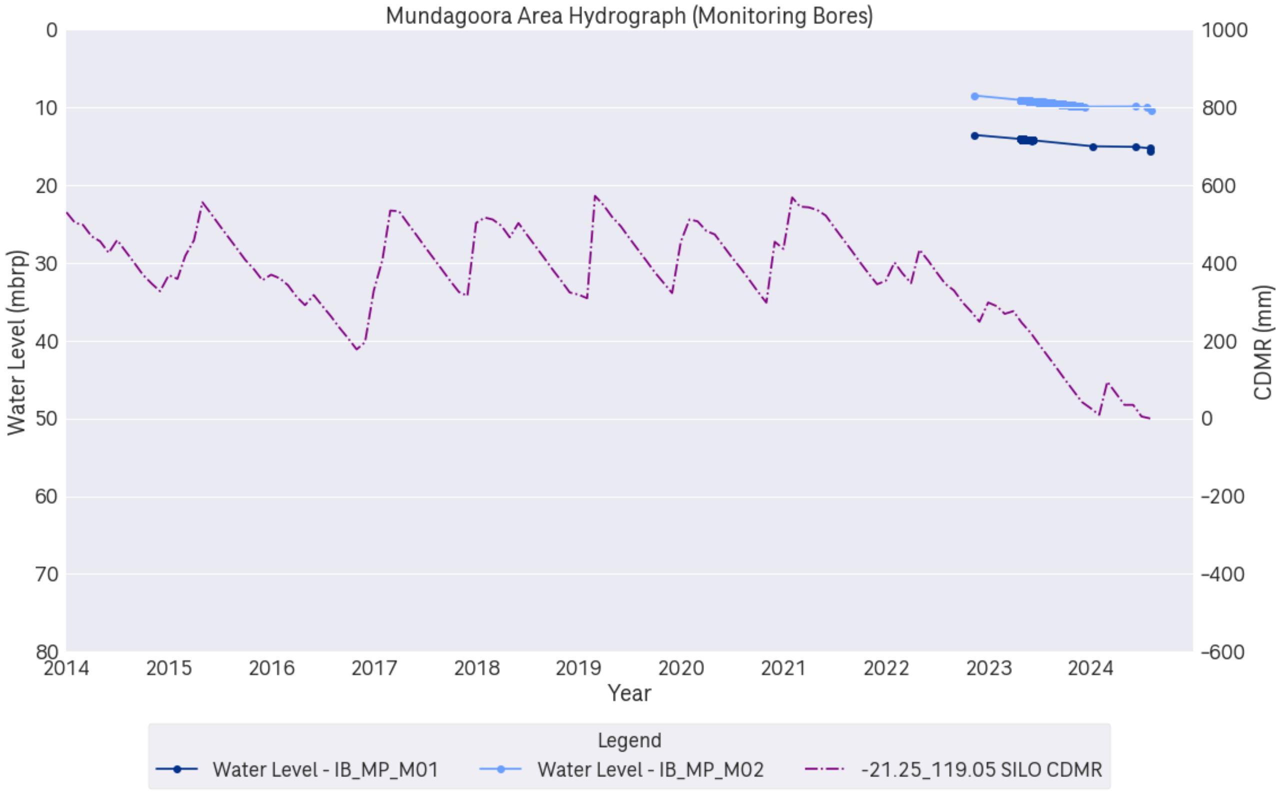
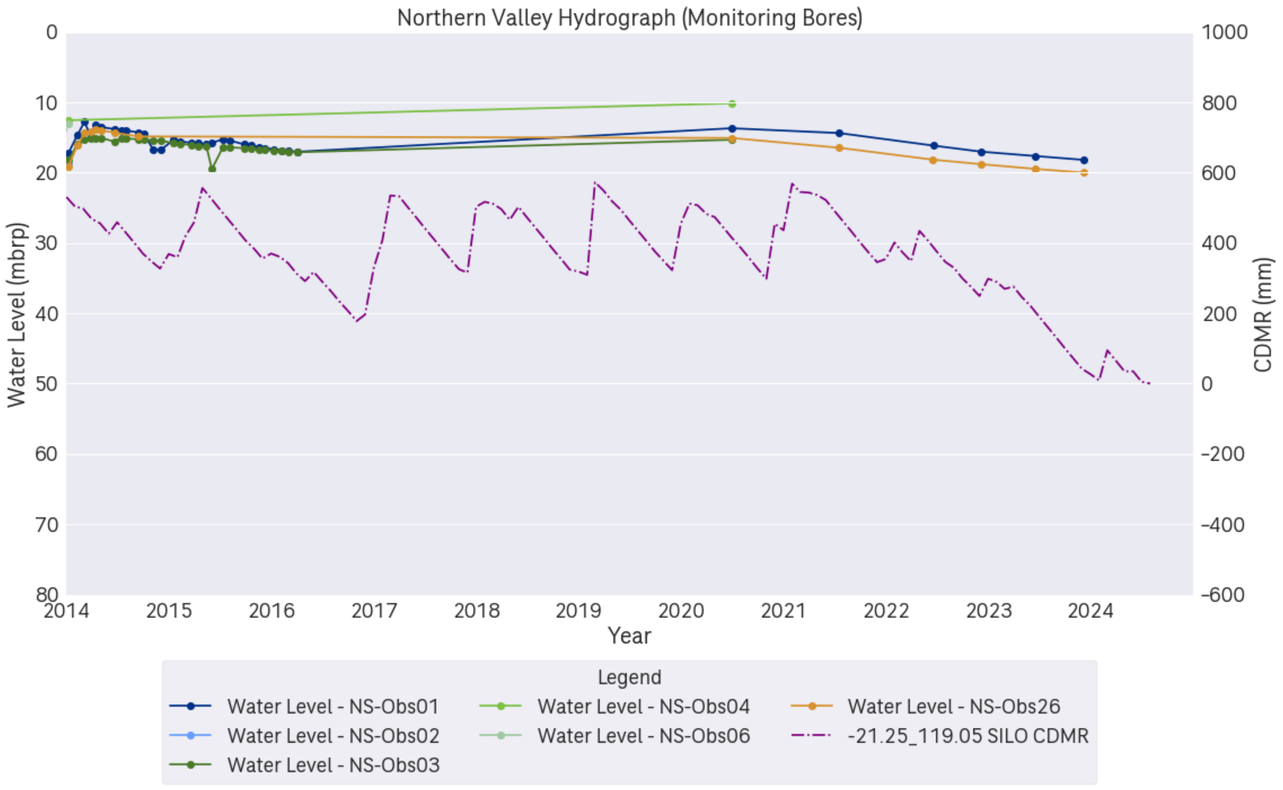


Figure 2-5 FMG Groundwater Monitoring / Production Bore Network within the potential GDV area


Western Borefield Hydrograph (Monitoring Bores)
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
CDMR (mm)
1000
800
600
400
200
0
−200
−400
−600
Year
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Legend
Water Level - NS-EXW15
Water Level - NS-ObsW01
Water Level - NS-ObsW01a
Water Level - NS-ObsW03a
Water Level - NS-ObsW17
-21.25_119.05 SILO CDMR


Waste Rock Dump 1 Area Hydrograph (Monitoring Bores)
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
CDMR (mm)
1000
800
600
400
200
0
−200
−400
−600
Year
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Legend
Water Level - NS-0664
-21.25_119.05 SILO CDMR


Mundagoora Area Hydrograph (Monitoring Bores)
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
CDMR (mm)
1000
800
600
400
200
0
−200
−400
−600
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Year
Legend
Water Level - IB_MP_M01
Water Level - IB_MP_M02
-21.25_119.05 SILO CDMR


Northern Valley Hydrograph (Monitoring Bores)
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
CDMR (mm)
1000
800
600
400
200
0
−200
−400
−600
2014
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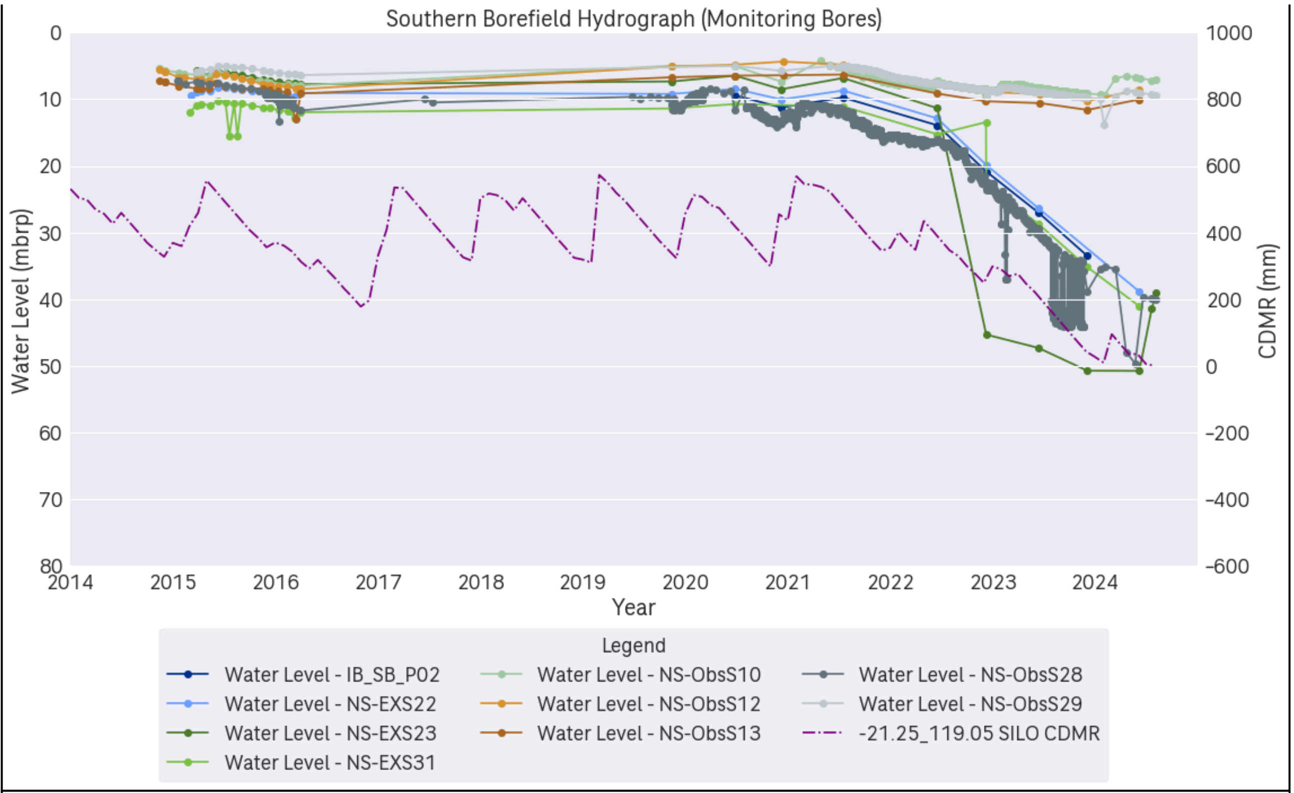
2021
2022
2023
2024
Year
Legend
Water Level - NS-Obs01
Water Level - NS-Obs02
Water Level - NS-Obs03
Water Level - NS-Obs04
Water Level - NS-Obs06
Water Level - NS-Obs26
-21.25_119.05 SILO CDMR


Southern Borefield Hydrograph (Monitoring Bores)
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
CDMR (mm)
1000
800
600
400
200
0
-200
-400
-600
2014
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2018
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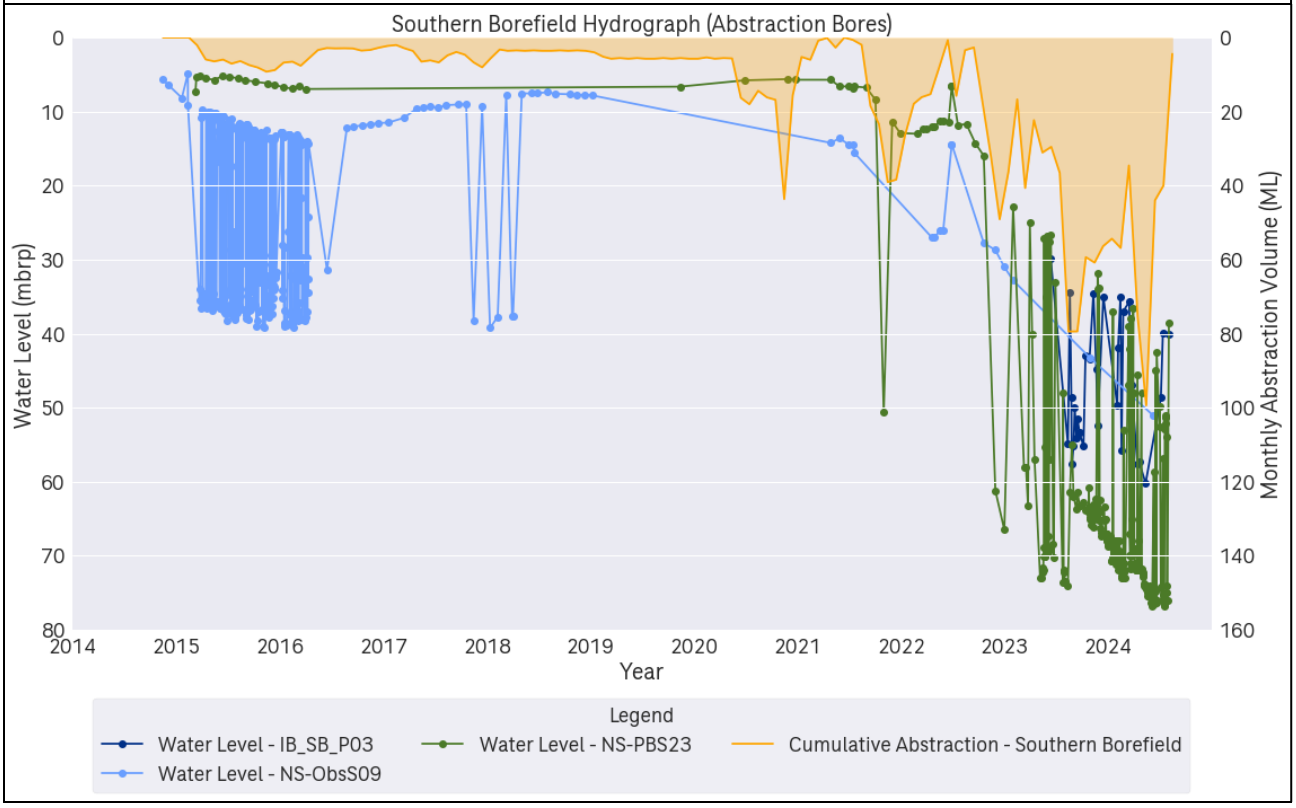
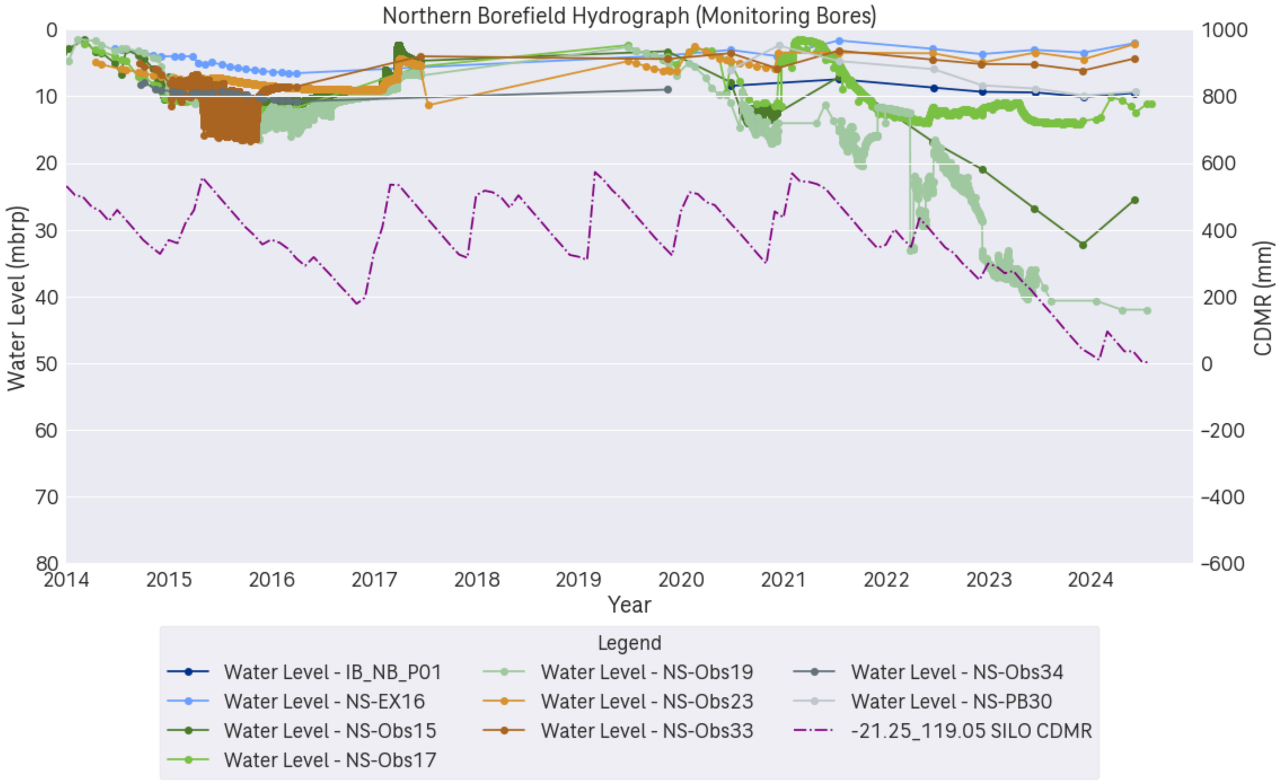
2021
2022
2023
2024
Year
Legend
Water Level - IB_SB_P02
Water Level - NS-EXS22
Water Level - NS-EXS23
Water Level - NS-EXS31
Water Level - NS-ObsS10
Water Level - NS-ObsS12
Water Level - NS-ObsS13
Water Level - NS-ObsS28
Water Level - NS-ObsS29
-21.25_119.05 SILO CDMR


Southern Borefield Hydrograph (Abstraction Bores)
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
Monthly Abstraction Volume (ML)
0
20
40
60
80
100
120
140
160
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Year
Legend
Water Level - IB_SB_P03
Water Level - NS-ObsS09
Water Level - NS-PBS23
Cumulative Abstraction - Southern Borefield


Northern Borefield Hydrograph (Monitoring Bores)
Water Level (mbrp)
0
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40
50
60
70
80
CDMR (mm)
1000
800
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400
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−200
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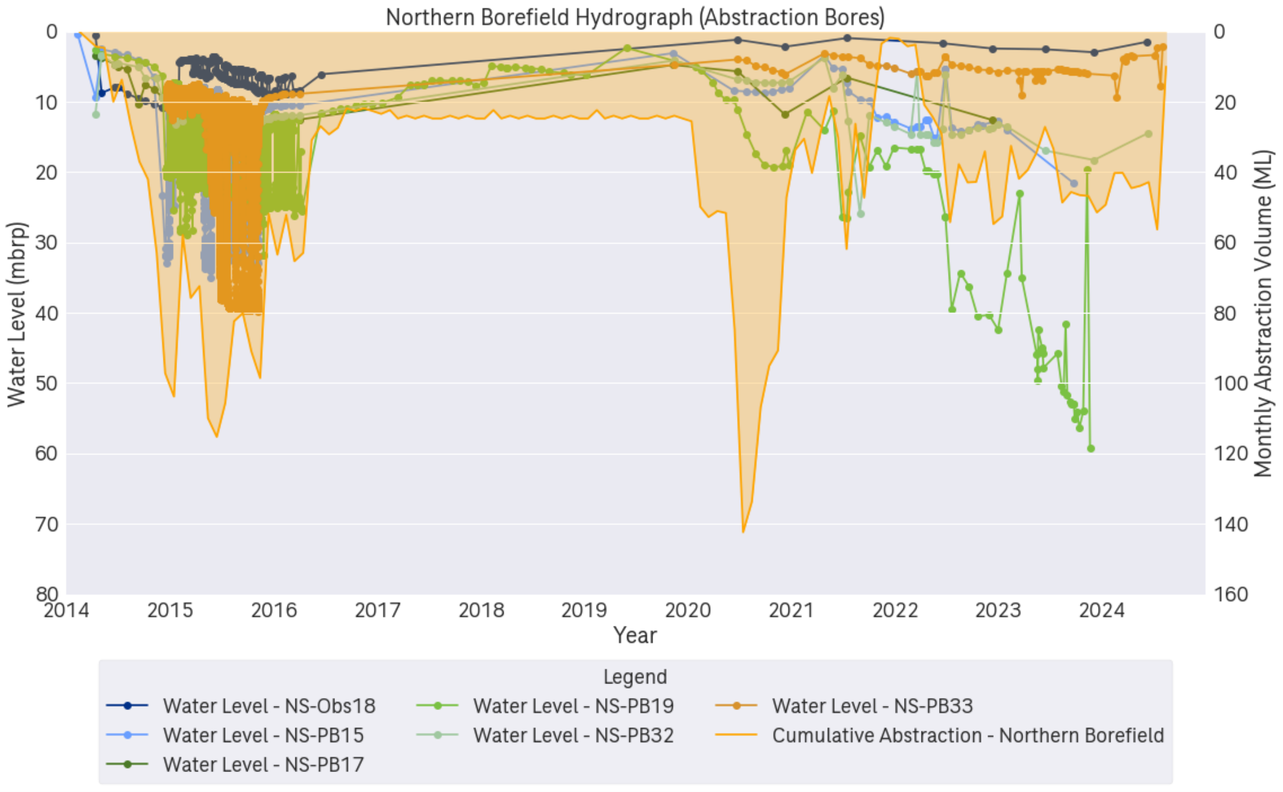
2023
2024
Year
Legend
Water Level - IB_NB_P01
Water Level - NS-EX16
Water Level - NS-Obs15
Water Level - NS-Obs17
Water Level - NS-Obs19
Water Level - NS-Obs23
Water Level - NS-Obs33
Water Level - NS-Obs34
Water Level - NS-PB30
-21.25_119.05 SILO CDMR


Northern Borefield Hydrograph (Abstraction Bores)
Water Level (mbrp)
0
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40
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60
70
80
Monthly Abstraction Volume (ML)
0
20
40
60
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140
160
2014
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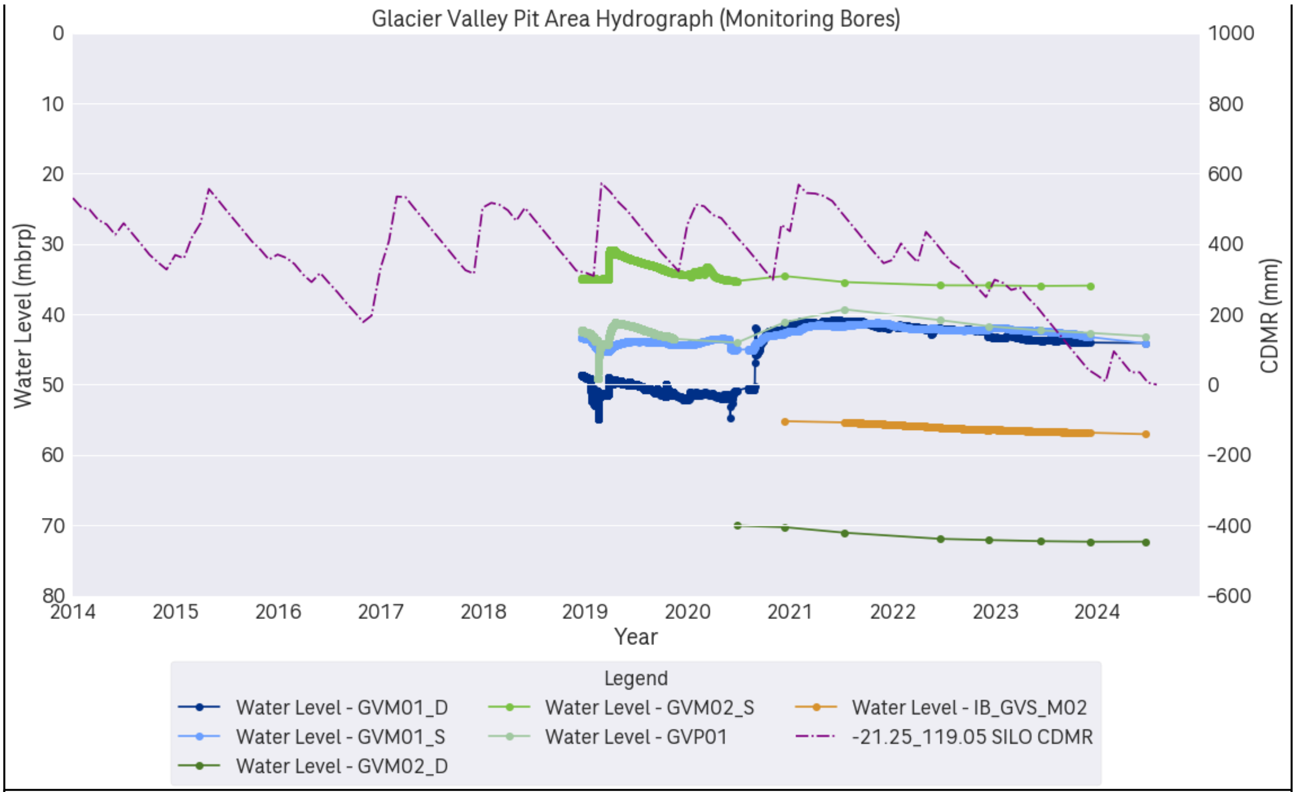
2021
2022
2023
2024
Year
Legend
Water Level - NS-Obs18
Water Level - NS-PB15
Water Level - NS-PB17
Water Level - NS-PB19
Water Level - NS-PB32
Water Level - NS-PB33
Cumulative Abstraction - Northern Borefield


Glacier Valley Pit Area Hydrograph (Monitoring Bores)
Water Level (mbrp)
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CDMR (mm)
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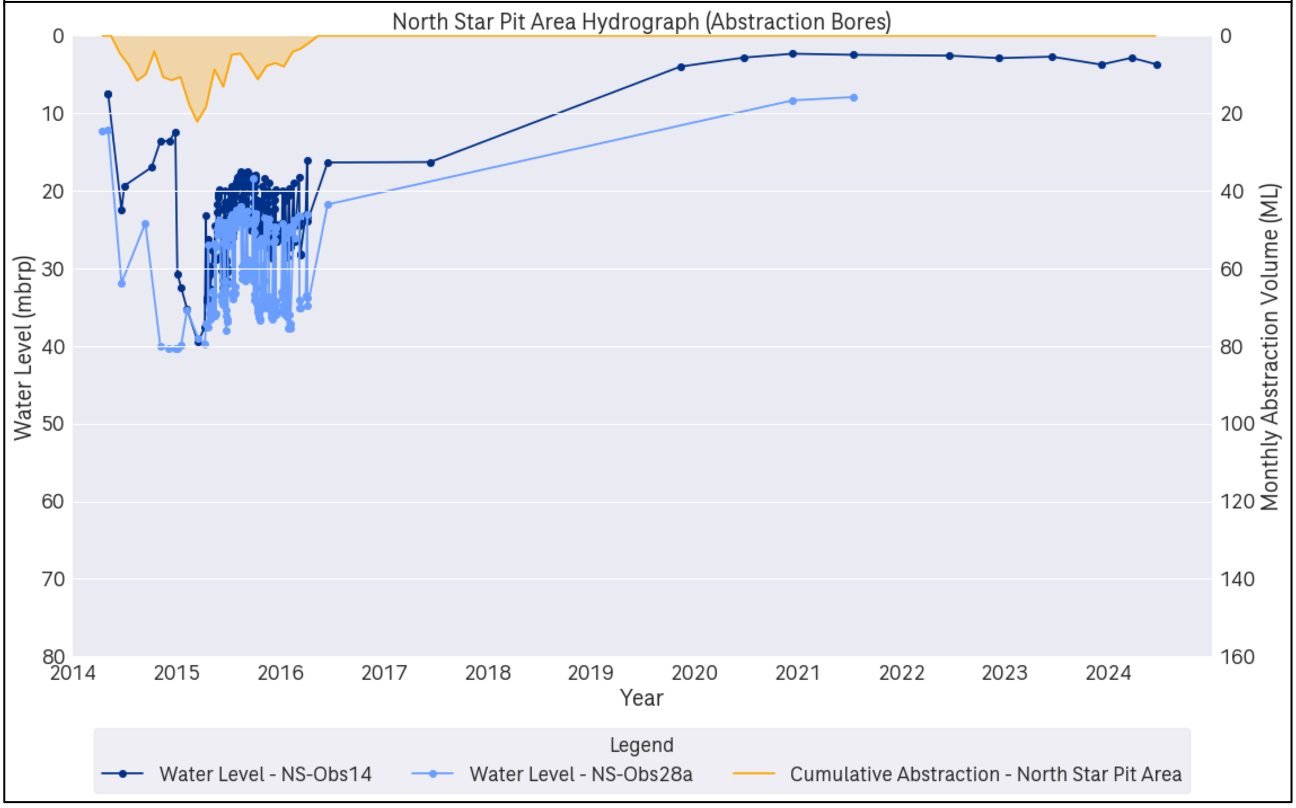
Year
Legend
Water Level - GVM01_D
Water Level - GVM01_S
Water Level - GVM02_D
Water Level - GVM02_S
Water Level - GVP01
Water Level - IB_GVS_M02
-21.25_119.05 SILO CDMR


North Star Pit Area Hydrograph (Abstraction Bores)
Water Level (mbrp)
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Monthly Abstraction Volume (ML)
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100
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140
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2024
Year
Legend
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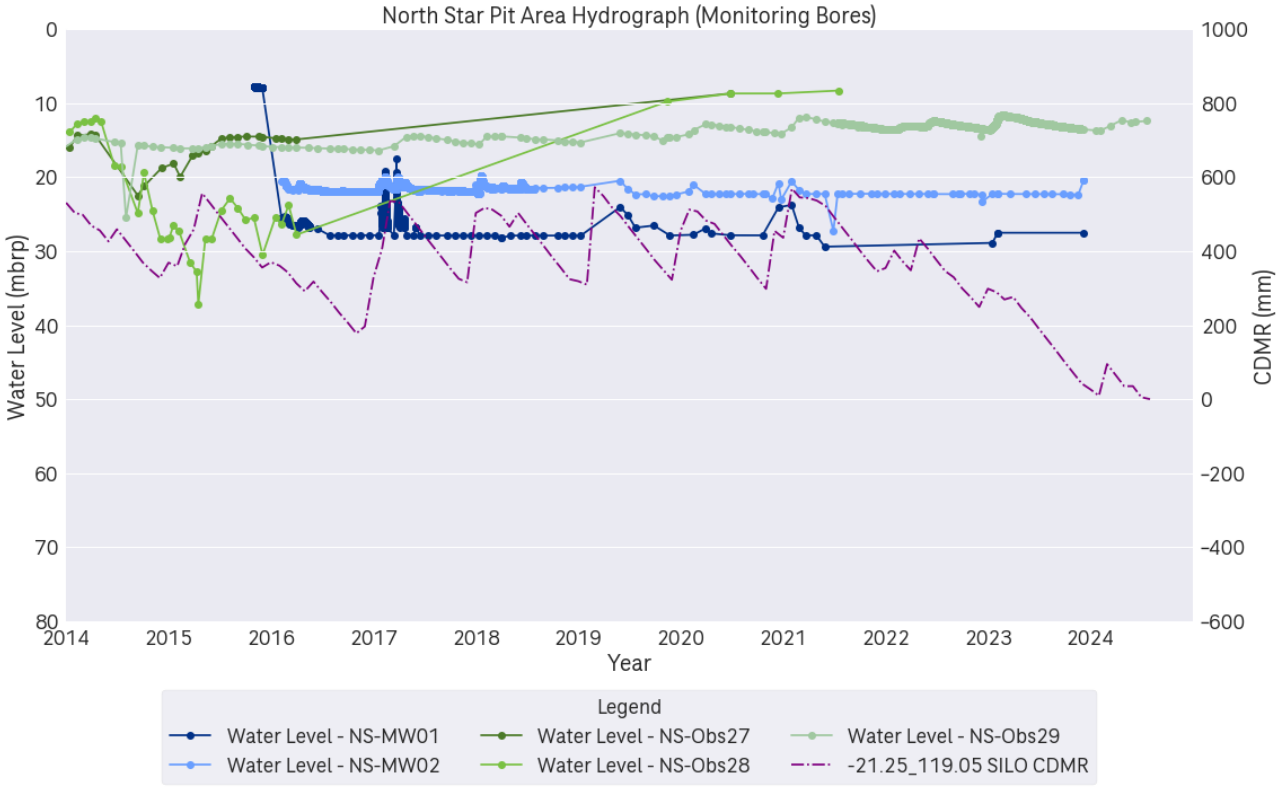
Water Level - NS-Obs28a
Cumulative Abstraction - North Star Pit Area


North Star Pit Area Hydrograph (Monitoring Bores)
Water Level (mbrp)
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CDMR (mm)
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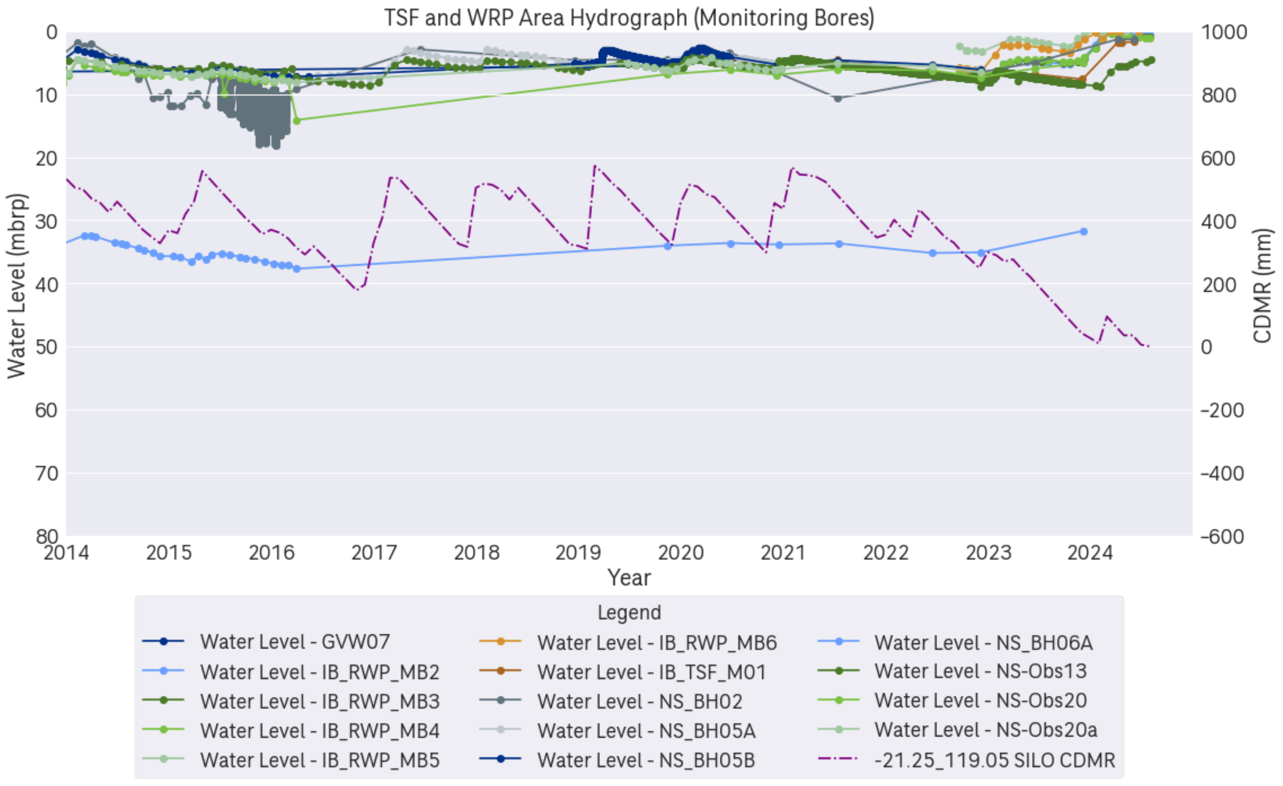
2024
Legend
Water Level - NS-MW01
Water Level - NS-MW02
Water Level - NS-Obs27
Water Level - NS-Obs28
Water Level - NS-Obs29
-21.25_119.05 SILO CDMR


TSF and WRP Area Hydrograph (Monitoring Bores)
Water Level (mbrp)
0
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CDMR (mm)
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−600
Year
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2019
2020
2021
2022
2023
2024
Legend
Water Level - GVW07
Water Level - IB_RWP_MB2
Water Level - IB_RWP_MB3
Water Level - IB_RWP_MB4
Water Level - IB_RWP_MB5
Water Level - IB_RWP_MB6
Water Level - IB_TSF_M01
Water Level - NS_BH02
Water Level - NS_BH05A
Water Level - NS_BH05B
Water Level - NS_BH06A
Water Level - NS-Obs13
Water Level - NS-Obs20
Water Level - NS-Obs20a
-21.25_119.05 SILO CDMR

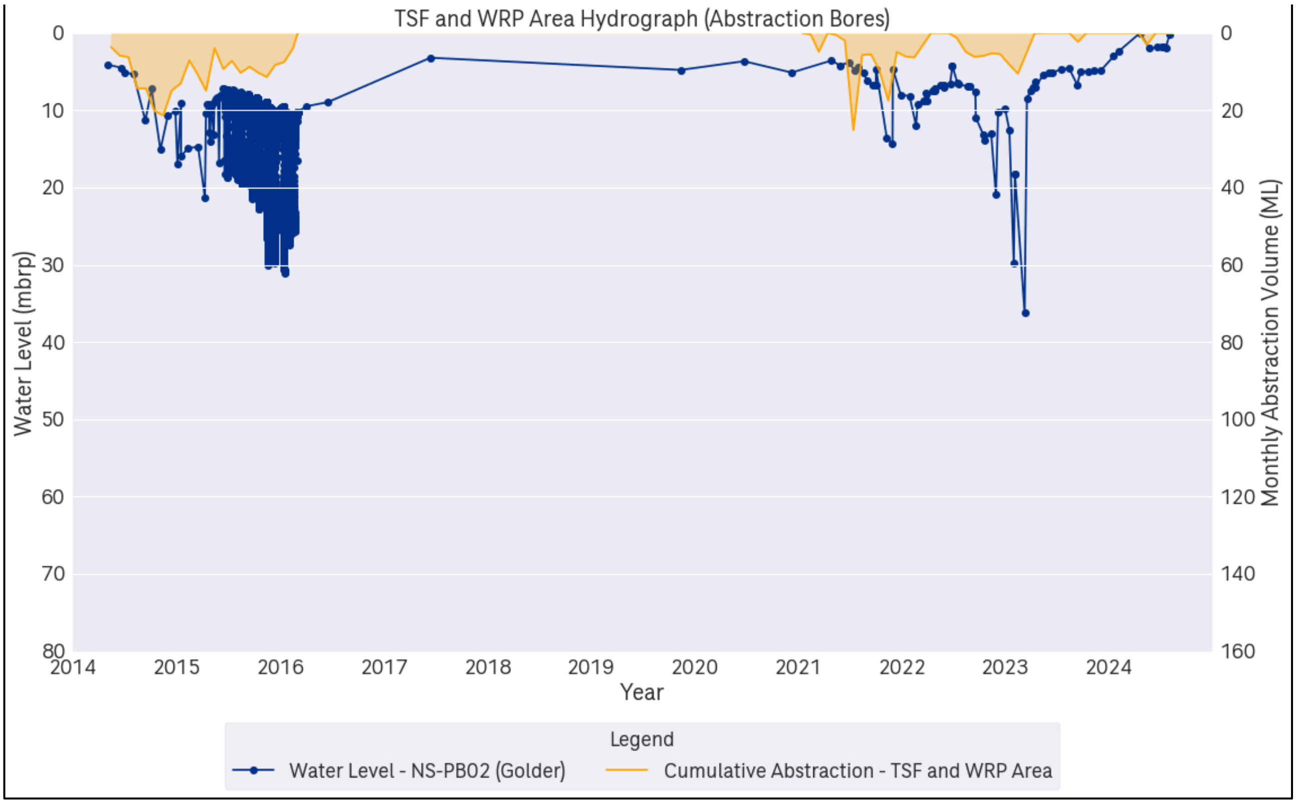


Figure 2-6 Hydrographs per mine area (depicted in Figure 2-5) and split by monitoring and production bores

2.6 Ecology

The National Vegetation Information System (NVIS) has classified the major vegetation group across the NSE as Hummock Grasslands (DCCEEW, 2017). This vegetation group is characterised by an open groundcover of spiny hummocks formed by grasses in the genus Triodia. These areas often have scattered acacias and eucalypts that emerge above the prominent hummock layer.

2.6.1 Significant Vegetation & Flora

The EPA Technical Guidance – Flora and Vegetation Surveys for Environmental Impact Assessment (EPA WA, 2016) outlines that vegetation may be considered significant for a variety of reasons, including;

- being identified as threatened ecological communities (TECs) or priority ecological communities (PECs);
- having restricted distribution;
- being linked with historical impacts from threatening processes;
- having a role as a refuge;
- providing a key function required for sustained ecological integrity of a significant ecosystem.

The same EPA guidance document (EPA WA, 2016) also outlines that flora may be considered significant for a variety of reasons, including;

- being identified as a threatened or priority species;
- being locally endemic or associated with a restricted habitat type (e.g. groundwater dependent ecosystems);
- being a new species or having features that indicate a potential new species;
- being a range representation (plants that occur at the geographic extremes of their species' distribution);

- being an unusual species (rare);
- having relictual status (representing taxonomic groups that have largely disappeared from the broader landscape).

One significant vegetation type (EvApTl) was identified in the Project Area in recent Ecoscape (2024) flora and vegetation surveys, due to it potentially representing GDV, which is classified as a restricted habitat type.

EvApTl is described as; *Eucalyptus victrix and Corymbia hamersleyana low open woodland over Acacia pyrifolia var. pyrifolia, A. tumida var. pilbarensis and Petalostylis labicheoides mid sparse shrubland over Triodia longiceps, Cymbopogon ambiguus and Stemodia grossa low open hummock/tussock grassland/forbland.*

The Mundagoora Pool hosts the EvApTl vegetation type and has also been shown to provide critical habitat for threatened species such as the endangered Northern Quoll and vulnerable Pilbara Leaf-nosed Bat, Ghost Bat, and Pilbara Olive Python (Spectrum Ecology, 2021). In this instance, EvApTl also provides a key function required for sustained ecological integrity of the ecosystem.

Section 3 Extent of Project Impact Area

The IESC (2019) includes a framework comprised of 6 steps that are recommended to be followed when considering the potential impacts to GDEs from mining (Figure 1-1). Step 1 of the framework is to define the project impact area, which includes the footprint of surface infrastructure and the extent of mine depressurisation.

This section establishes the project impact area, based on the outputs from a numerical groundwater model that was developed by Groundwater Consulting Pty Ltd (FMG IB, 2023b). The numerical groundwater model aimed to assess the water supply potential and dewatering requirements associated with the North Star Magnetite Project (Approved Proposal) and the Proposed Action (North Star Magnetite Project Extension). From this perspective, the numerical model drawdown outputs are considered to represent the cumulative impacts of Approved and Proposed Actions within the North Star Project Area.

The model area (567 km2) is much larger than the NSE itself (approximately 15 km^2) and the model derived drawdown outputs are considered to represent cumulative drawdown impacts.

Model uncertainty analysis indicated that the model predictions were sensitive to recharge and therefore a 30% reduction in rainfall recharge scenario was assessed. The result of reducing rainfall recharge was a significantly larger predicted drawdown extent, which means this scenario is representative of a conservative model output. The predicted drawdown extent associated with the 30% reduced recharge scenario was used as input to this risk assessment for potential GDV.

The predictive model run spans a period of proposed mining from July 2022 to June 2044 (end of mine life), with pit dewatering abstraction and a water supply borefield abstraction scheme that commences with an abstraction rate of 3.5 GL/year in 2022 and concludes with an abstraction rate of 2 GL/year in 2044.

The model derived drawdowns used for this risk assessment represent the end of mine life (i.e. 2044) drawdown, under a conservative reduced rainfall scenario (i.e. a 30% reduction in recharge). Both the cumulative drawdowns (associated with the Approved Proposal and Proposed Action) and the drawdowns associated with the NSE only (i.e. the Proposed Action only) are considered in this assessment.

The model predicted drawdowns are presented in Figure 3-1. Observations regarding the cumulative drawdowns associated with both the Approved Proposal and the Proposed Action, include the following;

- The most significant drawdown occurs within the existing North Star Pit Area where drawdown up to ~350 m is predicted. The drawdown is highly confined to the pit area and tapers off rapidly due to the presence of surrounding shales.
- Significant drawdown (up to ~230m) is also observed in the Proposed Action (Glacier Valley) Pit Area, however similar to the North Star Pit Area, the drawdown is highly localised in extent and does not propagate far from the pits themselves.
- The borefield abstractions in the Northern and Southern Borefield areas lead to drawdowns of 90-98 m below pre-development levels. The drawdown mainly propagates in a westerly direction and gradually declines to <2 m drawdown at a distance of around 15 km from the borefields themselves.
- Drawdown in the area of Mundagoora Pool is approximately 12 m.

Observations regarding the drawdowns associated with the Proposed Action only, include the following;

- The Proposed Action is associated with the significant drawdown of approximately 230 m in the Glacier Valley Pit Area. This is demonstrated by the increase in drawdown from approximately 6 m drawdown under the Approved mining scenario (Figure 3-1), compared to 230m drawdown under the cumulative mining scenario.
- There are no other additional drawdowns associated with the NSE Proposed Action, outside of the large drawdowns observed in the Glacier Valley Pit Area itself. This includes the area of Mundagoora Pool, where drawdown is approximately 12 m under the cumulative mining scenario.

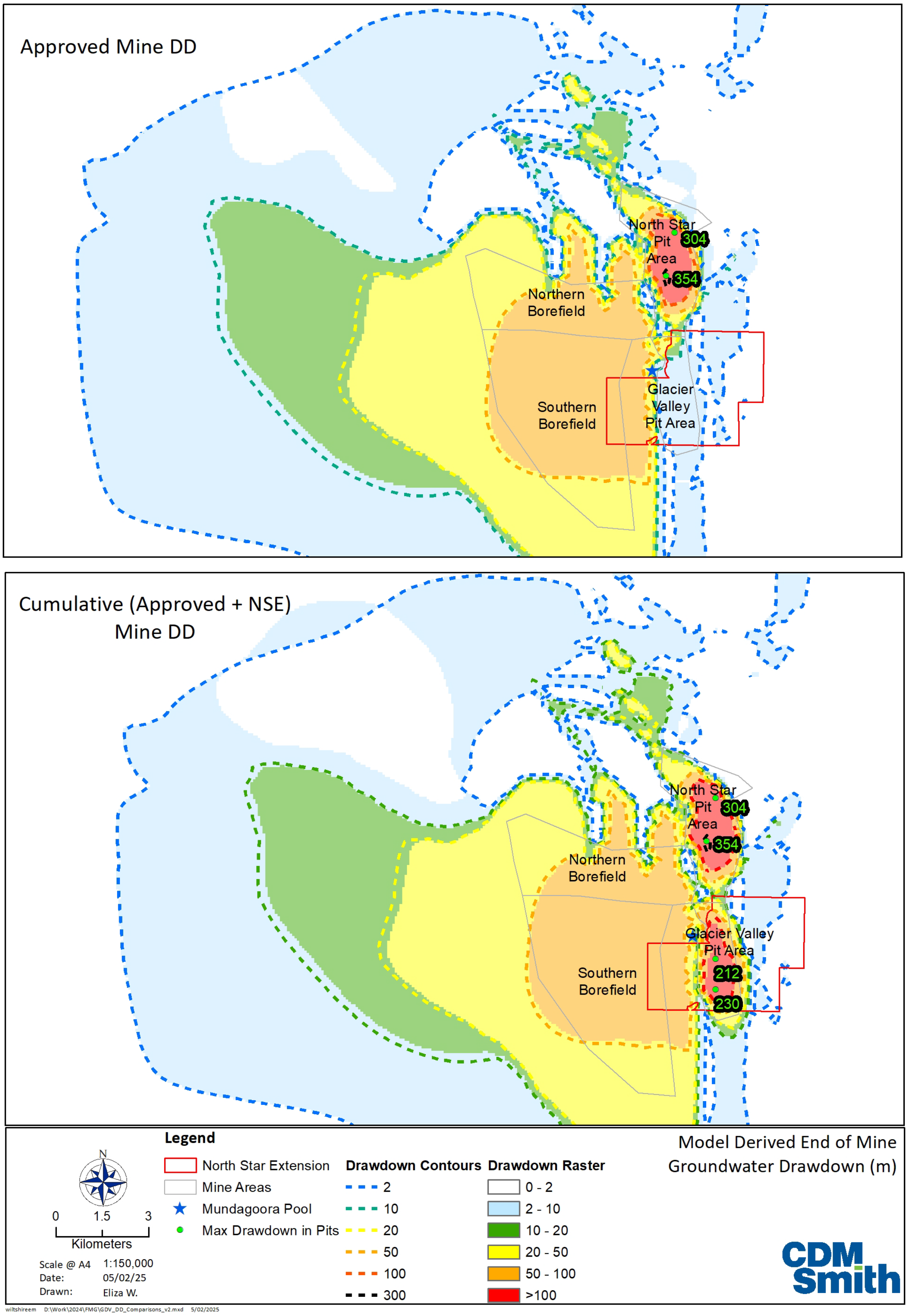


Figure 3-1 Model predicted groundwater drawdowns (Groundwater Consulting, 2023) associated with the Approved Proposal (North Star Magnetite Project) and the Cumulative activities that also include the Proposed Action (NSE).

Section 4 Extent of Potential GDV

Step 2 of the IESC (2019) GDE impact assessment framework is to identify potential GDEs in the project area. This section describes the approach to identifying the extent of the potential Terrestrial GDEs in the project area, based on a number of different information sources and approaches.

4.1 Extent of Potential GDV

There are existing national scale (1), Pilbara scale (2) and site specific (3) datasets of mapped potential GDV in the project area and these are described below and are depicted in Figure 4-1;

1. **The BOM Groundwater Dependent Ecosystem (GDE) Atlas**: The GDE Atlas (BoM 2024) has combined remote sensing data and GIS rules-based analysis to map the potential for groundwater/ecosystem interaction. The GDE Atlas indicates that the site has predominantly moderate potential for terrestrial GDEs, with minor areas classified as low potential, or no potential.
2. **Pilbara Riparian Vegetation Map**: A regional scale riparian vegetation map was produced by Alaibakhsh et al. (2017) using Landsat, a Principal Component Analysis and NDVI. The mapped riparian extent from this dataset is more refined than the GDE Atlas and Alaibakhsh et al. (2017) note that, of the areas of riparian vegetation mapped, approximately 10% is likely to be GDV.
3. **FMG Vegetation Surveys**: A number of flora and vegetation field surveys have been completed in the area, with the results extrapolated to provide a single FMG vegetation map that identifies areas of potential GDV. The identified potential GDV correlates well with the Pilbara Riparian Vegetation Map and corresponds with the following vegetation types;
    a. EvApTl – which is dominated by Eucalyptus *victrix* and Coymbia hamerleyana low open woodland over Acacia;
    b. EvAtCc – which is dominated by Eucalyptus *victrix* mid woodland over and Acacia tumida; and
    c. EcAaBe – which is Eucalyptus Camaldulensis and Eucalyptus *victrix* over Acacia.

E. *camaldulensis*, E. *victrix* and *Melaleuca argentea* are common phreatophytic tree species within riparian systems of the Pilbara bioregion and are often used to infer the relative presence of a potential GDE. However, the degree of dependence on groundwater is variable for these species and depends on the site-specific setting. According to IESC guidelines, all GDEs potentially affected by the project must be considered including those that are only partially or occasionally dependent on groundwater. Therefore, an additional assessment approach is included below that aims to provide a spatially continuous classification of all vegetation within the Project Area, to provide a high-level potential GDV dataset that can be refined via further analysis and data validation in subsequent steps of the assessment.

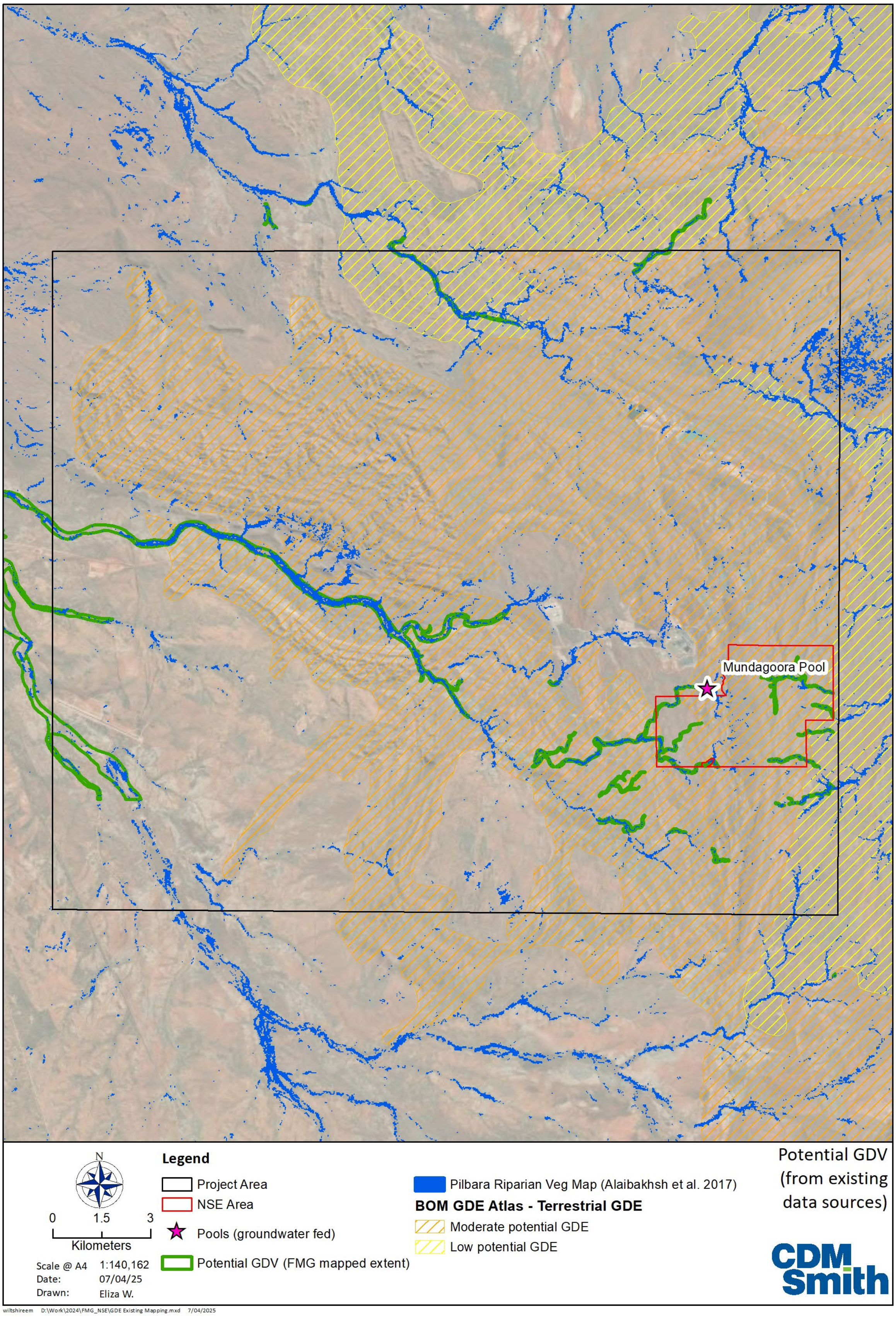


Figure 4-1 Potential GDV from existing data sources

4.2 NDVI Landcover Classification Analysis

4.2.1 Background

Remote sensing analysis provides a valuable means for determining the spatial extent of potential GDV over large and sometimes remote project areas. Long-term and readily available satellite imagery (such as Landsat) provides a continuous dataset of Normalised Difference Vegetation Index (NDVI) that can be used to support potential GDV mapping.

The land cover classification method developed by Barron et al. (2012) provides an approach to using NDVI to delineate potential GDV. The approach uses two multispectral indices, the NDVI and the Normalised Difference Wetness Index (NDWI), derived from Landsat imagery, to predict land cover classes. NDVI serves as a reliable indicator for density and vegetation health of green areas on the land surface and NDWI captures the moisture condition of vegetation cover. Combined changes in the NDVI and the NDWI reflect the land surface response to drying processes best during a period of prolonged drying and can be used to delineate GDV. A key assumption of the method is that in prolonged dry periods (>6 months), soil moisture stores are depleted and vegetation that maintains greenness and moisture, has access to groundwater. The method utilises NDVI and NDWI values to define five distinct land cover classes, including:

4. Class 1 - Vegetation with permanent access to groundwater (invariable and high NDVI & NDWI);
5. Class 2 - Vegetation with diminishing access to groundwater (variable NDVI & NDWI with some decline over dry season);
6. Class 3 – Vegetation not connected to groundwater (variable NDVI & NDWI with significant decline over dry season);
7. Class 4 - Water bodies that can persist through a prolonged dry period (invariable high NDWI and low NDVI); and
8. Class 5 – Other non-GDEs (invariable low NDVI).

Class 1 and 2 are flagged as potential GDEs, Class 3 is vegetation that doesn't use groundwater, Class 4 is water and Class 5 is other non-GDE (i.e. bare landscape).

4.2.2 Method

The land cover classification concept of Barron et al. (2014) has been applied to the Project Area.

A summary of the process is provided below:

1. **Landsat 5 Dataset Selection**: Barron and Emelyanova (2015) identified a dry period from 1988 to 1992 in the Pilbara, representing 80% of the long-term average precipitation. Therefore, this period was the focus of the assessment, as analysis in a dry period allows for better spectral separability between potential GDV that may be accessing water in contrast to surrounding drought stressed areas. Within the dry period, two specific dates were selected to represent 'end of wet season' and 'end of dry season'. An analysis of rainfall and evaporation data identified two key dates; end of the wet season = start April 1992 and end of dry = end November 1992.
2. **NDVI and NDMI Derivation**: NDVI and NDMI indices were calculated for both datasets, using Landsat data to capture vegetation health and moisture variations. NDMI (Normalised Difference Moisture Index) is similar to NDWI, but detects moisture levels in vegetation as opposed to open water bodies.
3. **ISODATA Clustering**: ISODATA unsupervised clustering was applied to group the grid data into meaningful classes. Various settings were tested, including data normalization, the number of iterations, and the minimum sample size per cluster. It was found that 100 iterations were sufficient for algorithm convergence.
4. **Clustering Consistency**: The clustering process was tested for optimal performance, and it was found that; increasing the iteration count beyond 100 and adjusting the minimum cluster size had no effect on the results. However, increasing the iteration count from 20 to 100 and normalizing the data before clustering did significantly impact the clustering outcomes, improving accuracy and convergence.
5. **Cluster Reduction**: The cluster results were further refined by reducing the clusters to 3, based on visual inspection and thresholding NDVI and NDMI values across wet and dry seasons.

4.2.3 Results

The results of the clustering and classification are presented in Figure 4-2, with the green point on the NDVI / NDMI plot representing the potential GDV class (slow drying). The NDVI / NDMI values are not as high as those that defined slow drying vegetation in the Barron et al. (2015) assessment and this is likely due to a combination of the fact that the GDV is sparse (and hence the NDVI results are a mixture of GDV and bare landscape per 30 m Landsat tile) and/or that groundwater doesn't contribute significantly to the total water requirements of the GDV.

The spatial extent of the slow drying vegetation (indicative of potential GDV) is shown in Figure 4-3 (green areas). The results have been compared to two existing datasets as a means of validating the results and these indicate;

- there is correlation between the slow drying vegetation and the existing mapped extent of potential GDV from FMG (i.e. wherever FMG have mapped GDV, this assessment has also mapped potential GDV); and
- the slow drying vegetation corresponds with the vegetation around the groundwater fed Mundagoora pool.

These correlations provide a source of validation of the landcover classification results.

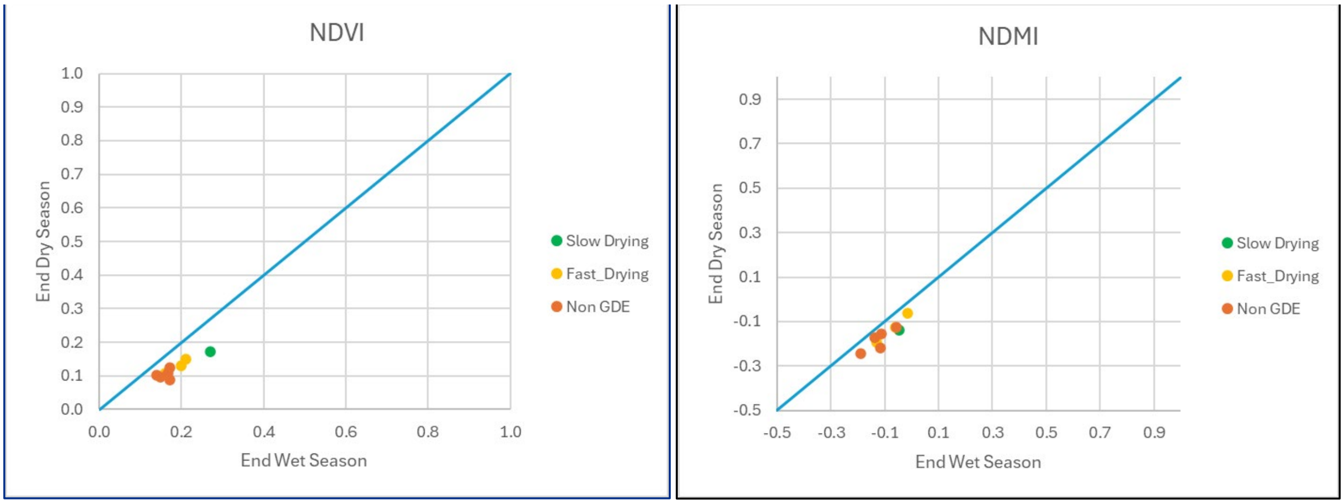


Figure 4-2 Classification results for NDVI and NDMI

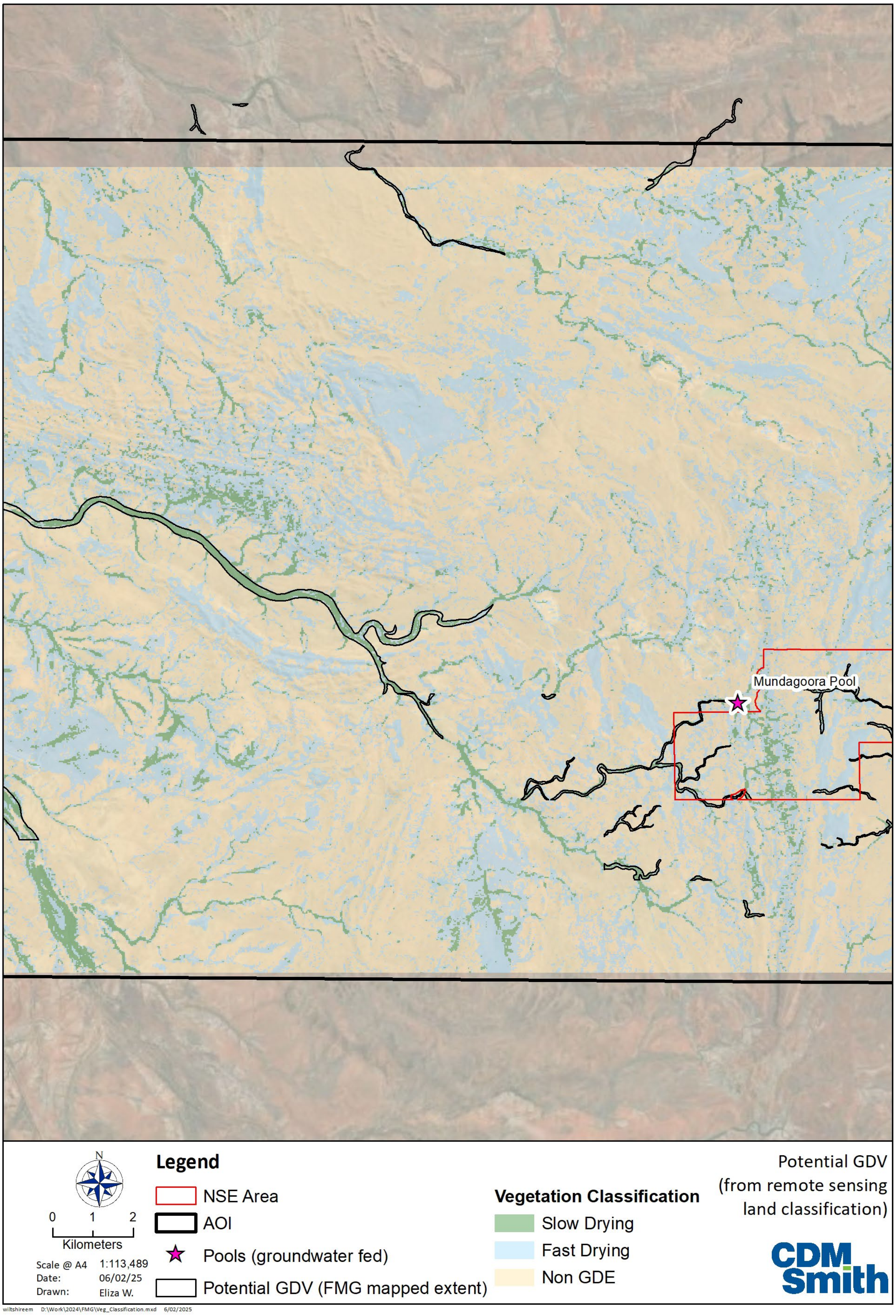


Figure 4-3 Potential GDV extent based on remote sensing land classification analysis

4.2.4 Refinement of Results Using Topographic Analysis

GDV mapping based on remote sensing will often be validated using other datasets such as groundwater level data from bores or (ideally) depth to watertable maps that can constrain the areas where GDV are more likely to occur. However, given the size of the project area, the heterogeneity of groundwater flow in a fractured rock aquifer and the sparsity of available bore data in the area of GDV, an alternate approach has been used here to constrain the remote sensing GDV mapping results. The approach utilises the high resolution (1m) LiDAR Digital Elevation Model (DEM) available for a large portion of the study area, and is based on the Multi-resolution Valley Bottom Flatness (MrVBF) index of Gallant and Dowling (2003).

The MrVBF method assesses the flatness and lowness of the terrain over multiple scales and DEM resolutions in order to identify valley bottoms, which represent areas that are flat across multiple scales, and remain low relative to the surrounding relief at coarser scales. The algorithm uses a sigmoid/logistic transform to rescale terrain slope angles and elevation percentile into a 0 to 1 range, and then combines these results across multiple levels of DEM smoothing and coarser grid resolutions. The resulting index classifies the landscape in terms of elevated areas (values <0.5), steep areas (values from 0.5 to 1.5) and flat/large valley bottoms (values > 1.5).

The elevated areas identified by MrVBF (with values <1.5) were subsequently excluded from the mapped extent of potential GDV based on remote sensing. This led to a 23% reduction in mapped GDV and has improved the GDV mapping in elevated parts of the project area. An example of the refinement in the NSE area is provided in Figure 4-4 below, with the orange area indicating the mapped GDV that has been excluded from the previous mapped extent (from the remote sensing NDVI analysis) based on the MrVBF analysis.

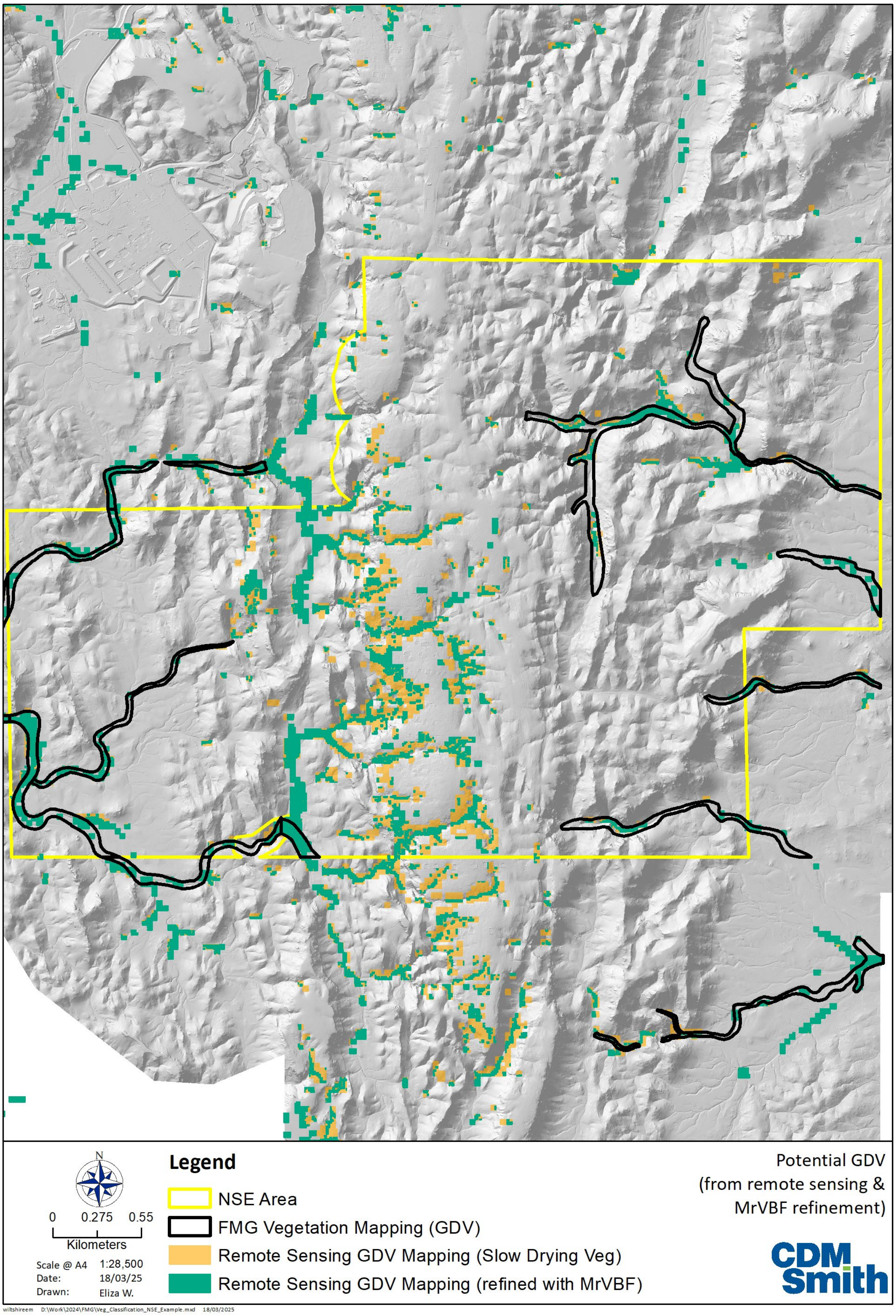


Figure 4-4 Potential GDV extent from; FMG mapping, remote sensing (NDVI analysis) and the refined remote sensing extent using the MrVBF terrain analysis

4.3 Summary

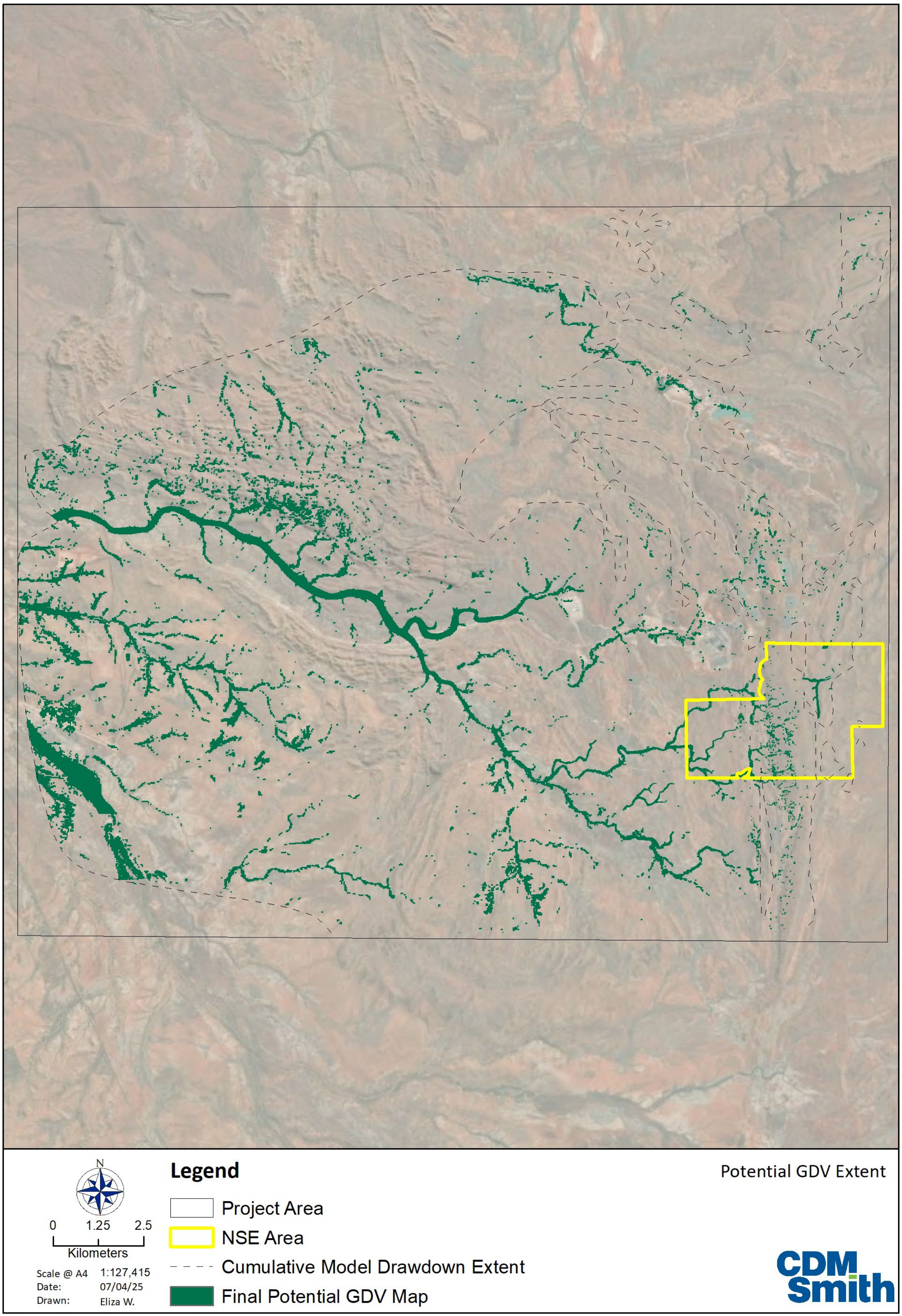
The final potential GDV map for the Project Area is included in Figure 4-5 and shows the GDV within the potential area of impact (where cumulative mine drawdown is >2m). The final potential GDV map is derived from a combination of data sources, following an overarching precautionary principle, as per IESC (2019) advice.

This means that if either of the two primary input datasets (i.e. the FMG Vegetation Field Map and the remote sensing potential GDV map) indicated there was a potential for GDV, the final potential GDV map adopted that classification. This approach is shown in Table 4-1.

This approach is conservative towards the vegetation and will ensure that there are no areas of potential GDV in the Project Area that have not been identified for inclusion in the risk assessment. The approach is in alignment with the IESC (2019) and it is appropriate given the level of uncertainty inherent in both methods.

Table 4-1 Final Potential GDV Mapping Precautionary Approach

	FMG Vegetation Field Mapping Dataset	Remote Sensing GDV Mapping Dataset	Final Potential GDV Map
Potential GDV Mapped	✓	✓	✓
	✓	X	✓
	X	✓	✓
	X	X	X



wiltshireem D:\Work\2024\FMG_NSE\Final_GDV_Map_v2.mxd 7/04/2025

Figure 4-5 Final Potential GDV Map

Section 5 Ecohydrological Conceptual Model

Step 3 of the IESC (2019) GDE impact assessment framework is to assess the level of groundwater dependent of the GDEs and the potential pathways for mine related impacts. This section describes the ecohydrological conceptual model for the GDV, which captures the key aspects of the GDV that inform its groundwater dependence and sensitivity to changes in groundwater.

5.1 Background

E. victrix has been identified in field surveys (Ecoscape, 2020) as the primary potential GDV in and around the NSE, with a minor *E. camaldulensis* presence also recorded.

E. *victrix* is considered to be a facultative phreatophyte (Batini, 2009), defined as a species that requires groundwater at some stage of their life cycle. Water inputs from flooding appear to be important for sustaining E. *victrix* communities in most environments, regardless of the groundwater level. Regular flood events are required to recharge soil moisture in the vadose zone and provide enough soil water to sustain E. *victrix* during lengthy periods of drought that can last many months to years (Cook & Eamus, 2018).

E. *camaldulensis* is a well-studied facultative phreatophyte (compared to the E. *victrix)* and is known to be dependent on groundwater for part its lifecycle and/or in times of drought. It was not a dominant component of any vegetation types found in the Project Area and occurred as isolated individual plants or small populations in the central north area of the site and far west. However, it is noted by Pfatusch et al. (2014) that distinguishing between E. *camaldulensis* and E. *victrix* in the field is difficult and relies on characteristics of seed capsules that are not always present.

Pfautsch et al. (2014) investigated the response of E. *victrix* to mine related changes in groundwater levels at another mine site in the Pilbara region of Western Australia. Foliage density and water use (sap flow) were measured in E. *victrix* at four sites: a control site with shallow watertable (6 m), a control site with deep watertable (29 m), a site where groundwater depth declined from approximately 8 to 19 m over a 3 year period, and a site where groundwater rose from approximately 16 to 7 m over a 3 year period. Over the 4 year study period, foliage density varied within relatively small ranges, and did not reflect depth or access to groundwater. Trees that had access to shallow watertables used more water than trees located in areas of deeper watertables. The fact that the trees located in areas where the watertables were shallower (6-7 m deep) had much higher rates of water use (sap flow), is a strong indication that the trees were accessing groundwater. Furthermore, where groundwater had risen from 16 m up to 7 m, the tree water use was higher than at the control site where groundwater had remained at 6 m depth. This was taken to suggest that the original water table depth of 16 m at the former site had led to increased root development, such that trees were able to access greater amounts of groundwater when the water table rose.

The Pfautsch et al. (2014) study suggests the E. *victrix* is a highly tolerant vegetation species that can adapt to changes in water availability. They refer to the E. *victrix* as demonstrating 'opportunistic physiognomy in using water', which suggests they will change themselves physically (from the stomata to the root length) to adapt to changes in water availability.

5.2 Root Growth Depth and Rate

Rooting depth at the site cannot be quantified directly, and hence the work of existing studies that have focused on similar tree species is drawn upon here. The work of Fan et al. (2017) focused on collating and analysing over 2,000 literature sources of root depth observations from a variety of methods, including root system excavation, soil trench walls, soil monoliths, road cuts, quarry exposures, stream bank erosion exposures, soil coring, block sampling, rhizotron imaging and natural or injected isotopes or other chemical tracers found in plant tissues. From this, Fan et al. (2017) demonstrated a mean rooting depth of Eucalyptus species of 8.71 m based on 45 rooting depth observations and emphasised that water table depth was a strong determinant of rooting depth (Figure 5-1). Fan et al. (2017) describes the watertable as having a "push-pull" impact on root depth; pushing roots shallower to avoid oxygen stress and pulling them deeper to tap the capillary rise.

An analysis of baseline (i.e. unimpacted by operational groundwater abstraction) groundwater levels in areas of potential GDV in the Project Area has been undertaken to provide an indication of the potential rooting depth of the GDV. This analysis showed the maximum watertable depth ranged from 5 m to 72 m with a median of 12 m across the Project Area (within the areas of potential GDV).

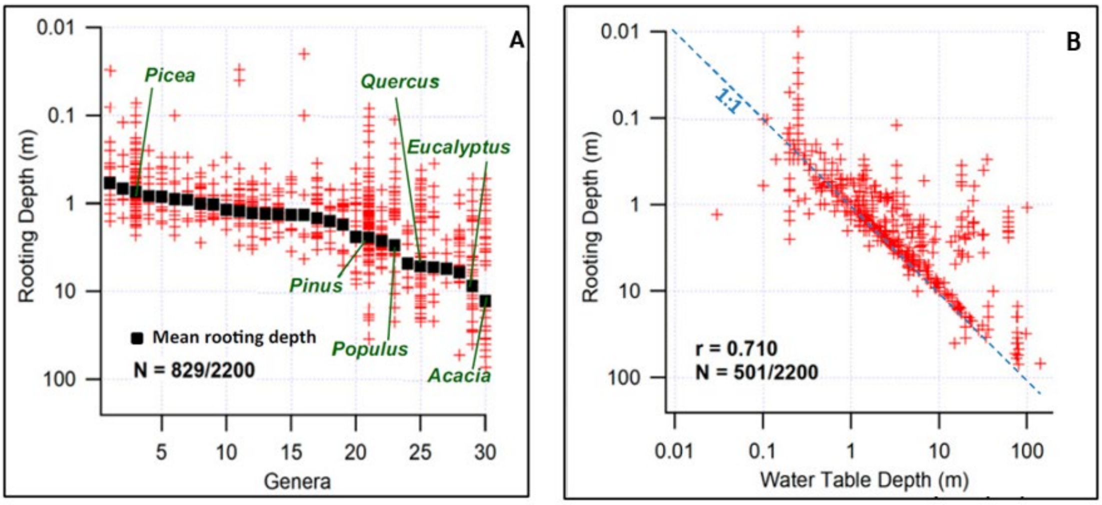


Figure 5-1 A) Rooting depth per genera, showing a median rooting depth for Eucalyptus of 8.71m, B) Correlation between rooting depth and water table depth for trees of various species (Fan et al., 2017).

5.3 GDV Sensitivity Analysis

5.3.1 Northern and Southern Borefields

The landcover classification assessment has provided a spatially continuous map of potential GDV for the Project Area, which can then be used to undertake additional analyses to improve the understanding of the sensitivity of the GDV to changes in groundwater.

The approach to the sensitivity analysis included the following;

- Step 1: Identify two areas that are in close proximity to each other, where the watertable is stable and the watertable has mine-related drawdown impacts;
- Step 2: Use the Project Area potential GDV map to delineate ‘patches’ of potential GDV (slow drying vegetation) in the areas identified in Step 1;
- Step 3: Extract Sentinel 2 NDVI data for the patches of potential GDV identified in Step 2 from 2019 to present (10 m resolution NDVI data is available for this period only);
- Step 4: Generate a timeseries of median NDVI for the patches of GDV in the area of stable and mine-impacted watertables and compare the results to discern the GDV sensitivity to changes in the watertable.

The results of the sensitivity analysis are included in Figure 5-2 below for the Northern Borefield and Figure 5-3 for the Southern Borefield.

The timeseries NDVI represents the greenness of the vegetation, with a higher NDVI value representing greener canopies. It is important to note that the annual cyclical pattern of the potential GDVs NDVI is not representing a cycle of increasing and decreasing tree health or stress, rather it represents seasonal vegetation activity, as it undertakes its annual growth cycle (or its phenology). If the trees were stressed, the NDVI trend would be overserved as a change in profile from one year to another.

The results in the figures below indicate that the potential GDV have low sensitivity to watertable drawdown, given very similar NDVI patterns are recorded in the patches of GDV that are located in areas of no drawdown versus drawdown, in both the Southern and Northern Borefield areas.

These results are in line with the observations of the Pfautsch et al. (2014) study of mine dewatering impacts on E. *victrix* in the Pilbara. This study demonstrated a remarkable capacity of E. *victrix* to sustain a significant short-term decline in depth to groundwater. Over a 4 year period of high extraction rates (>96 ML/day) and fast groundwater level declines (>1 cm per day) there was negligible impact on the condition of the E.*victrix* that were subjected to around 11 m of drawdown.

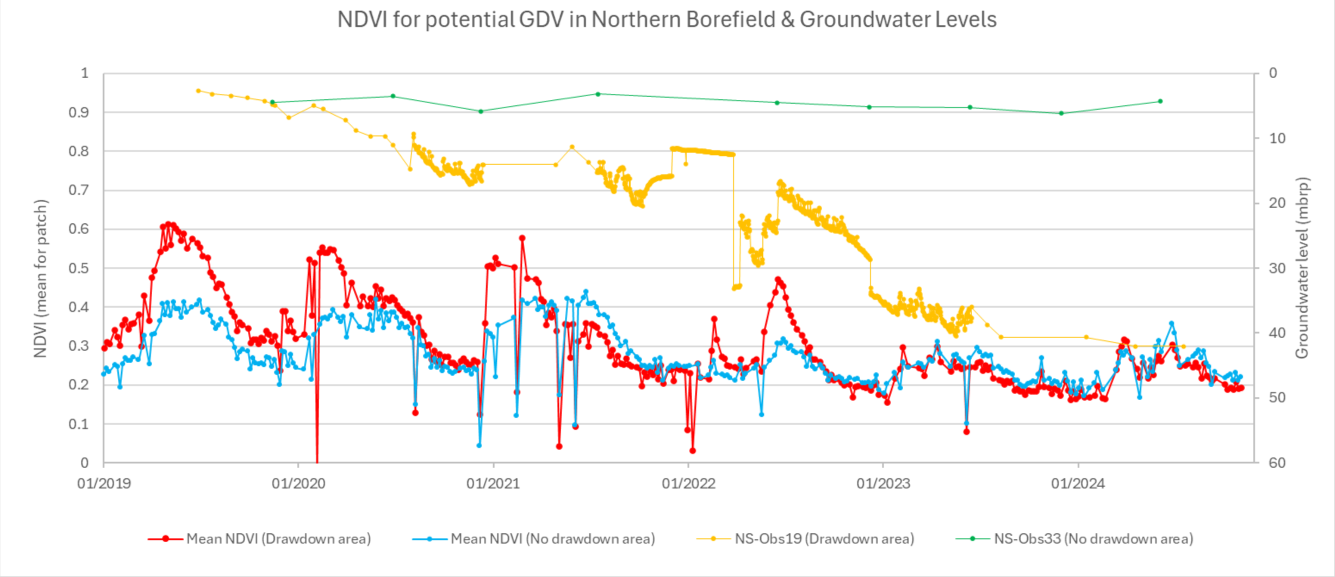


Figure 5-2 NDVI for potential GDV in an area of stable and declining watertables in the Northern Borefield area

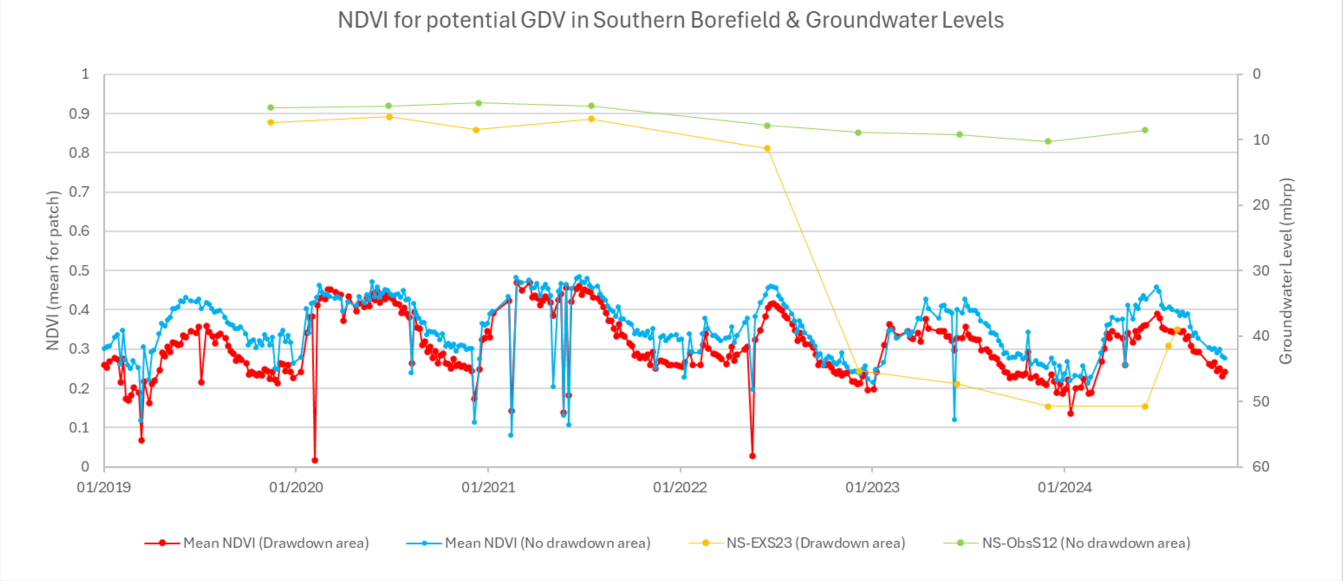


Figure 5-3 NDVI for potential GDV in an area of stable and declining watertables in the Southern Borefield area

5.3.2 Mundagoora Pool

The sensitivity assessment approach described above cannot be applied to the Mundagoora Pool area, as it hasn't been subjected to large mine-related watertable drawdowns that would allow for such a comparison to be made.

However, the timeseries NDVI dataset for the patch of slow-drying potential GDV mapped around the pool, indicates that groundwater provides a significant component of the GDV water source in this area, with an NDVI fluctuating between 0.4 and 0.8. This means this GDV will have a higher sensitivity to changes in groundwater levels. This is consistent with the conceptual model for the groundwater dependent Mundagoora Pool, which is characterised by shallow groundwater constantly discharging into the pool.

Pfautsch et al. (2014) also recognised that GDV had a higher sensitivity to watertable fluctuations in areas of shallower watertables and referred to this as the 'life history concept of roots'. This was based on the observation that the E. *victrix* located in areas of deeper watertables maintained their function during periods of mine-related groundwater decline. The concept suggests that the impact of groundwater drawdown will affect trees growing over historically shallow groundwater more negatively compared with trees that have developed over historically deeper levels of groundwater.

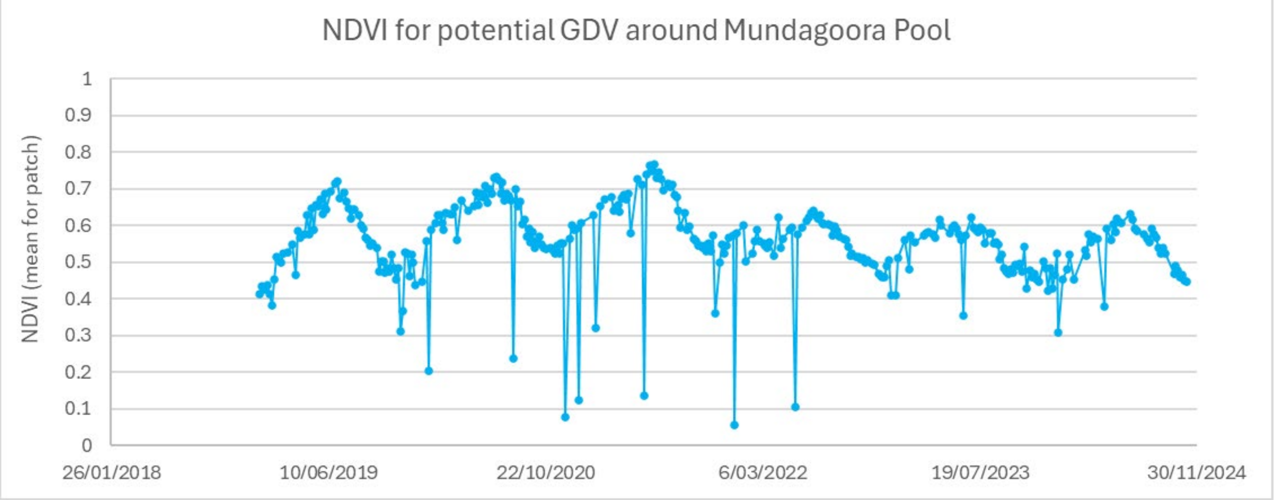


Figure 5-4 Mundagoora Pool GDV NDVI

5.4 Summary of Ecohydrological Conceptual Model

Distribution: The potential GDV Landsat mapping indicates GDV is mainly associated with the riparian corridor throughout the Project Area. While there is higher confidence in the GDV distribution in areas where FMG has undertaken ecological surveys to ground-truth the presence of the potential GDV, the new GDV distribution map (based on remote sensing analysis) provides a spatially continuous layer of potential GDV to be considered within the area of drawdown impact.

Value: E. *victrix* has high value under the EPA technical guidance (2016), as it is part of the significant vegetation type EvApTl. E. *victrix* also represents a potential GDV and is therefore considered significant flora by the EPA due to it representing flora from a restricted habitat type. Value is discussed in the subsequent section (6.2).

Water Source: E. *victrix* is a facultative phreatophyte that requires groundwater at some stage of its life cycle. It draws upon a number of different sources of water to meet its water requirements, including unsaturated zone soil moisture derived from rainfall and surface water and groundwater sourced from the capillary zone associated with the watertable.

The exact contribution of the various water sources will vary spatially and temporally. The portion of the trees water requirements provided by groundwater will be greater where watertables are shallower and when unsaturated soil moisture stores are depleted (i.e. during prolonged drought periods).

Sensitivity to watertable changes: E. *victrix* have low sensitivity to watertable drawdown in areas of deeper watertables (i.e. the riparian corridor) and high sensitivity in areas where the watertable is shallow (i.e. Mundagoora Pool). This is supported by the NDVI assessment and the 'life history concept of roots' described by Pfautsch et al. (2014).

Rooting depth: The rooting depth of the E. *victrix* can be inferred from long-term watertable elevations because they demonstrate 'opportunistic physiognomy in using water' (i.e. they will extend their roots to the watertable if shallow soil stores are depleted and the watertable has declined). The median watertable depth recorded for monitoring bores across the Project Area (deepest water level recorded per bore during baseline conditions) is 12 meters below natural surface (mbns) and this can be used as an indication of the maximum rooting depth of the vegetation.

5.4.1 Mundagoora Pool

Mundagoora Pool is a key target area for groundwater and pool water level monitoring due to fringing riparian and grassland vegetation likely providing foraging habitat for the endangered Northern Quoll and vulnerable species including the Pilbara Leaf-nosed Bat, the Ghost Bat, and the Pilbara Olive Python. Hydrobiology (2023) undertook baseline surveys of surface water pools between 2019 and 2022 and from this, the following key features of the Mundagoora Pool was established;

- **Setting**: Mundagoora Pool has a catchment area of approximately 3.3 km^2, draining two similarly sized basins (to the northeast and southeast) and discharging to Cockatoo Creek and the Turner River.
- **Structure**: Mundagoora Pool is 25 m in length (north-south), 15 m at its widest point (east-west) and is relatively deep (up to 3.5 m). It contains a hard rock bottom at the inflow point, likely to be scoured out (removal of deposited sediments) during high-flow events.
- **Flow regime**: Mundagoora Pool is a permanent pool. The pool inflow is over a steep rock face (waterfall) and the outflow is over a sill with little variation in pool height over wet/dry season (controlled by the sill level). Water levels remain relatively constant within the pool with the exception of short duration peaks during high rainfall events (Figure 5-5). Mundagoora pool only flows during these high rainfall events, when water levels increase to above the pool overflow levels and typically recede within less than 24 hours.
- **Groundwater contribution**: Mundagoora Pool appears to be largely sustained by groundwater and is periodically flushed with fresh surface water flows after rainfall events. It takes approximately 3 weeks for the groundwater to displace the surface water flows once a flushing event has occurred. This is supported by the pool conductivity that is typically very slightly brackish (~850 µS/cm) except during a surface water flow event that leads to freshening (<50 µS/cm) (Figure 5-5). Although the flushing process occurs regularly, it is not considered to be a major ecological driver, due to the stable ecology of the system before and after the surface water flushing events.
- **Pool water quality**: Mundagoora Pool is a clear water pool with low average turbidity (1.9 NTU), neutral average pH (7.29), low average salinity (876.3 µS/cm) and moderate average oxygenation (6.4 mg/L). Average Total Nitrogen, Total Phosphorus, Nitrate (NO3-) and Nitrate/Nitrite (NOx) concentration exceeded the 95% species protection levels (ANZG, 2018). All dissolved metals in the Late Dry 2022 were below ANZG (2018) Default Guideline Values.
- **Ecology**: The pool water is clear and dominated by submerged vegetation/algae and abundant fish (common species, not endangered). The permanent nature of the pool provides habitat to an abundance of fish, macroinvertebrates, and extensive beds of macrophytes and established riparian vegetation. The EvApTl vegetation type has been identified at the pool, which includes the potentially GDV species of Eucalyptus victrix. Downstream of the pool is dominated by dense emergent vegetation (reeds and sedges), which extends down a shallow braided channel for several hundred metres from the pool.

A simple conceptual model for the Mundagoora Pool has been developed as part of this project and is presented in Figure 5-7. This includes under baseline and end of mine conditions, in the absence of any groundwater management or mitigation. The primary feature of this cross section (that runs in a west to east direction through the pool between the two available groundwater monitoring bores as shown in Figure 5-6) is that groundwater feeds the pool via a throughflow mechanism. This is supported by the salinity of the pool water being greater than rainfall and the fact that the water level in the pool is relatively constant. Furthermore, if the pool was a sink (i.e. a terminal pool with no groundwater throughflow out of the system), the salinity would concentrate more over time. Although the pool is flushed during high rainfall events, this is not considered a critical process that maintains the pool. The critical input to maintaining the pool is the groundwater contribution.

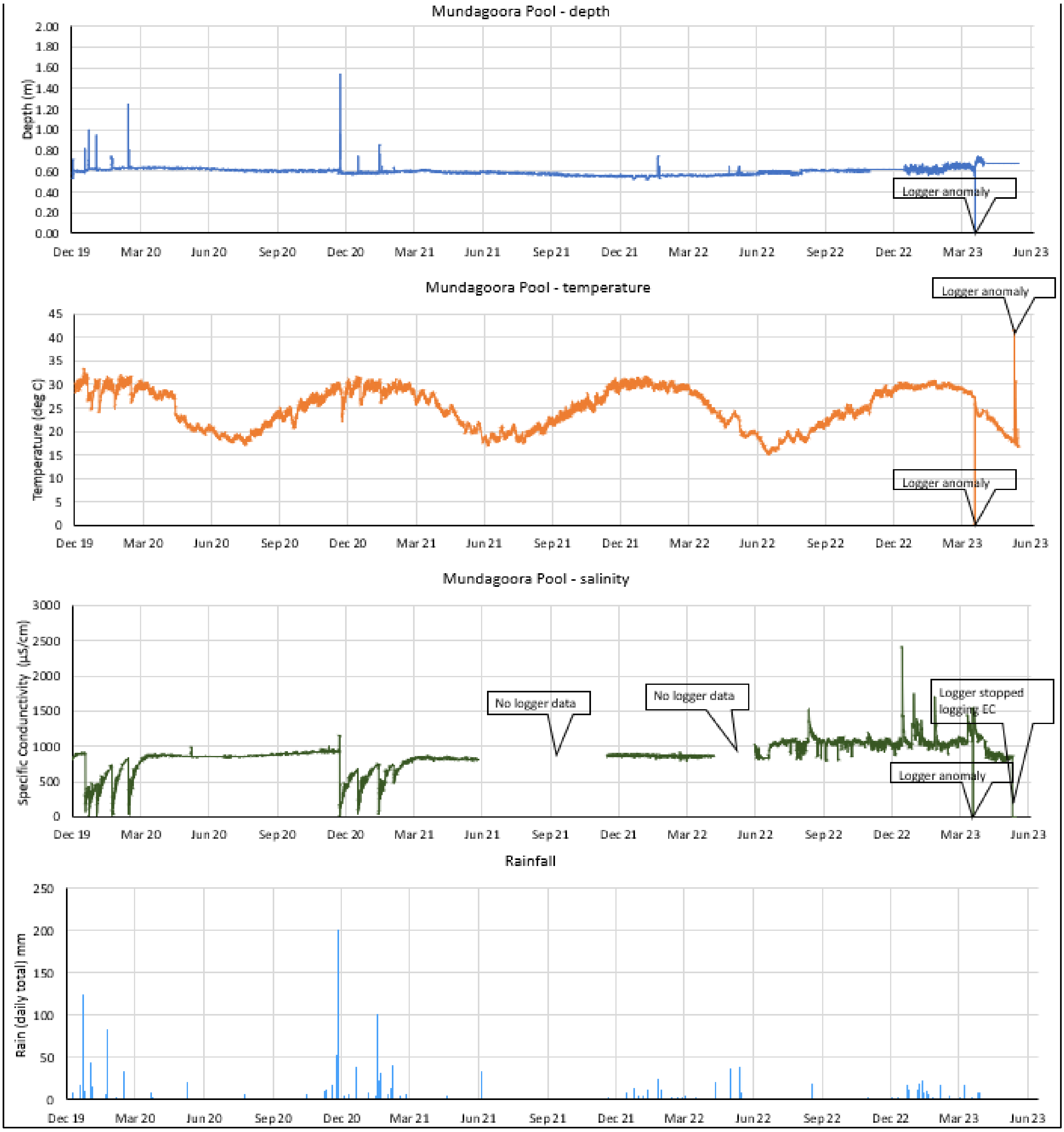


Figure 5-5 Mundagoora Pool – monitored data

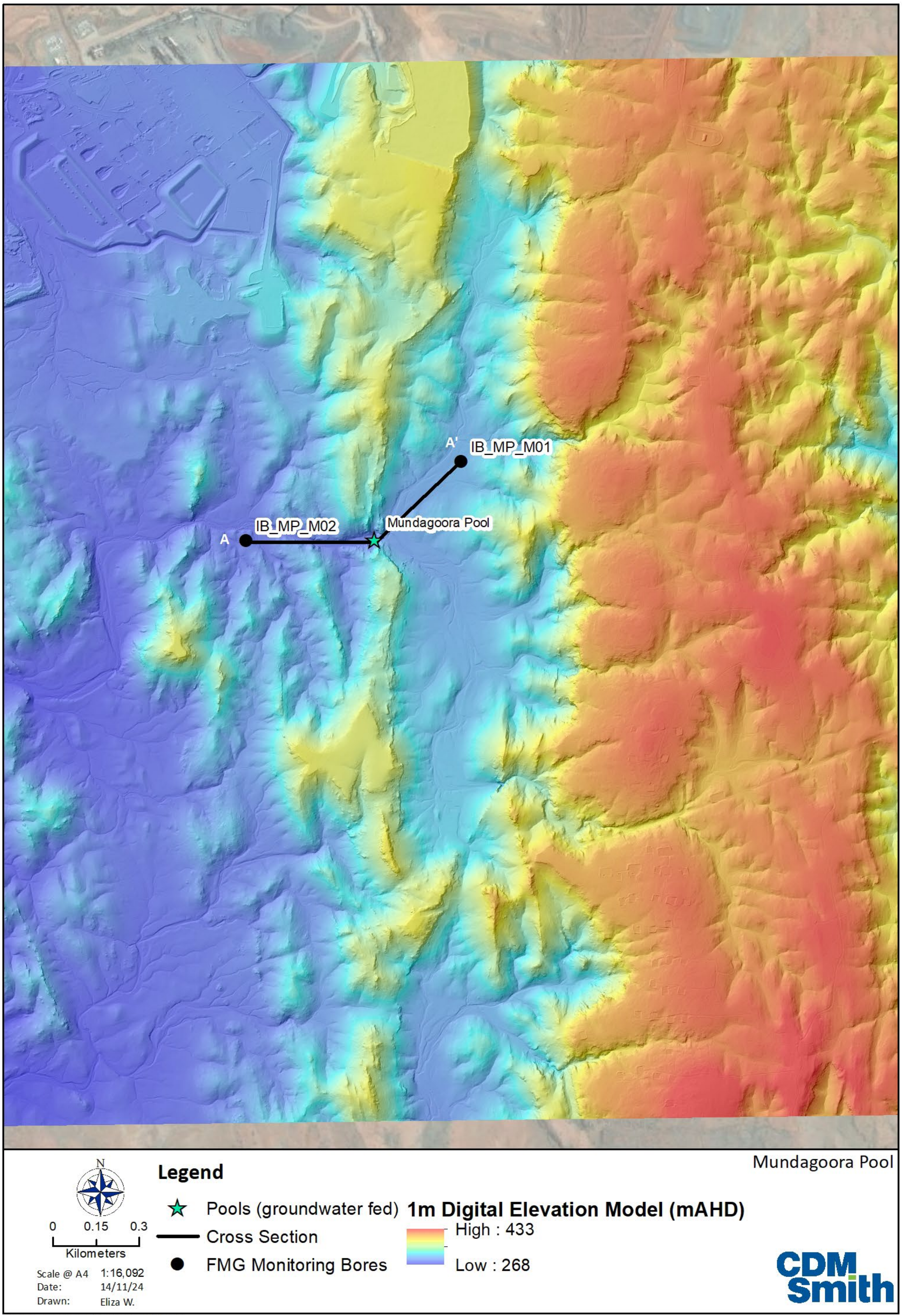


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Figure 5-6 Topographic Elevation around Mundagoora Pool and location of cross-section and monitoring bores

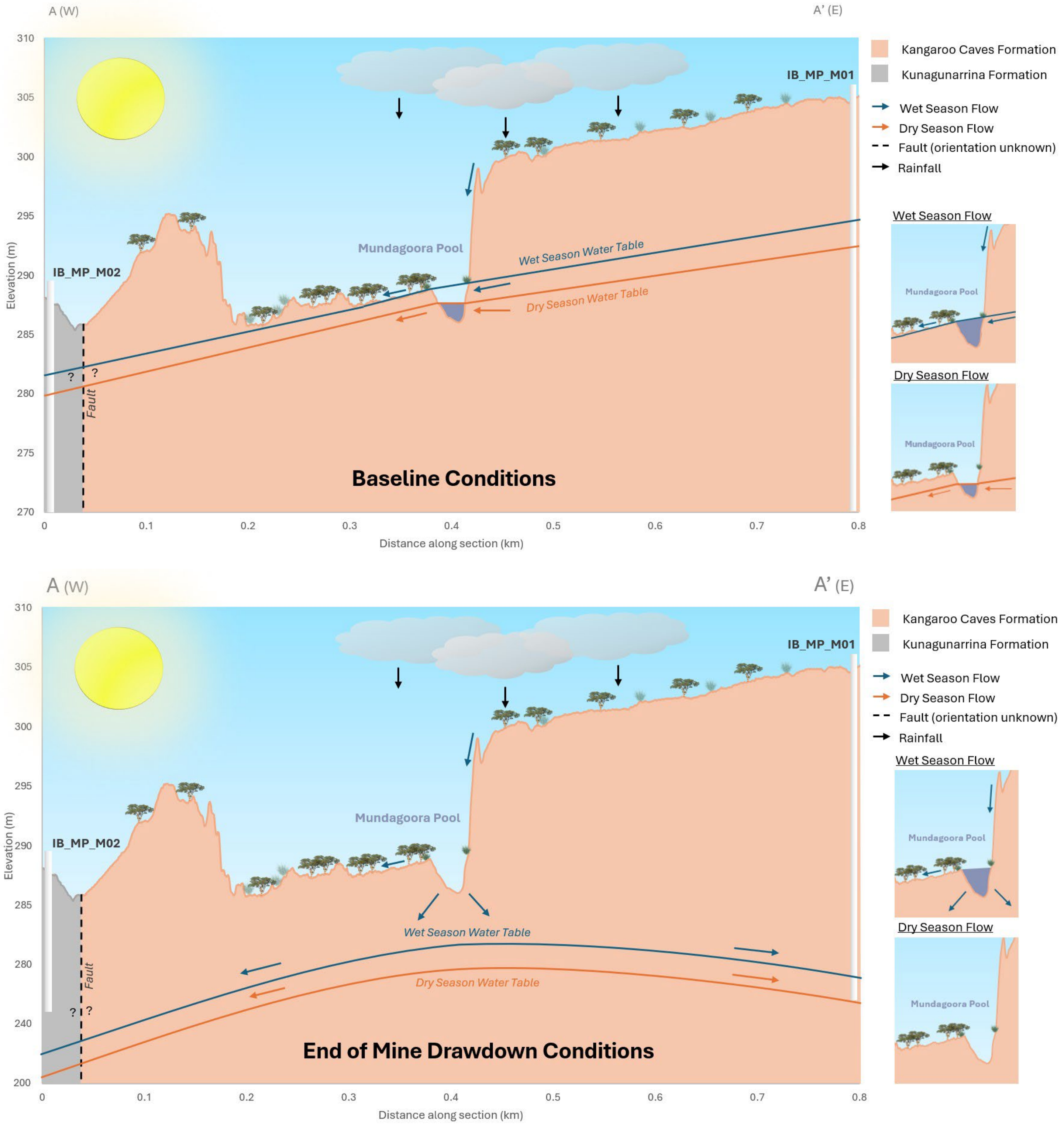

Figure 5-7 Conceptual model for the Mundagoora Pool under baseline and end of mine predicted drawdown conditions with no groundwater management

5.5 Potential Impact Pathways

The potential impact pathway for the GDV in the Project Area has been considered based on the guidance of the IESC (2024) and the **driver->source-> stressor->receptor** concept, whereby;

- **Driver**: Fortescue's mine operations in the North Star Project Area. This includes the North Star Magnetite Project (Approved Proposal) and the Proposed Action (North Star Magnetite Project Extension).
- **Source**: Dewatering of the North Star and Glacier Valley pit areas and water supply borefield abstraction.
- **Stressor**: Watertable decline associated with the pit dewatering and water supply borefield abstraction and the propagation of the decline over time.
- **Receptor**: The receptor is the potential GDV in the Project Area and the important aspects of this GDV (with specific consideration of this threat pathway), has been included in the ecohydrological conceptual model above.

Section 6 Baseline Ecological Monitoring

Step 4 of the IESC (2019) GDE impact assessment framework is to identify the baseline ecological condition and value of the GDE. This section provides a description of these aspects of the GDV, based on the previous ecological field surveys and assessments that have been undertaken within the Project Area.

6.1 Previous Vegetation Monitoring

FMG IB have undertaken annual vegetation health monitoring at North Star since 2017, as per the *Iron Bridge Vegetation Health Monitoring and Management Plan* (662NS-0000-PL-EN-0004 Rev 2). The annual vegetation health monitoring programs include analysis of; vegetation condition, Leaf Water Potential (LWP), tree health and NDVI analysis. Through their monitoring program FMG IB have aimed to establish the baseline ecological condition for potential GDV with a representative subset of sites for future monitoring, aligning with IESC recommendations.

Ecoscape (2024) provides a comprehensive summary of all of the survey data and concludes the following;

- There are a total of 201 vascular flora species, including four significant flora;
- No vegetation types were considered analogous to Threatened Ecological Communities (TECs) or Priority Ecological Communities (PECs);
- One vegetation type EvApTl has been identified that is representative of potential GDV.
- No vegetation or landforms consistent with sheet flow dependent vegetation were recorded.

Although annual vegetation health monitoring has been completed at North Star since 2017, the initial focus was on NDVI analysis of riparian vegetation downstream from the Tailings Storage Facility, Waste Rock Dump and Processing Infrastructure (Ecoscape 2017, Ecoscape 2019). The program’s scope was expanded in 2019 to include monitoring of significant pool vegetation potentially impacted by changes to groundwater and surface water flow, and in 2023 to include potential GDV monitoring. Additionally, monitoring of significant pools also provides insight into PGDV, as relevant tree species (Eucalyptus camaldulensis and Eucalyptus victrix) have been observed at these locations.

6.1.1 Ecological Monitoring Sites

The riparian vegetation is monitored at a number of locations and these are shown in Figure 6-1, including;

- Six “PGDV Sites”, including three sites in areas of potential impact and three sites in areas where impacts are not expected to occur (i.e. reference sites); and
- Seven Significant Pool Vegetation sites.

At these sites, measurements of LWP, vegetation condition and vegetation health are collected and this is coupled with a site specific assessment of NDVI. An additional site is also monitored downstream from the North Star mining infrastructure.

6.1.2 Summary of 2023 Monitoring Results

A summary of the 2023 ecological surveys results (Ecoscape 2024) is provided in Table 6-1 and indicates that most sites assessed exhibited vegetation in very good condition and medium health. Notable exceptions include:

- Camp Pool (a pool located north of the Project Area and monitored as a reference site) showed significantly lower predawn LWP than other sites, indicating potential drought stress (this has been noted for future monitoring).
- PGDVI3 and the downstream riparian vegetation zone sites fell below the lower confidence interval of the control-impact NDVI model predictions for six and eleven consecutive months, respectively. However, these deviations were not reflected in the baseline comparison NDVI model and, therefore, did not trigger

management actions under the Iron Bridge Vegetation Health Monitoring and Management Plan. Both sites have been recommended for on-ground validation in the next vegetation survey.

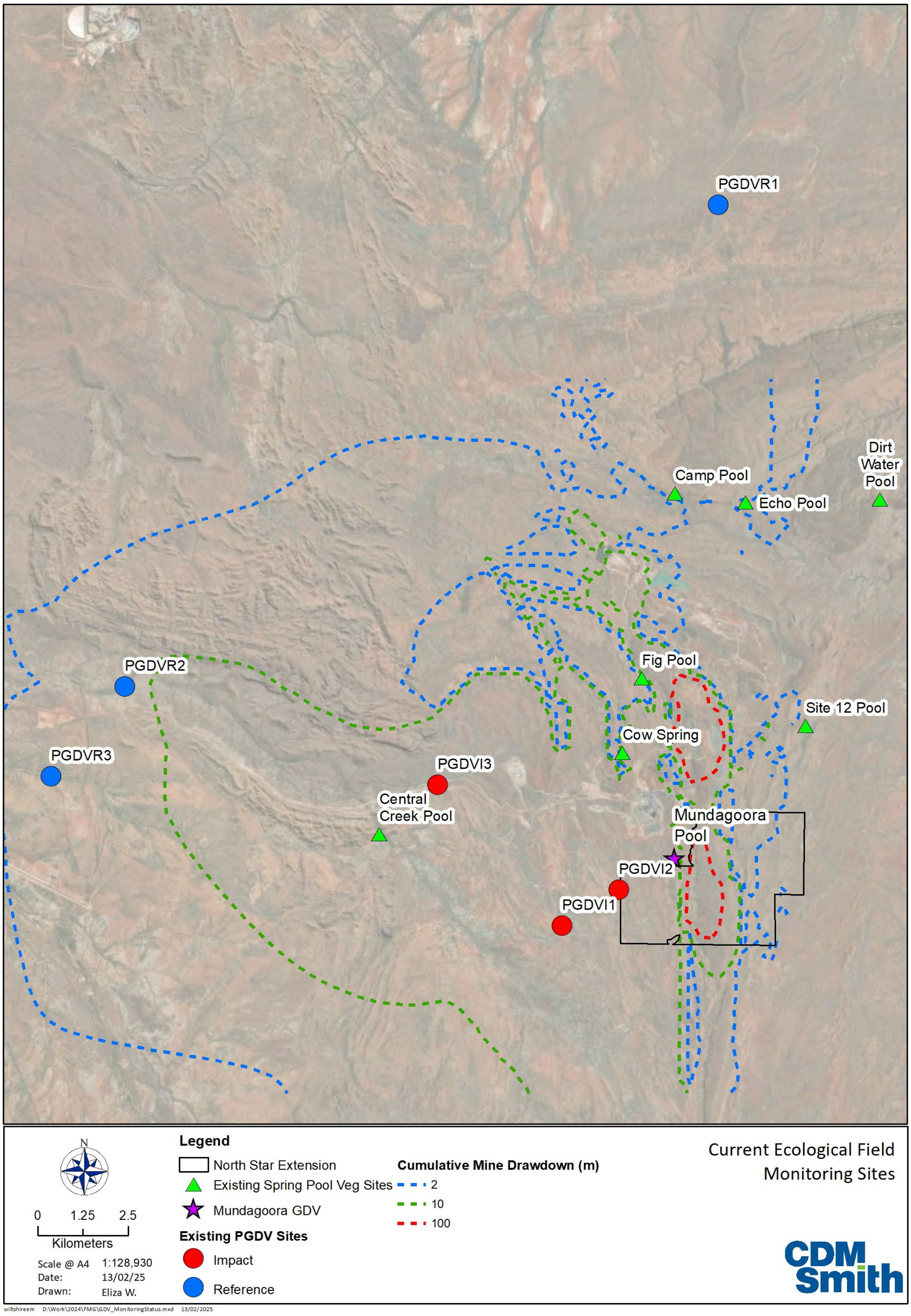

Figure 6-1 Locations of established ecological monitoring sites

Table 6-1 Summary of vegetation monitoring

Group	Monitoring Sites	Vegetation Condition	Leaf Water Potential (LWP)	Tree Health	NDVI
Significant Pool Vegetation	Four potential impact sites. Three reference sites.	Very Good condition for all seven monitoring sites. Flowing water in all pools apart from Central Creek Pool and Site 12 Pool, consistent with previous years.	Dominant tree species inconsistent between sites with *Eucalyptus camaldulensis* (three sites), *Eucalyptus victrix* (one site) and *Melaleuca argentea* (five sites) represented. *Eucalyptus camaldulensis* at Camp Pool showed significantly lower predawn LWP indicating results, indicating potential drought stress.	General medium health based off crown extent, density and variable new growth between sites.	Monthly means NDVI for the Significant Pools sites did not fall outside of the +/- 3 for BL or CI model predictions.
Potential GDV	Three potential impact sites. Three reference sites.	Very Good condition for all six monitoring sites. No water present at the sites during November 2023 monitoring.	A substantial difference between all predawn and midday LWP results indicates the dominant tree species *Eucalyptus victrix* was unlikely to be experiencing drought stress at all sites in November 2023. However, this is a baseline due to not previously having been monitored.	General medium health based off crown extent, density results and variable new growth between sites.	Monthly mean NDVI for potential GDV did not fall outside of the +/- 3 for BL model predictions and all CI model predictions for more than three consecutive months except for PGDVI3 where six consecutive months were below the lower confidence interval until August 2023. Likely attributed to clearing of an access road and powerline near PGDVI3.
Downstream Riparian Vegetation	NDVI only	-	-	-	Monthly mean NDVI for downstream riparian vegetation GDV did not fall outside of the +/- 3 for BL model predictions but did for 11 consecutive months for CI model predictions. Further NDVI analysis showed the underperformance extended downstream towards the Mundagoora Pool. Potentially explained by reduced inflows to the upper part of the creek due to construction of a sediment basin.

6.1.3 Summary of Ecological Condition

Vegetation condition for riparian vegetation was rated as Very Good by Ecoscape (2024) at both the Significant Pool and Potential GDV sites for the entirety of their present program durations, as summarised in Table 6-2. This classification was made in accordance with the Native Vegetation Condition Assessment and Monitoring Manual for Western Australia (Casson et al., 2009) and the EPA Technical Guidance – Flora and Vegetation Surveys for Environmental Impact Assessment (EPA, 2016). Both documents reference the Keighery 1994 Vegetation Condition Scale, which describes a Very Good classification as vegetation where structure is altered with obvious signs of disturbance, including repeated fires, presence of weeds, logging and grazing.

For Significant Pools, all seven monitoring sites were assigned a Very Good condition due to slight evidence of cattle grazing and minimal / nil weed invasion with no changes to this condition status since baseline monitoring in 2019. All six 2023 Potential GDV monitoring sites were assessed to be in Very Good condition also with slight evidence of cattle grazing and minimal / nil weed invasion.

Table 6-2 Vegetation Condition from Ecoscape Vegetation Health Monitoring Programs

		Year				
		2019	2020	2021	2022	2023
Monitoring Sites	Significant Pools	Very Good	Very Good	Very Good	Very Good	Very Good
	Potential GDV	-	-	-	-	Very Good

6.2 Value

Eucalyptus victrix has no recognised national value under the Environment Protection and Biodiversity Conservation (EPBC) Act 1999 and is listed under the 'not threatened' conservation code by the Western Australian Herbarium (WAH).

However, as discussed in Section 2.6.1, *E. victrix* is classed as a component of significant vegetation and is potentially classed as significant flora according to EPA technical guidance (2016). *E. victrix* is found as part of the vegetation type EvApTl at sites such as Mundagoora Pool where it provides habitat for the endangered Northern Quoll and vulnerable Pilbara Leaf-nosed Bat, Ghost Bat, and Pilbara Olive Python (Spectrum Ecology, 2021). EvApTl is thereby classed as significant vegetation as it provides a key function required for sustaining the ecological integrity of the ecosystem. *E. victrix* also represents a potential GDV and is therefore considered significant flora by the EPA due to it representing flora from a restricted habitat type.

E. victrix has therefore been assigned a high value in this assessment due to it providing critical habitat for endangered and vulnerable species and potentially representing a restricted habitat type.

Section 7 Risk Assessment

Step 5 of the IESC (2019) GDE impact assessment framework is to assess the potential impacts on GDEs and to determine the risks related to the mining activity. This section includes a risk assessment of mine-related activities to GDV.

7.1 Risk Assessment Approach Overview

The risk assessment approach is consistent with the Australian / New Zealand Standard ISO 31000:2018 Risk management guidelines, which indicate that a risk assessment should consider the likelihood and consequence of the risk source, where;

- Risk source: is an *element which has the potential to give rise to risk;*
- Likelihood: is *the chance of something happening; and*
- Consequence: is *the outcome of an event.*

For this risk assessment, these aspects are defined as:

- Risk source: *FMG mine operations.*
- Likelihood: *the magnitude and duration of mine-related watertable drawdowns, as predicted by the groundwater model (Groundwater Consulting Pty Ltd, 2023).*
- Consequence: *the sensitivity of the potential GDV to watertable drawdown and the value of the vegetation.*

The risk assessment can therefore be described as the product of the likelihood that mine operations will change the shallow groundwater system and the consequence of the change from the perspective of the value and sensitivity of the potential GDV.

The risk assessment approach is developed in alignment with the WA Department of Water and Environmental Regulation (DWER) *Guideline – Risk assessments* (2017).

7.2 Likelihood

The **likelihood** of an impact to GDV is indicated by the **magnitude** and **duration** of mine-related watertable drawdowns, as predicted by the groundwater model (FMG IB, 2023b).

Magnitude of drawdown

The magnitude of drawdown thresholds range from very low to very high and are linked to the concept of the maximum rooting depth of the vegetation.

These thresholds have been defined largely based on two main lines of evidence;

1. The long term maximum baseline watertable depth across the Project Area was 12 m (50th percentile); and
2. A comprehensive assessment undertaken by Pfautsch et al. (2014) in the Pilbara area that was designed to understand the impact of mine-related groundwater drawdown on the E. *victrix.* This demonstrated that there was negligible long-term impact on the E.*victrix* after a 4 year period of groundwater decline at a rate of >1 cm/day, that reduced the watertable from 8.3 to 19.2 mbns (a 10.95 m drawdown). The trees were monitored for sap flow rates and foliage density and although the trees showed some reduction in foliage density during the dewatering period, they recovered fully in the following wet season.

From this, the magnitude of drawdown thresholds were defined as; low = 2-10 m, medium = 10-20 m and high = >20 m drawdown.

Duration of drawdown

The duration of the drawdown is the other aspect of the likelihood consideration for GDV, as it accounts for the fact that the GDV may be resilient to short-term groundwater declines but over the longer-term, tree health may suffer. Based on the observations of Pfautsch et al. (2014) a 4-year duration was attributed to the low threshold and were progressively increased to represent increasing threat to GDV (Medium = 4-10 years and High = >10 years).

7.2.1 Results

The likelihood results are presented below for the cumulative mine scenario (Table 7-1) and for NSE only mine activities (Table 7-2).

The duration of drawdown was scored equally across all areas and for both scenarios, as High, given that dewatering will commence in 2026 and will continue until the end of mine-life, which is approximately 20 years in duration.

Note that it is possible that the drawdown impacts are more short-lived in some areas (i.e. where the propagation of drawdown takes some years to manifest). Additional outputs from the numerical model provided in different formats may increase the discretisation of the likelihood score across the Project Area. For example, a dataset that indicates the time of maximum drawdown across the project area and/or a set of timeseries hydrographs of drawdown at key locations across the Project Area may allow for further discretisation of this component of the risk assessment in future revisions.

The magnitude of drawdown was determined by intersecting the predicted drawdown outputs from the numerical groundwater model (described in Section 3) with the spatially mapped area of GDV (described in Section 4.3).

The results for the cumulative mine scenario are shown in Figure 7-1 and this shows the potential GDV areas intersect all threshold groupings, ranging from Low to High magnitude of drawdown. When both the magnitude and duration are considered together, the likelihood matrix (Table 7-1) shows a range of likelihood of impact ranging from Possible to Likely to Almost Certain.

The drawdown at the Mundagoora Pool is approximately 12-14 m (Medium drawdown magnitude).

Table 7-1 Likelihood Matrix for Cumulative Drawdown (Approved Proposal and Proposed Action)

		Magnitude of Drawdown		
		Low 2-10 m	Medium 10-20 m	High >20 m
Duration of Drawdown	Low <4 years	Rare	Unlikely	Possible
	Medium 4-10 years	Unlikely	Possible	Likely
	High > 10 years	**Possible** 883 ha PGDV (46% of total)	**Likely** 379 ha PGDV (20% of total), inc. Mundagoora GDV	**Almost Certain** 643 ha PGDV (34% of total)

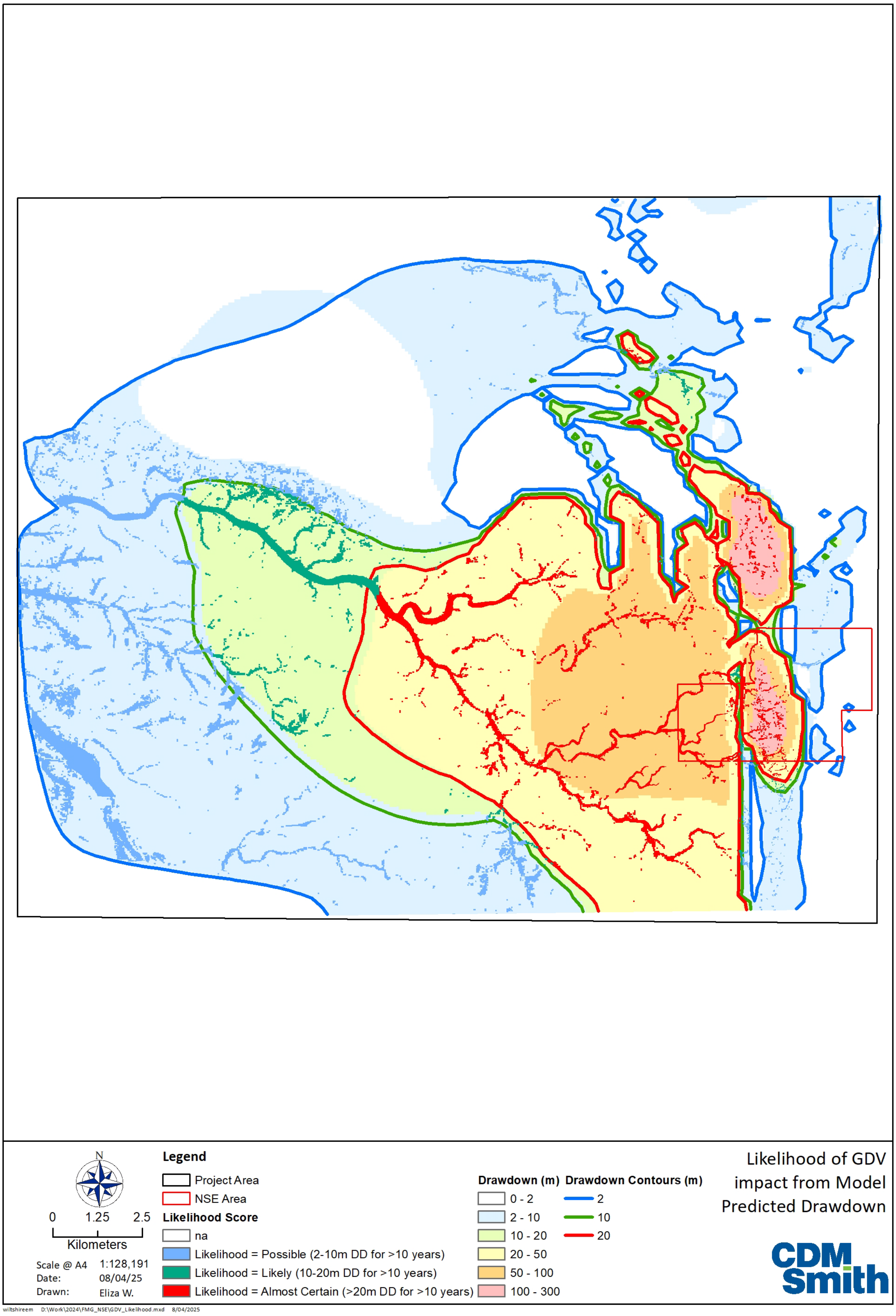

Figure 7-1 Likelihood of (cumulative mine) drawdown impact on potential GDV in the Project Area

The area of GDV associated with the NSE only drawdowns is much smaller relative to the area of GDV associated with the cumulative drawdown area. The results for the NSE only mine scenario (Table 7-2) indicate the potential GDV areas intersect all threshold groupings ranging from Low to High. When the drawdown magnitude is considered in combination with the duration of drawdown, this results in the likelihood of impact ranging from Possible to Almost Certain. The amount of GDV in the High drawdown area is small (13 ha) and occurs within 500 m of the NSE Disturbance Footprint (Figure 7-2). The GDV within the NSE Disturbance Footprint itself is excluded from the drawdown assessment, as the vegetation in this area is proposed to be cleared.

The increase in drawdown at the Mundagoora Pool from the Approved Proposal (drawdown ~10-12 m) to also including the Proposed Action (drawdown ~12-14m) is small (~ 2m).

Table 7-2 Likelihood Matrix for NSE Drawdown Only (Proposed Action only)

		Magnitude of Drawdown		
		Low 2-10 m	Medium 10-20 m	High >20 m
Duration of Drawdown	Low <4 years	Rare	Unlikely	Possible
	Medium 4-10 years	Unlikely	Possible	Likely
	High > 10 years	**Possible** 4 ha PGDV (19% of total)	**Likely** 4 ha PGDV (19% of total)	**Almost Certain** 13 ha PGDV (62% of total)

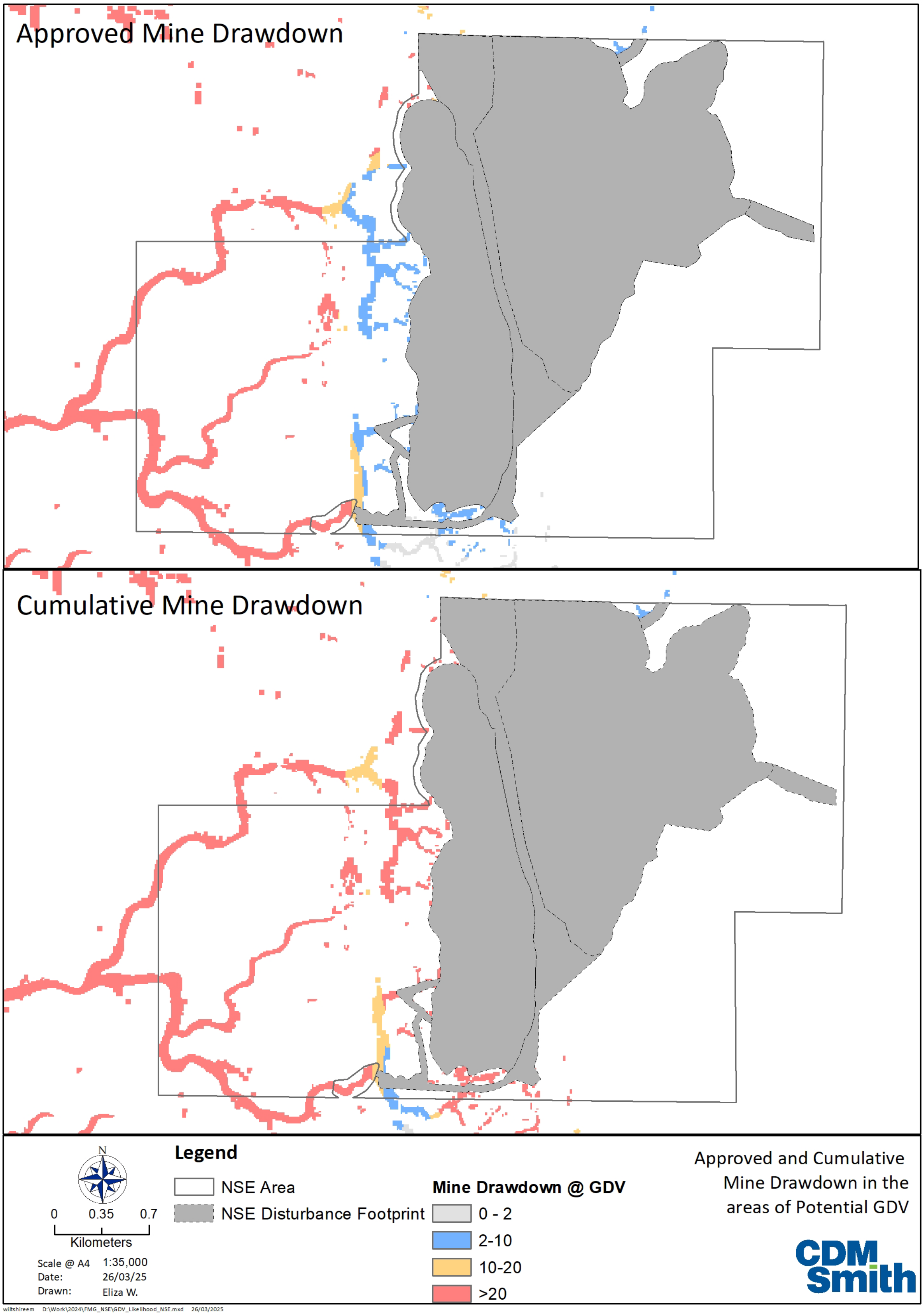

Figure 7-2 Likelihood of (cumulative and approved mine) drawdown impact on potential GDV in the NSE Area

7.3 Consequence

For the GDV risk assessment, **consequence** considers the **sensitivity** of the potential GDV to watertable drawdown and the **value** of the vegetation.

Value

The definition of ecological value relates to the conservation value of the vegetation according to the state and federal guidelines. It is also guided by the EPA (2016) advice regarding the attributes of vegetation that determine its significance. The value classifications are defined as;

1. High Value Vegetation includes:
   a. threatened ecological communities (TECs); or
   b. priority ecological communities (PECs); or
   c. vegetation that provides critical habitat/refuge for threatened / priority fauna; or
   d. vegetation with a restricted distribution (e.g. groundwater dependent vegetation).
2. Medium Value Vegetation includes:
   a. providing an important function required to maintain ecological integrity of a significant ecosystem.
3. Low Value Vegetation includes:
   a. vegetation with none of the above attributes defined for medium and high value.

As discussed in Section 6.2, the potential GDV is a significant vegetation type because it has a restricted distribution and has a role as a refuge. In some areas, such as at the Mundagoora Pool, this vegetation type has also been identified as providing a critical habitat for threatened species of fauna. Based on this, the potential GDV is classified as having a high value where it occurs in the Project Area.

Sensitivity

Sensitivity is the degree of resilience of the GDV to the threat of mine related abstraction and this is assessed here as the relative contribution groundwater provides to its total water requirements. The sensitivity ranking criteria are defined as follows:

- Low – GDE has sufficient water requirements supplied from source other than groundwater; such that changes in the groundwater regime would cause negligible impact to the vegetation condition.
- Medium – groundwater contributes to water requirements, but the vegetation has capacity to cope with changes to the groundwater regime. Changes in the groundwater regime would cause a measurable impact to the vegetation condition; however, the vegetation has evolved to have resilience to changes in the groundwater regime.
- High – High groundwater contribution to water requirements; such that changes to the groundwater regime would cause a negative impact to the vegetation condition.

The sensitivity analysis (Section 5.3) has indicated that the potential GDV has a low sensitivity to changes in groundwater levels. This is supported by the investigation of Pfautsch (2014) of the same GDV species, that demonstrated the trees resilience to mine-related dewatering operations over a four-year period.

The local area of GDV associated with the Mundagoora Pool has a high sensitivity, as this vegetation has adapted to a setting where shallow groundwater is available on a permanent basis, thus maintaining a high NDVI through wet and dry seasons.

7.3.1 Results

The consequence matrix below (Table 7-3) shows that the high value and low sensitivity of the potential GDV located broadly across the Project Area in association with the major drainage lines, results in a Moderate Consequence. The high value and high sensitivity of the GDV associated with the Mundagoora Pool, results in a Severe Consequence.

The consequence terminology is based on the DWER (2017) risk assessment guidelines and include; slight, minor, moderate, major and severe. Definitions of these terminology from the perspective of this assessment is included in Table 7-4 below. Based on these definitions the consequence scores can be read as:

- Riparian vegetation GDV with Moderate Consequence associated with drawdown impact: there will be negligible impact to the vegetation condition of high value GDV; and
- GDV at Mundagoora Pool with Severe Consequence associated with drawdown impact: there will be a negative impact to the vegetation condition of high value GDV.

The GDV consequence results are shown in Figure 7-3.

Table 7-3 Consequence Matrix

		Value		
		Low	Medium	High
Sensitivity	Low	Slight	Minor	**Moderate** 1,905 ha PGDV (100% of total)
	Medium	Minor	Moderate	Major
	High	Moderate	Major	**Severe** <1 ha PGDV at Mundagoora Pool

Table 7-4 Consequence score definition (based on DWER, 2017 risk assessment guidelines)

Consequence Score	Specific Consequence Criteria
Severe	Severe impact to GDV based on; ▪ High sensitivity environmental receptors with High value (i.e. there will be a negative impact to the vegetation condition of high value GDV).
Major	Major impact to GDV based on; ▪ Medium sensitivity environmental receptors with High value (i.e. there will be a tolerable impact to the vegetation condition of high value GDV); or ▪ High sensitivity environmental receptors with Medium value (i.e. there will be a negative impact to the vegetation condition of medium value GDV).
Moderate	Moderate impact to GDV based on; ▪ Low sensitivity environmental receptors with High value (i.e. there will be negligible impact to the vegetation condition of high value GDV); or ▪ Medium sensitivity environmental receptors with Medium value (i.e. there will be a tolerable impact to the vegetation condition of medium value GDV); or ▪ High sensitivity environmental receptors with Low value i.e. (there will be a negative impact to the condition of vegetation that has no significant value).

Consequence Score	Specific Consequence Criteria
Minor	Minor impact to GDV based on; ▪ Low sensitivity environmental receptors with Medium value (i.e. there will be negligible impact to GDV with medium significant value); or ▪ Medium sensitivity environmental receptors with Low value (i.e. there will be a tolerable impact to the condition of vegetation that has no significant value).▪
Slight	Slight impact to GDV based on; ▪ Low sensitivity environmental receptors with Low value (i.e. there will be negligible impact to the condition of vegetation that has no significant value).

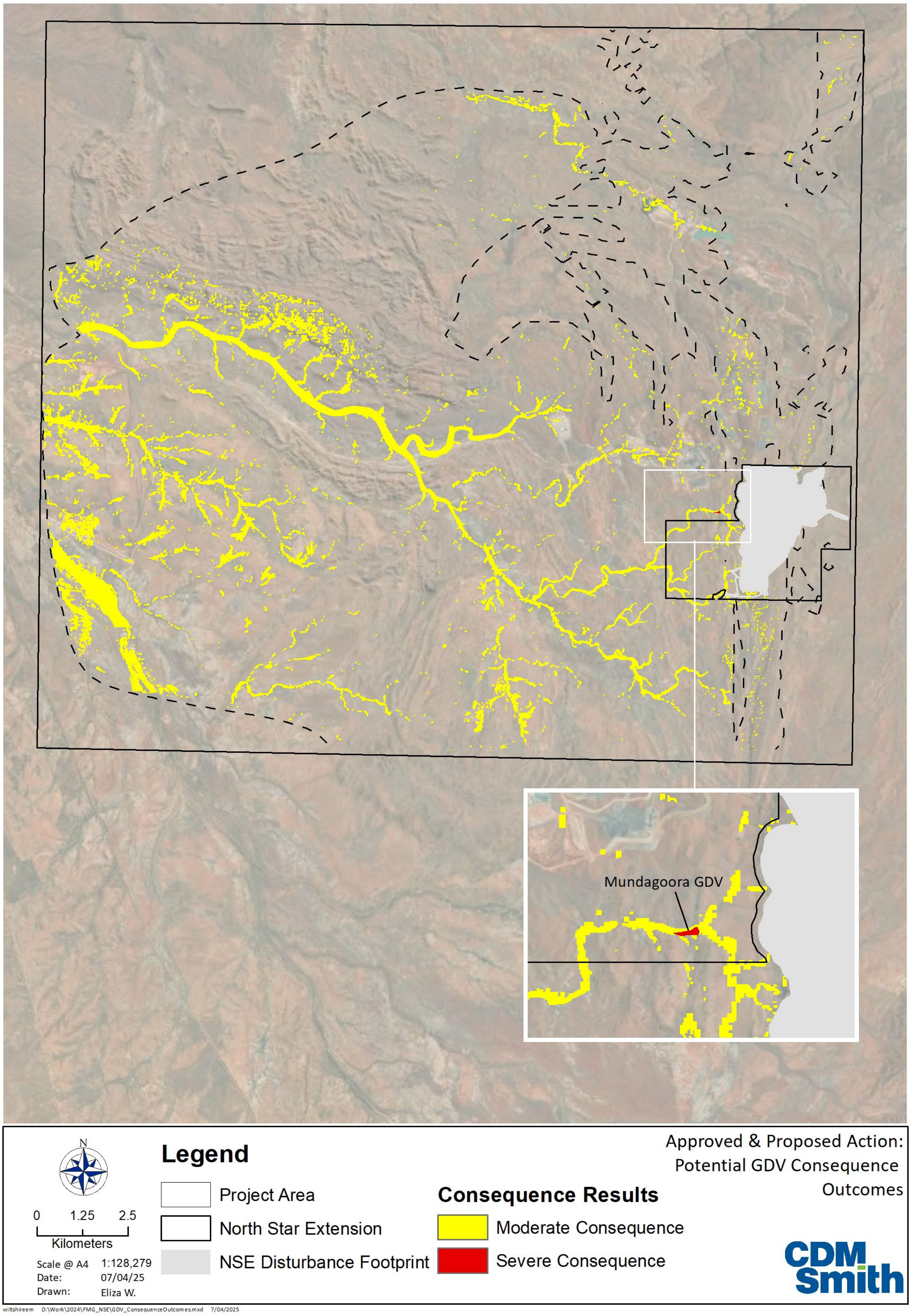

Figure 7-3 Potential GDV Consequence Associated with a Watertable Decline

7.4 Risk

The final risk outcome is a combination of the Likelihood and Consequence risk matrices which have the following results, summarised from the above sections;

- Likelihood;
  - Cumulative (Approved and Proposed Action) drawdown led to Possible, Likely and Almost Certain likelihood of impact for PGDV along the riparian zone and Likely for Mundagoora Pool;
  - NSE only (Proposed Action) drawdown also led to Possible, Likely and Almost Certain likelihood of impact for PGDV along the riparian zone, albeit the area of impact as much smaller (~1% of the area of GDV);
- Consequence; Potential GDV in the Project Area has a Moderate Consequence associated with potential watertable drawdown and Mundagoora Pool GDV has a Severe Consequence associated with potential watertable drawdown.

The resulting risk is summarised below and represents t**he inherent risks in the absence of a groundwater management and mitigation plan**.

For the cumulative mine drawdown (associated with both the Approved and Proposed Action), there is an Extreme inherent risk to Mundagoora Pool GDV and Medium to High inherent risk to the potential GDV associated with the riparian corridor. These results are summarised in Table 7-5 and are shown in Figure 7-4 and are largely in-line with previous assessments of unmitigated risks to Mundagoora Pool and potential GDV, which concluded Very High and High risks associated with each, respectively (FMG IB. (2023c).

Most of the risk depicted in Figure 7-4 (cumulative mine scenario) is associated with the Approved action. For the Proposed Action mine drawdown only, there is only a very small area of GDV that has an elevated risk profile associated with the addition of the NSE. Table 7-6 indicates there is an additional 21 hectares of GDV that have an elevated risk profile associated with the additional of the NSE. Figure 7-5 shows the areas of high and medium risk GDV associated with the NSE are located within close proximity to the NSE Disturbance Footprint (vegetation within the disturbance footprint is not consider in the assessment, as it is proposed for clearing).

Notably the Extreme risk area associated with Mundagoora Pool GDV is not included in Figure 7-5 that depicts the GDV with an increased risk profile due to the Proposed Action. This is because the Approved action has generated the Extreme Risk for this GDV (due to ~10-12m drawdown) and the additional drawdown associated with the Proposed Action (drawdown increases to ~12-14m) does not increase the GDV risk categorisation.

The area of impacted potential GDV is much larger for the Cumulative scenario relative to the area of potential GDV impacted by the Proposed Action alone, which only represents ~1% of the GDV area at risk.

Table 7-5 Risk Matrix for Cumulative Drawdown (Approved Proposal and Proposed Action)

		Consequence				
		Slight	Minor	Moderate	Major	Severe
Likelihood	Rare	Low	Low	Medium	Medium	High
	Unlikely	Low	Medium	Medium	Medium	High
	Possible	Low	Medium	**Medium** **883 ha PGDV (46%)**	High	Extreme
	Likely	Medium	Medium	**High** **379 ha PGDV (20%)**	High	**Extreme** **Mundagoora GDV (<1ha)**
	Almost Certain	Medium	High	**High** **643 ha PGDV (34%)**	Extreme	Extreme

Table 7-6 Risk Matrix for NSE Drawdown Only (Proposed Action only)

		Consequence				
		Slight	Minor	Moderate	Major	Severe
Likelihood	Rare	Low	Low	Medium	Medium	High
	Unlikely	Low	Medium	Medium	Medium	High
	Possible	Low	Medium	**Medium** **4 ha PGDV (19%)**	High	Extreme
	Likely	Medium	Medium	**High** **4 ha PGDV (19%)**	High	Extreme
	Almost Certain	Medium	High	**High** **13 ha PGDV (62%)**	Extreme	Extreme

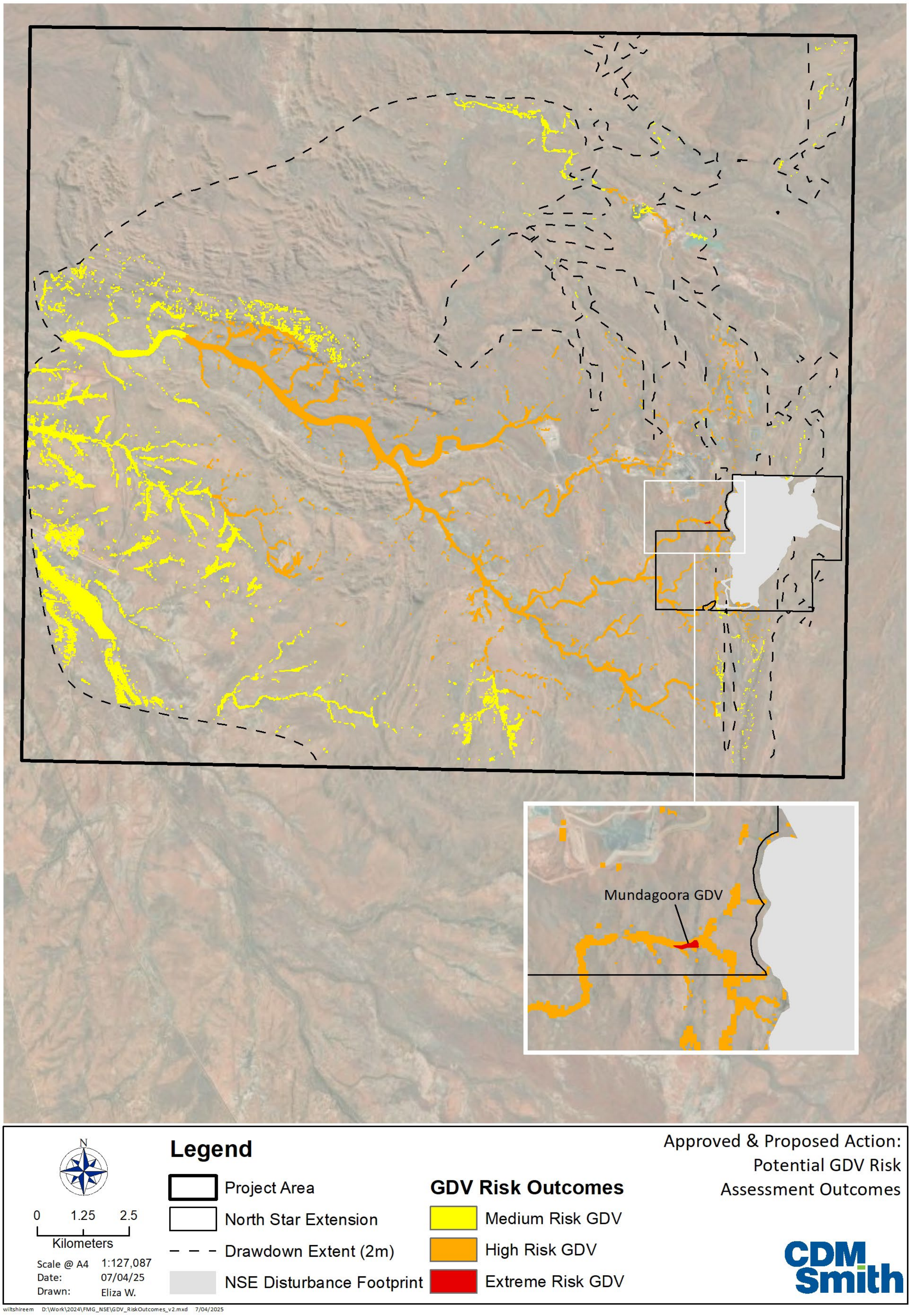

Figure 7-4 Potential GDV Risk Assessment Outcome (Cumulative drawdown from Approved and Proposed Actions)

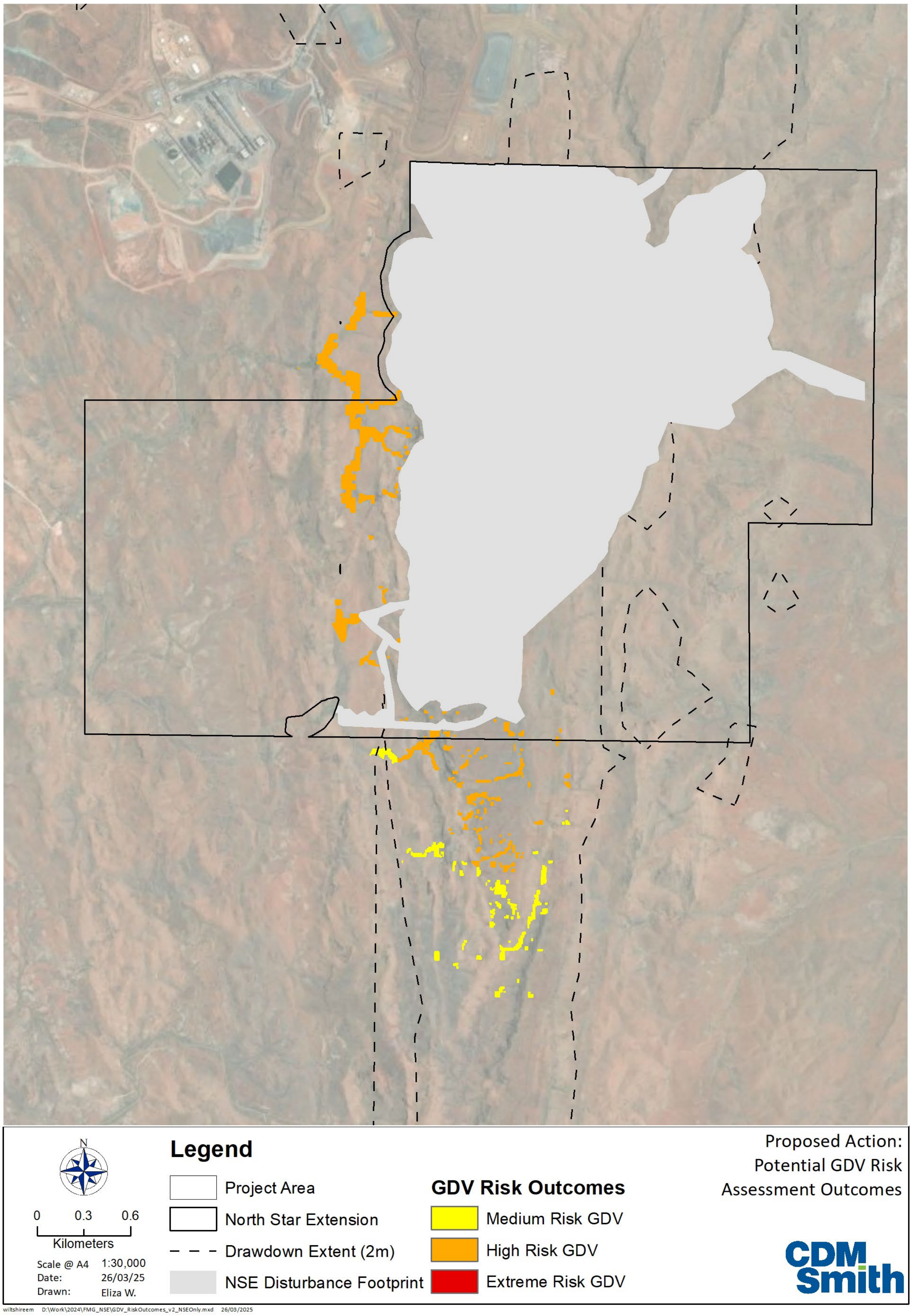

Figure 7-5 Potential GDV Risk Assessment Outcome – Proposed Action Only

Section 8 GDV Management

Step 6 of the IESC (2019) GDE impact assessment framework is to prioritise options to avoid or mitigate impacts on GDEs and establish a monitoring plan to test the effectiveness of mitigation strategies. This section describes FMGs current monitoring and mitigation plan.

8.1 Current Monitoring Network

The current groundwater monitoring network and ecological monitoring network and are shown in previous figures (Figure 2-5 and Figure 6-1, respectively). These show that there is an extensive coverage of groundwater monitoring bores and there is a set of PGDV and significant pool monitoring sites established in the Project Area. The PGDV ecological monitoring sites include three sites in areas of predicted mine drawdown (Impact Sites) and three sites in areas of minimal predicted mine drawdown (Reference Sites). The field surveys at these sites include measurements of LWP, vegetation condition and tree health.

8.2 Current Management Plan

The North Star Groundwater Operating Strategy (GWOS) (FMG, 2023d) describes the management objectives and the adaptive management strategy for North Star and includes the following components;

- Current groundwater, pool and vegetation monitoring;
- Trigger levels; and
- A summary of potential adaptive management strategies that may be applicable in response to a trigger level exceedance.

Section 9 Conclusions

This GDV assessment has followed the IESC (2019) risk assessment framework, including the following;

- Step 1 Define the Project Impact Area;
- Step 2 Identify Potential GDV;
- Step 3 Assess Groundwater Dependence;
- Step 4 Determine Baseline Ecological Condition;
- Step 5 Assess Impacts; and
- Step 6 Groundwater Management Plan.

This GDV risk assessment has found that there is Medium to High unmitigated risk to potential GDV associated with the Approved Action and an Extreme unmitigated risk at the Mundagoora Pool.

The Proposed Action leads to a small increase in the area of GDV with an increased risk profile (~1% of the area of GDV at risk from the Approved Action alone). There is only a small increase in the model predicted drawdown at Mundagoora Pool due to the Proposed Action, with the drawdown increasing from 10-12m to 12-14m and maintaining its Extreme risk profile.

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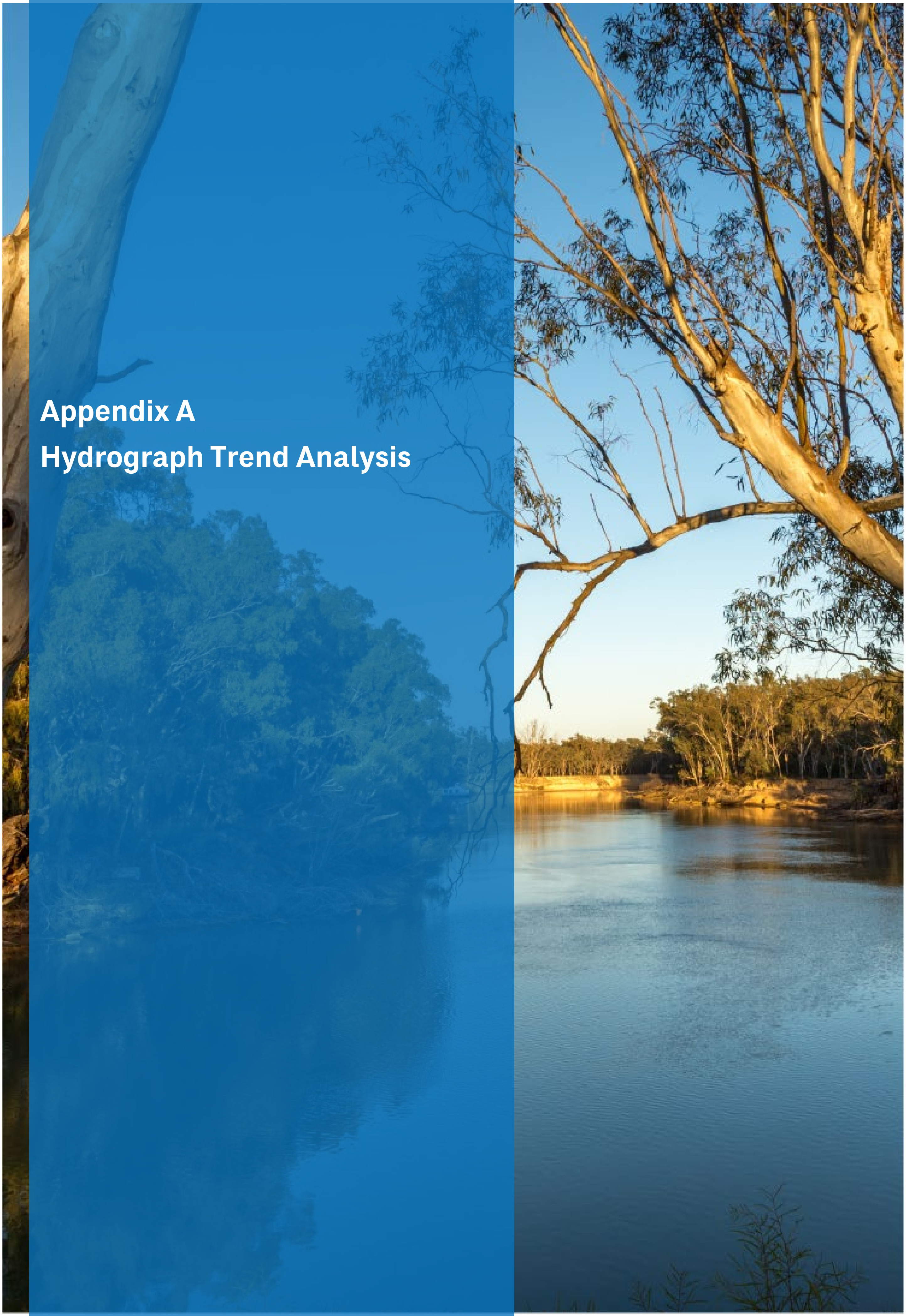
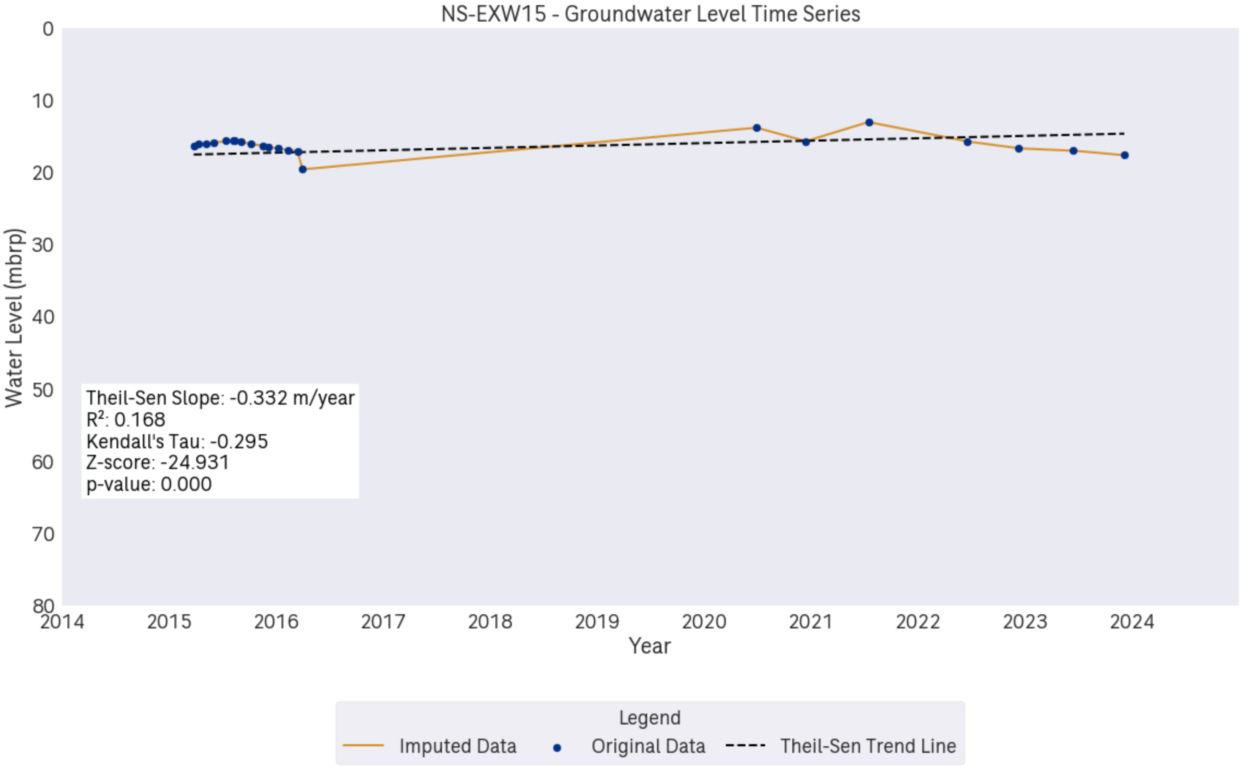
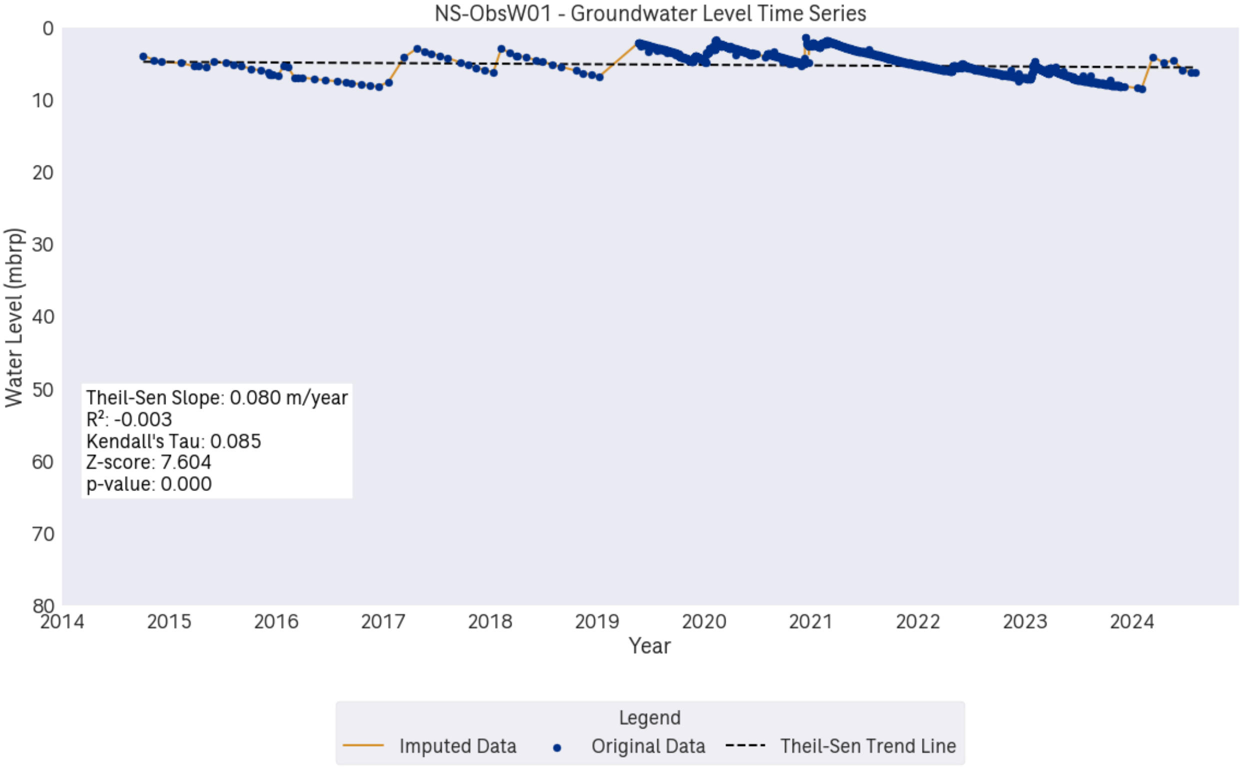
Appendix A
Hydrograph Trend Analysis

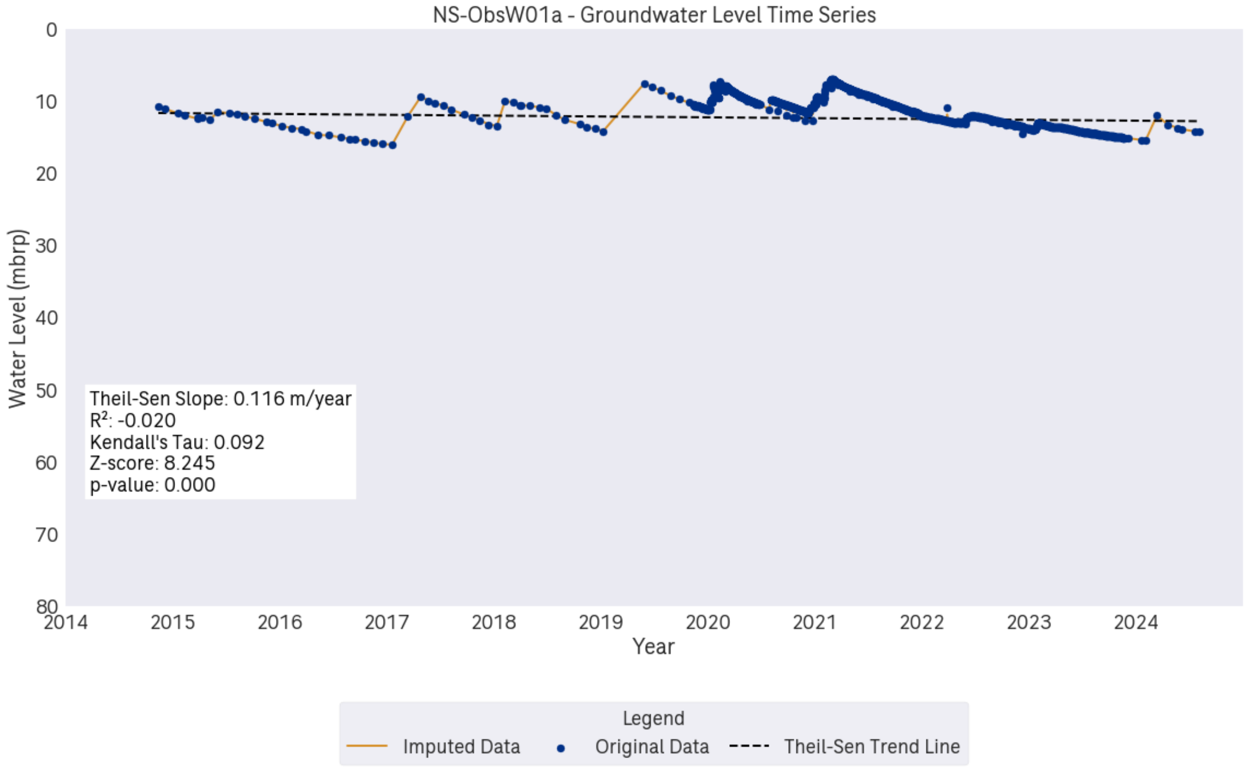


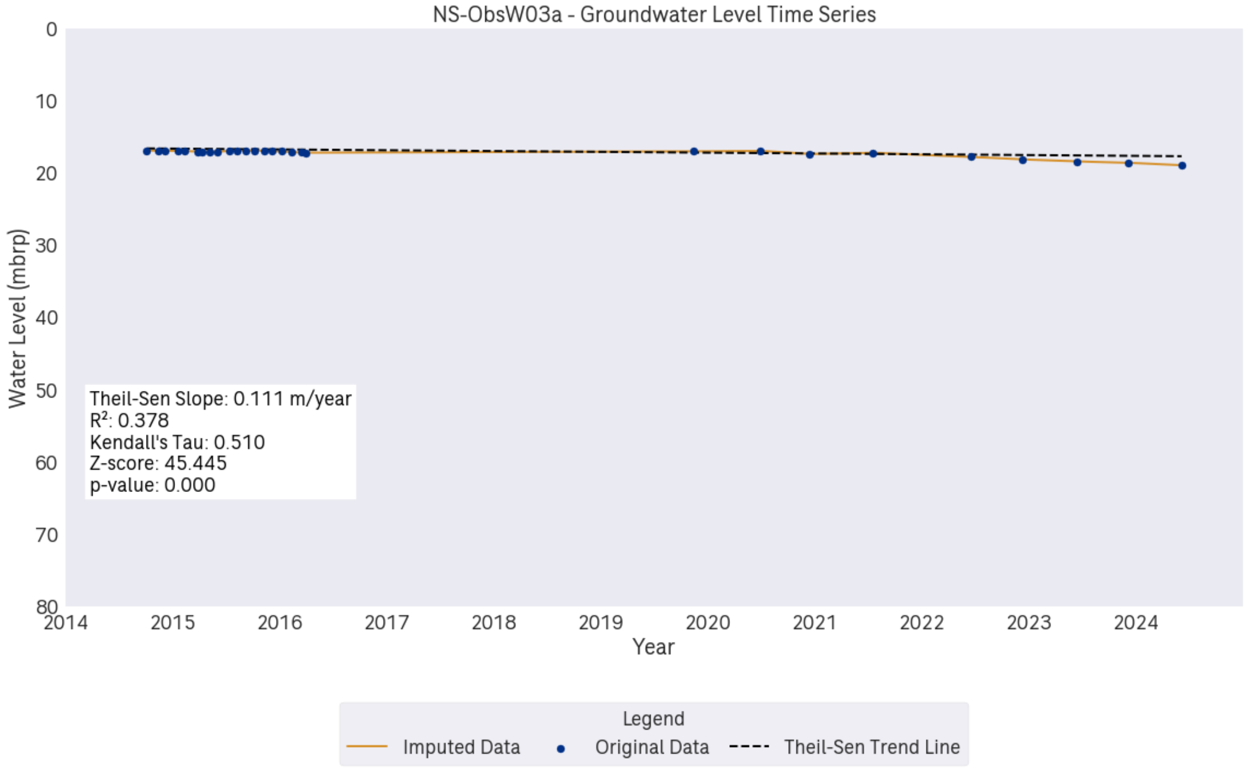
A.1 Western Borefield

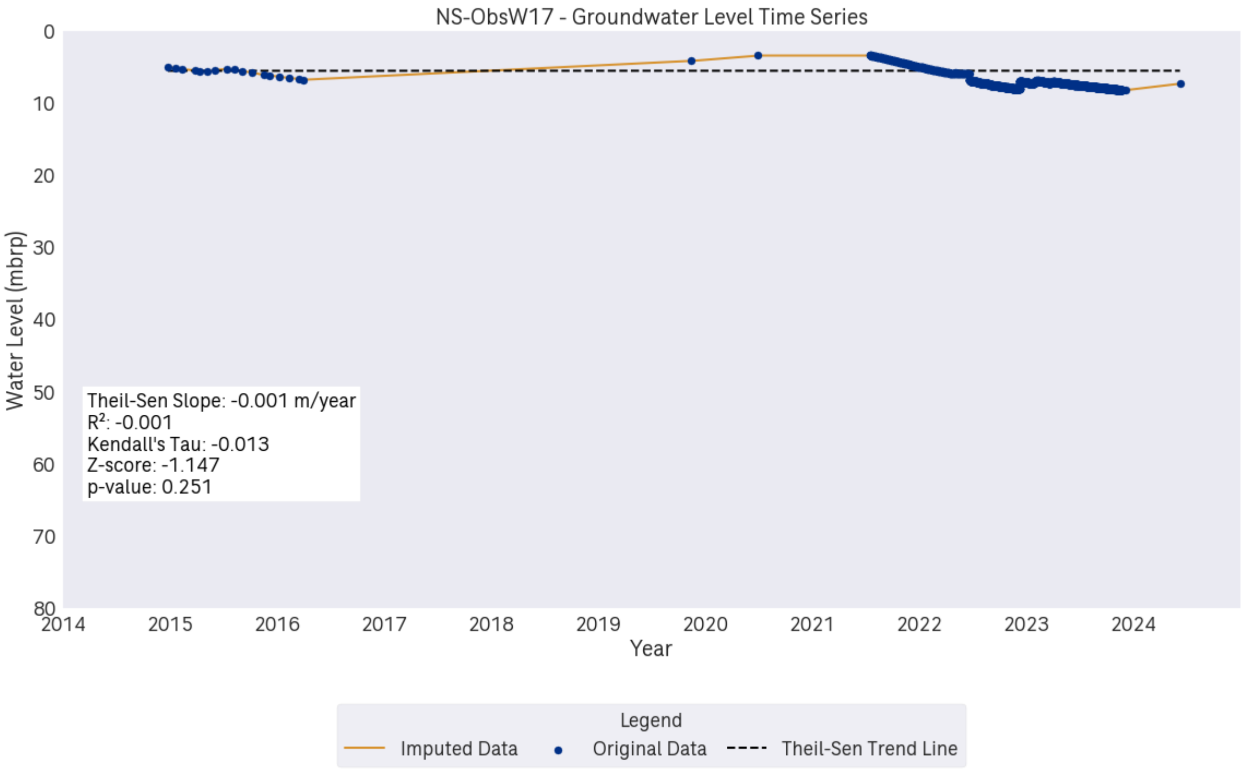
A.1.1 Baseline Period (2014 – 2024)





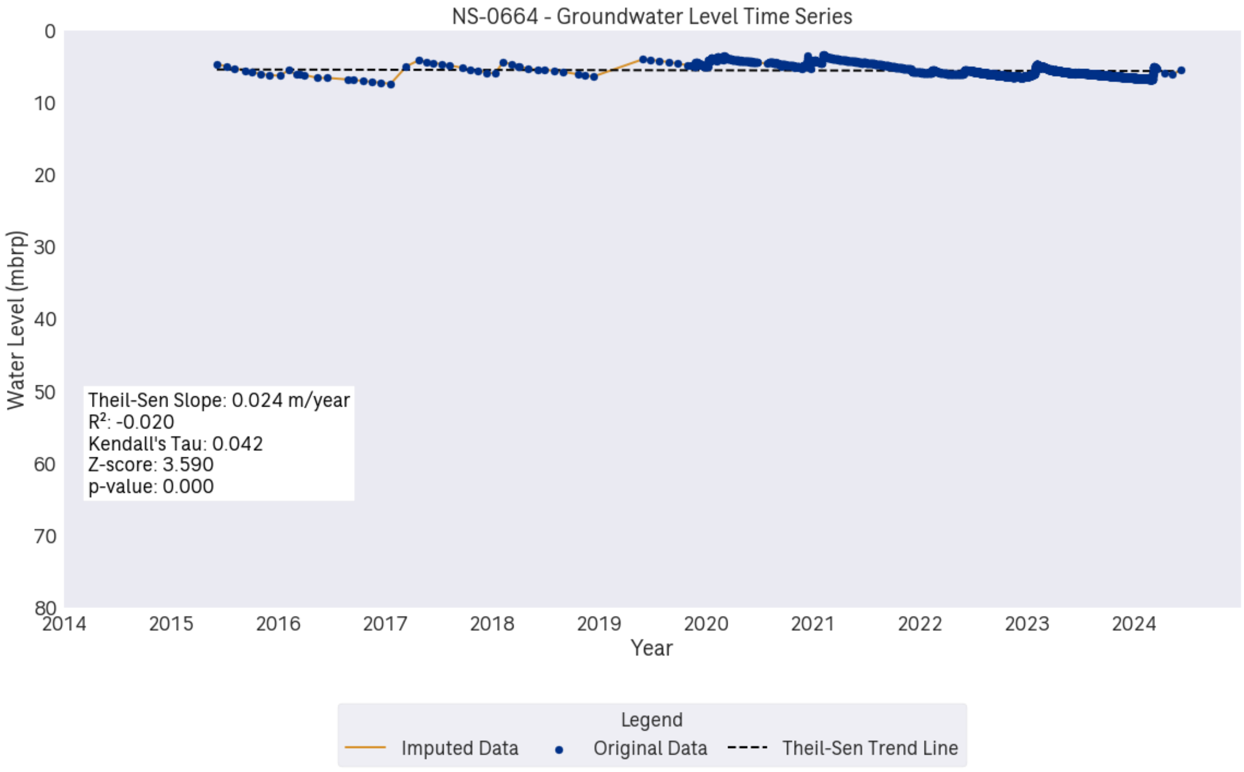

NS-ObsW01a - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
Year
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Theil-Sen Slope: 0.116 m/year
R^2: -0.020
Kendall's Tau: 0.092
Z-score: 8.245
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line


NS-ObsW03a - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
Year
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Theil-Sen Slope: 0.111 m/year
R^2: 0.378
Kendall's Tau: 0.510
Z-score: 45.445
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line



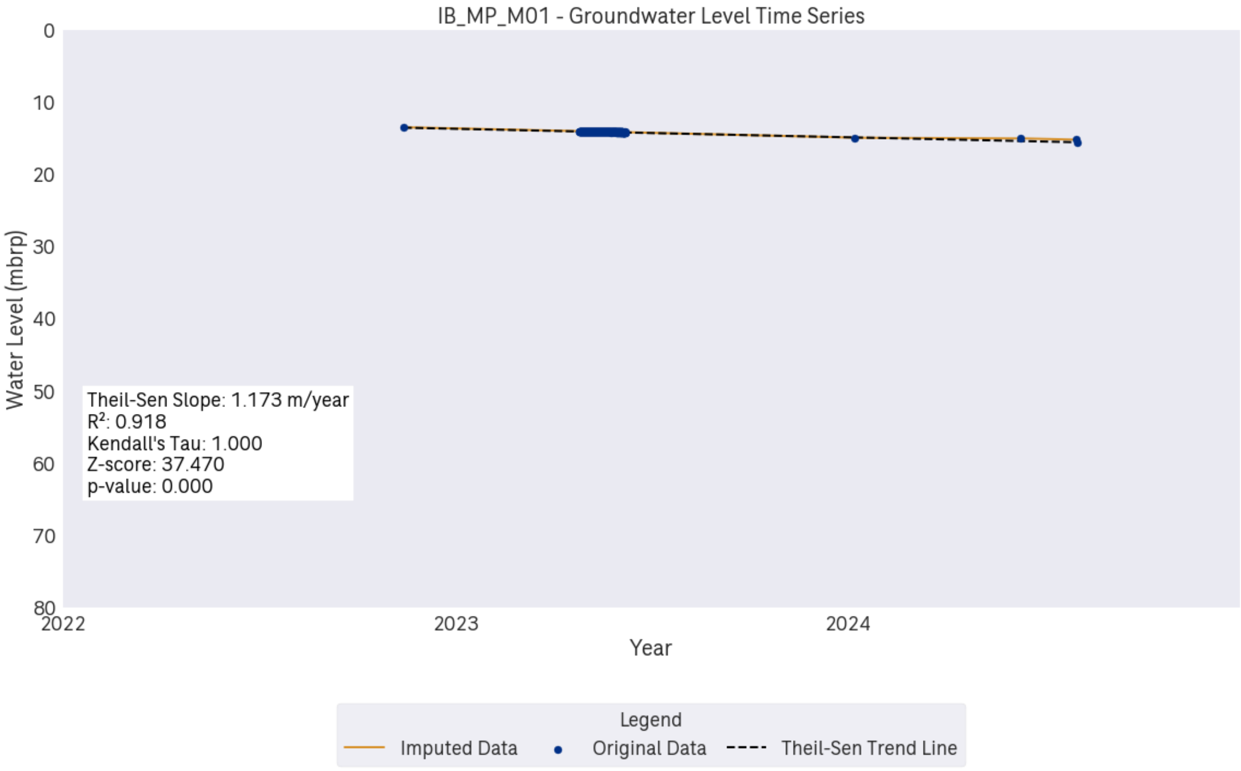
A.2 Waste Rock Dump 1 Area

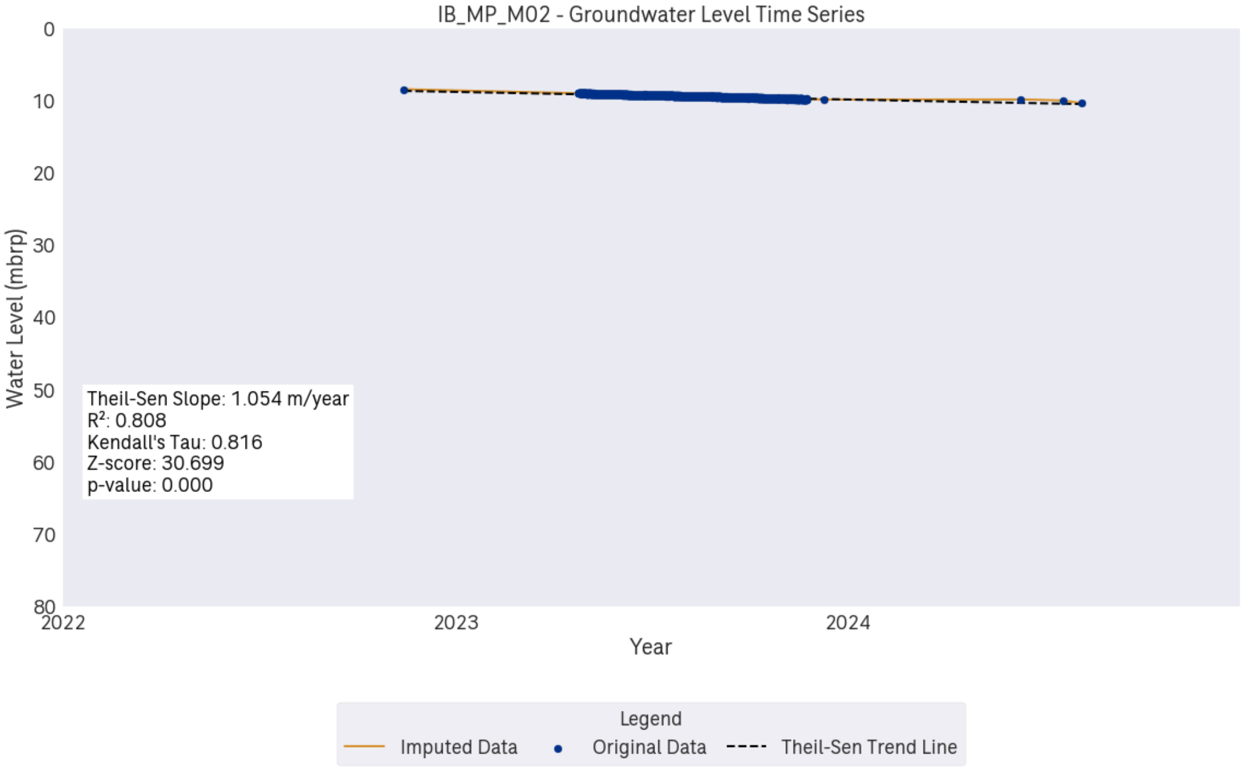
A.2.1 Baseline Period (2014 – 2024)



A.3 Mundagoora Area

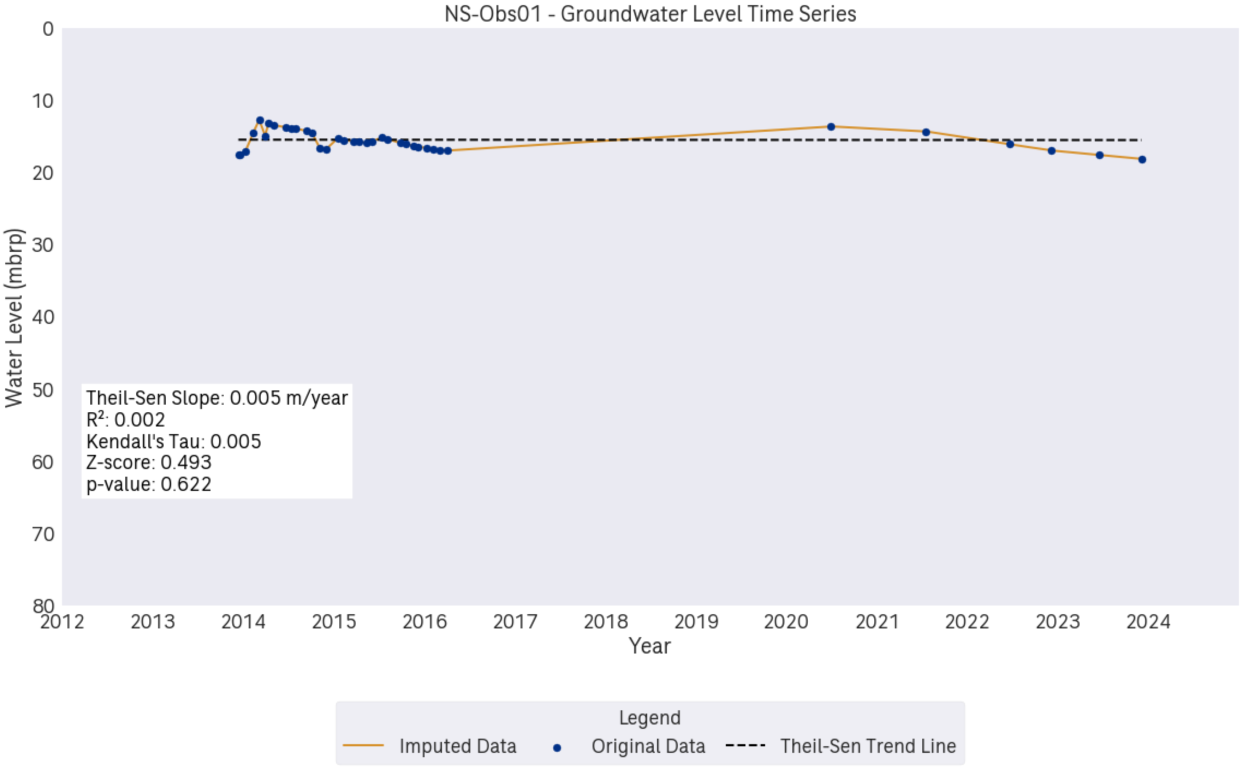
A.3.1 Baseline Period (2022 – 2024)

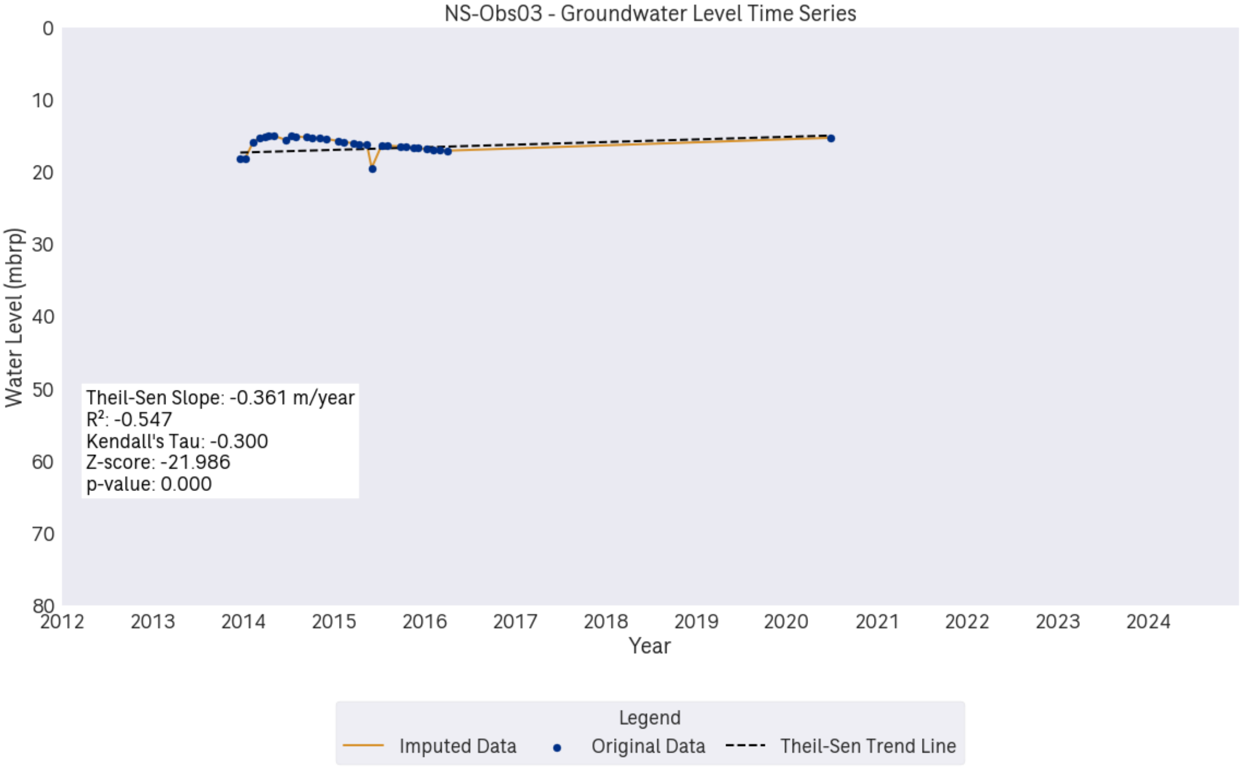


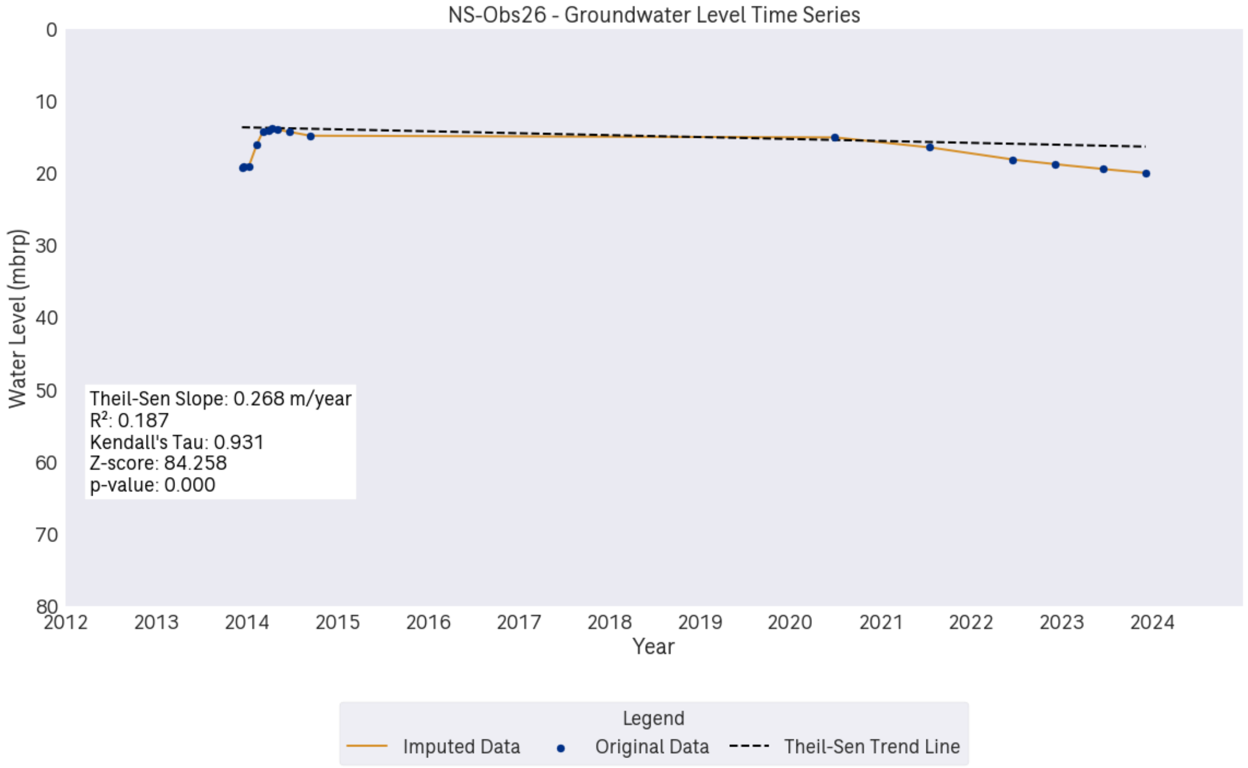


A.4 Northern Valley

A.4.1 Baseline Period (2013 – 2024)

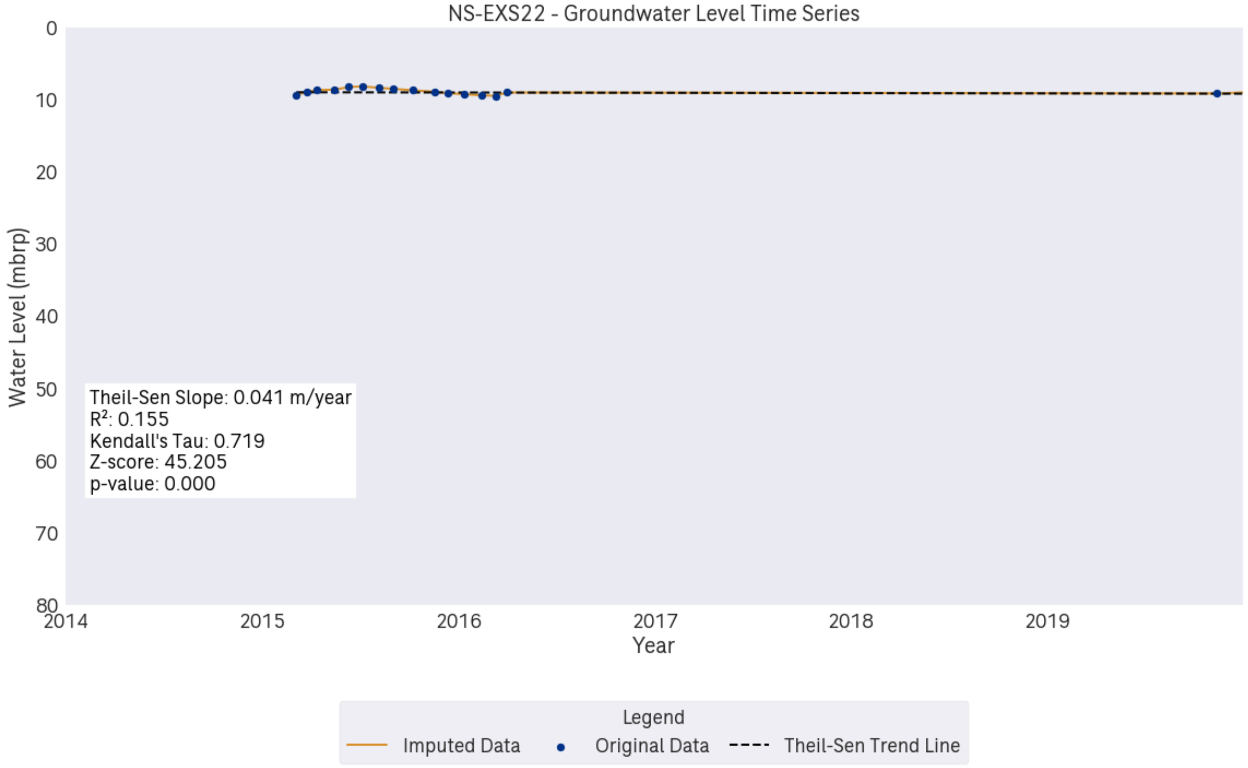


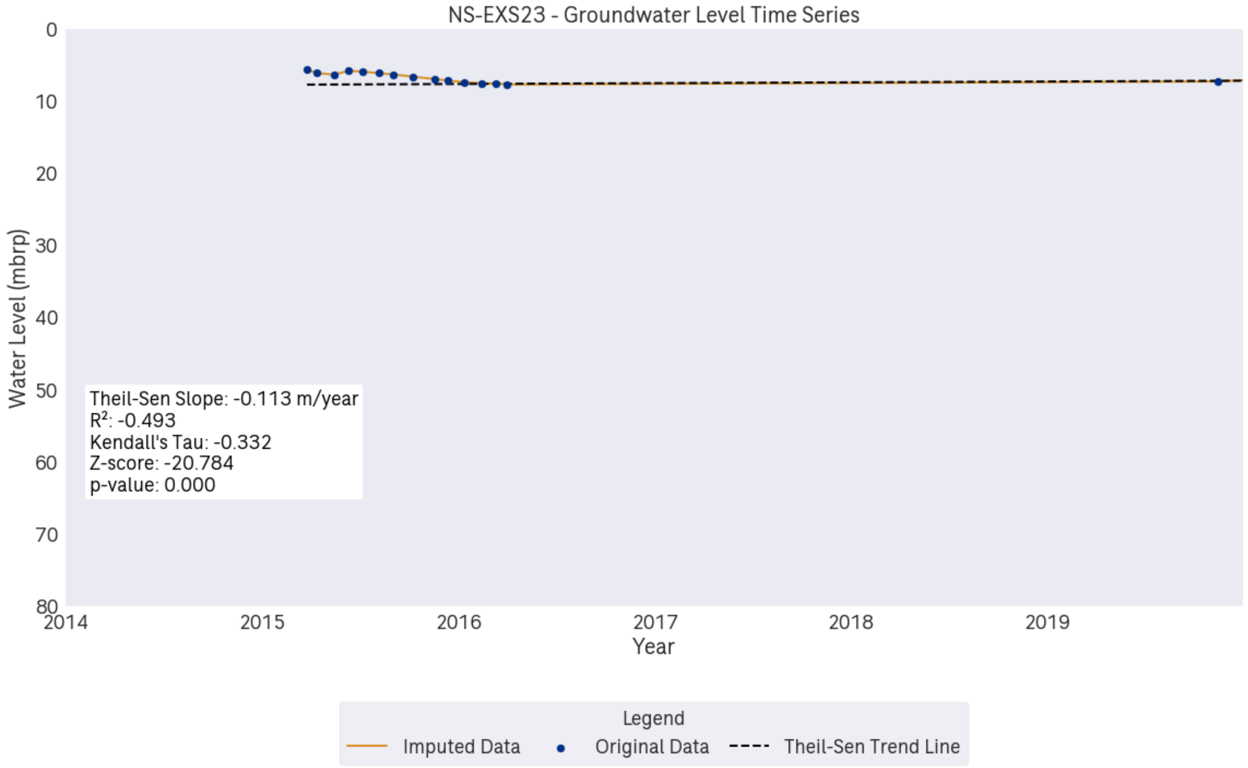


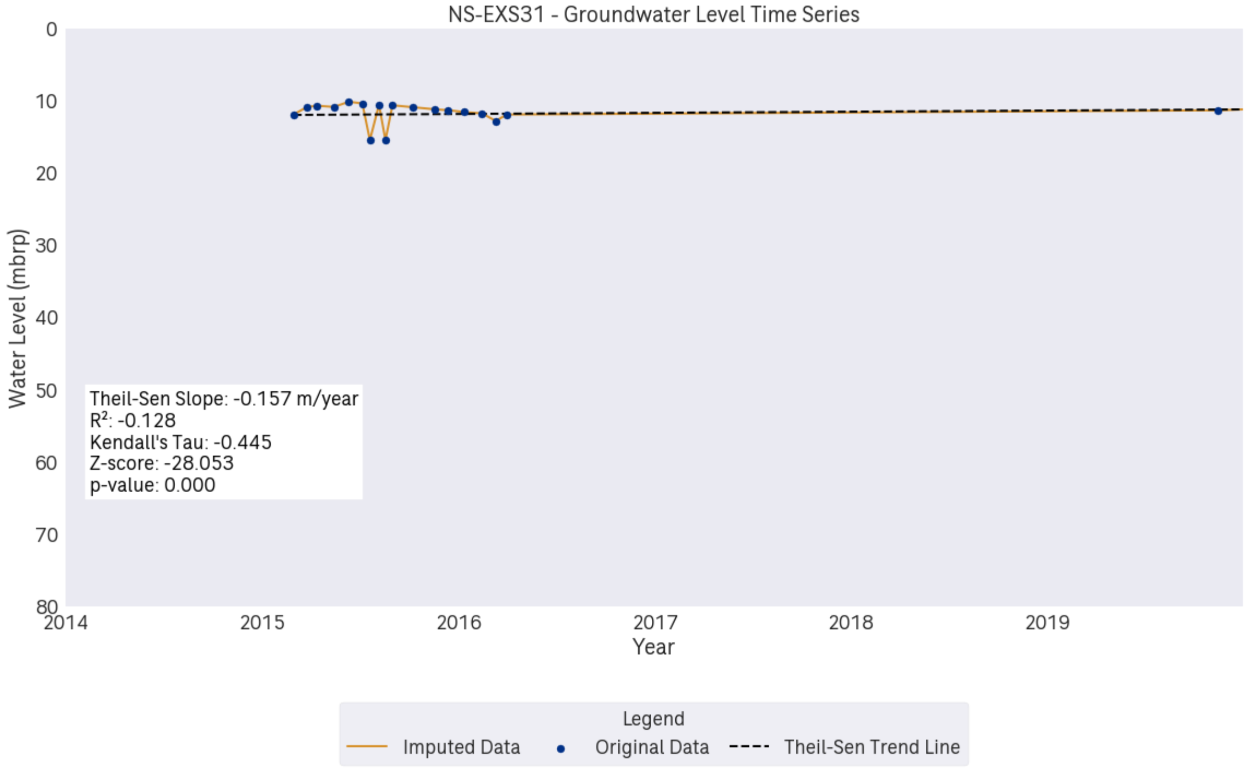


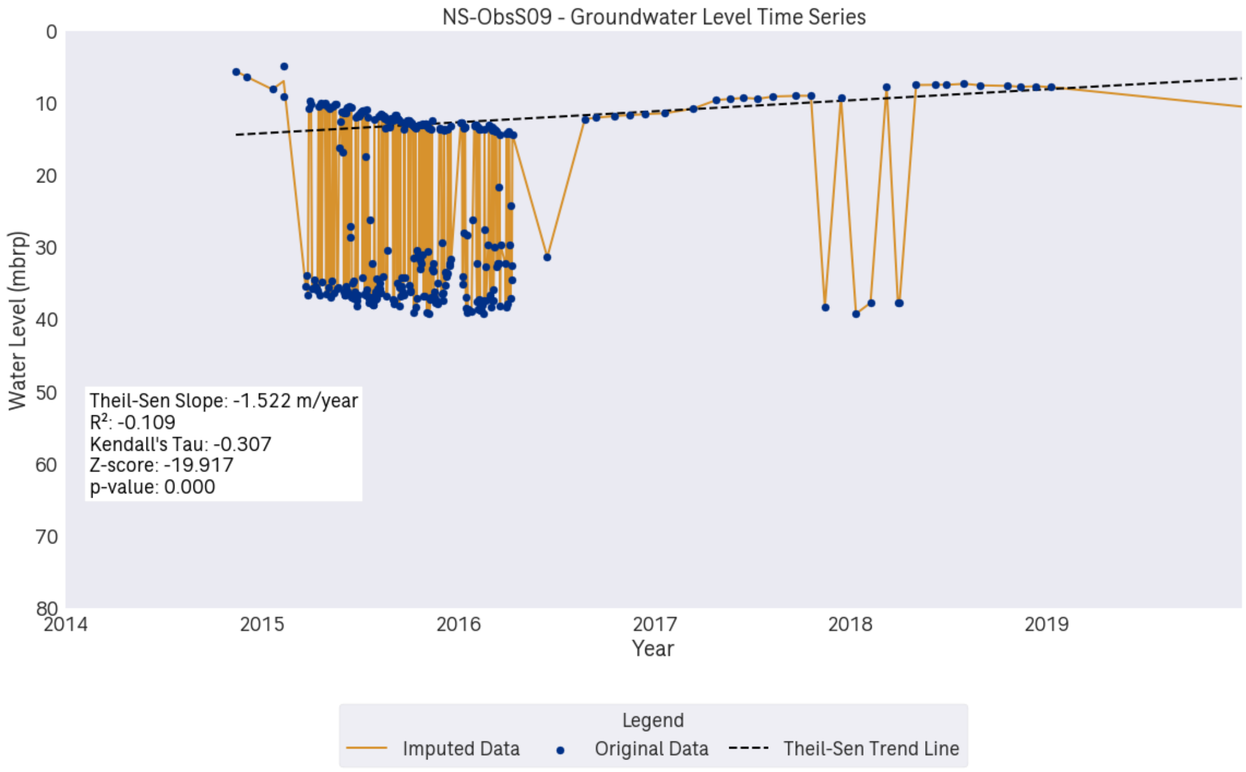
A.5 Southern Borefield

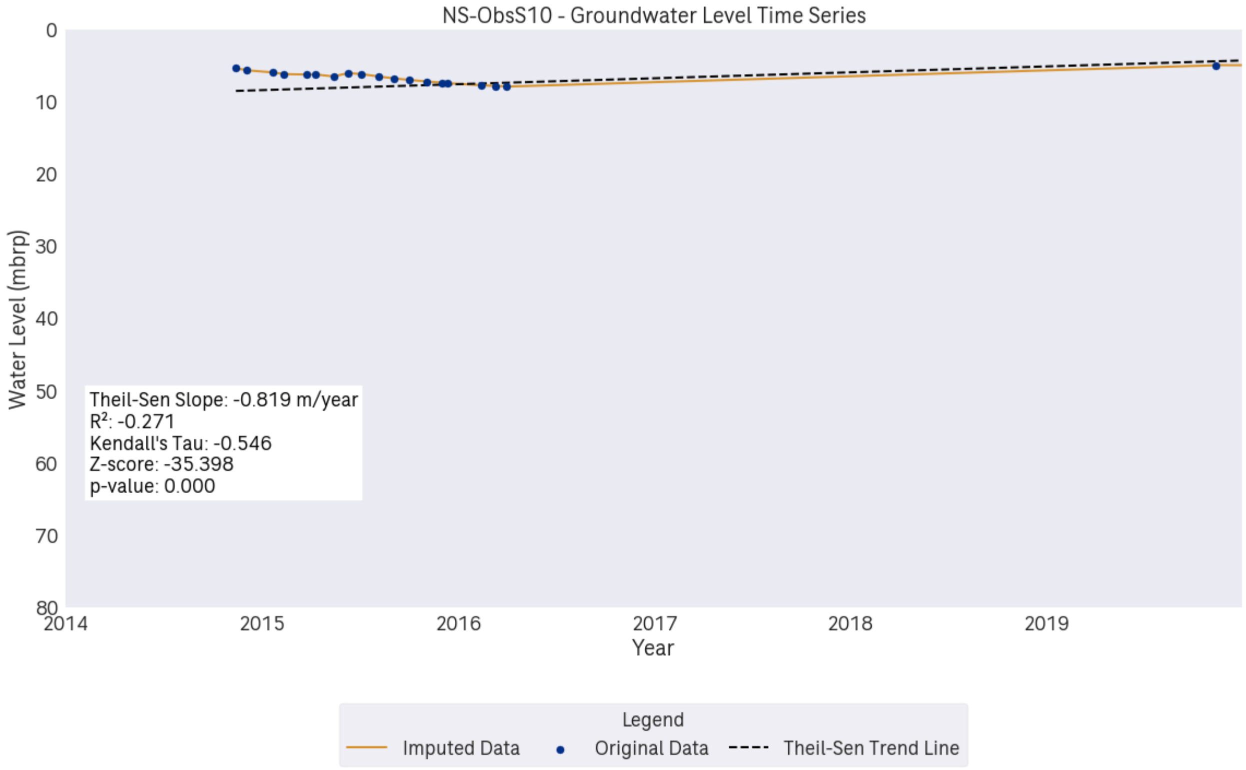
A.5.1 Baseline Period (2014 – 2020)

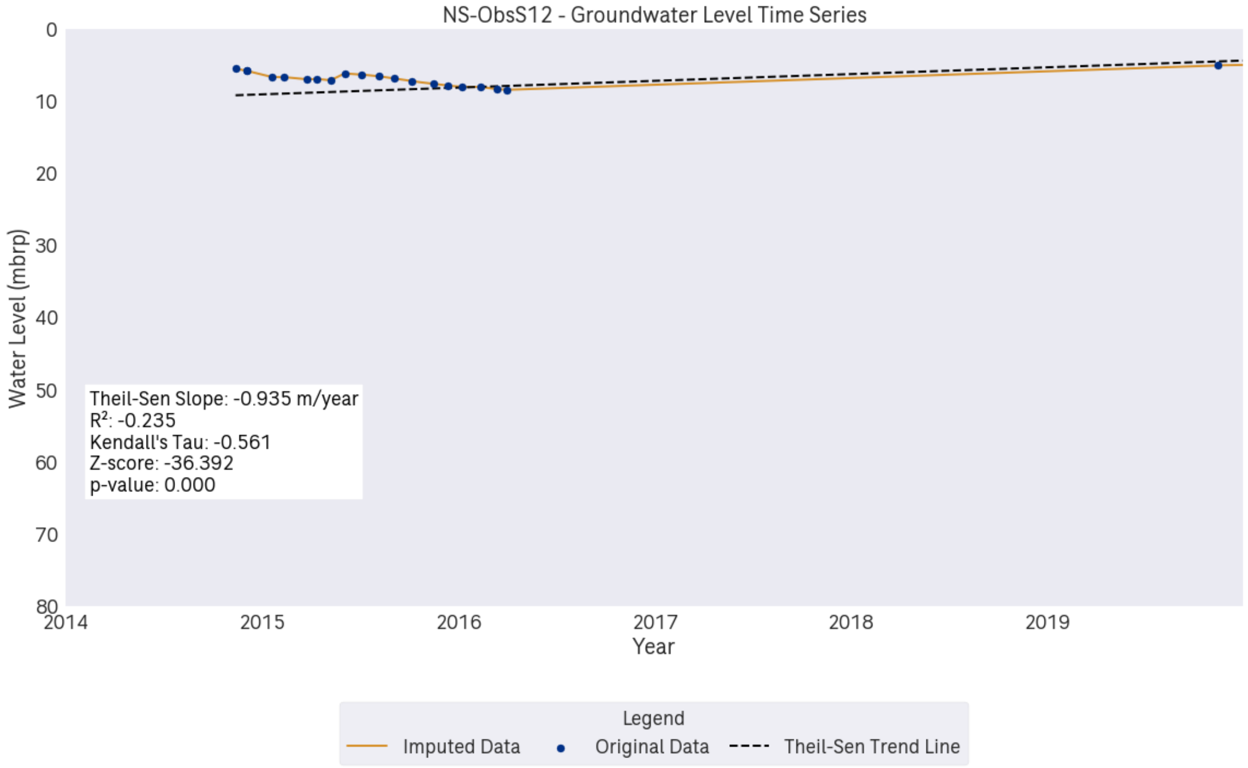


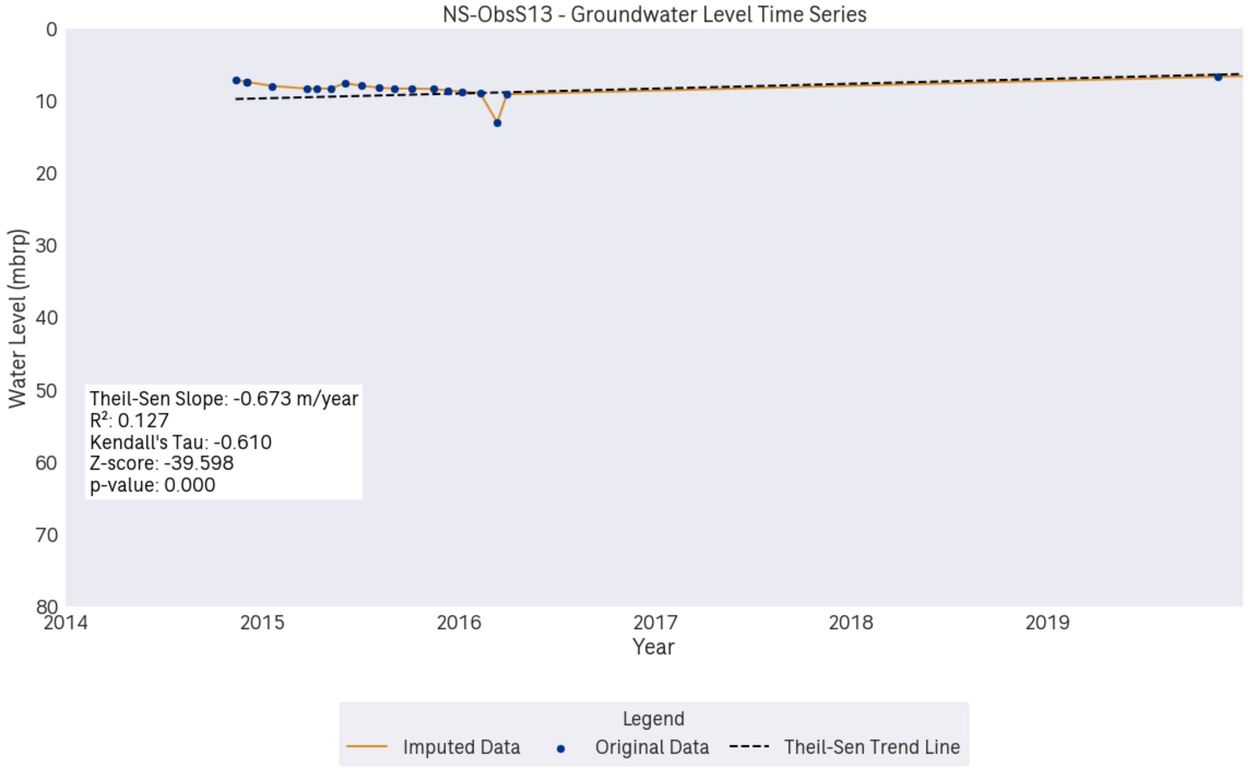

NS-EXS23 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2014
2015
2016
2017
2018
2019
Year
Theil-Sen Slope: -0.113 m/year
R²: -0.493
Kendall's Tau: -0.332
Z-score: -20.784
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line

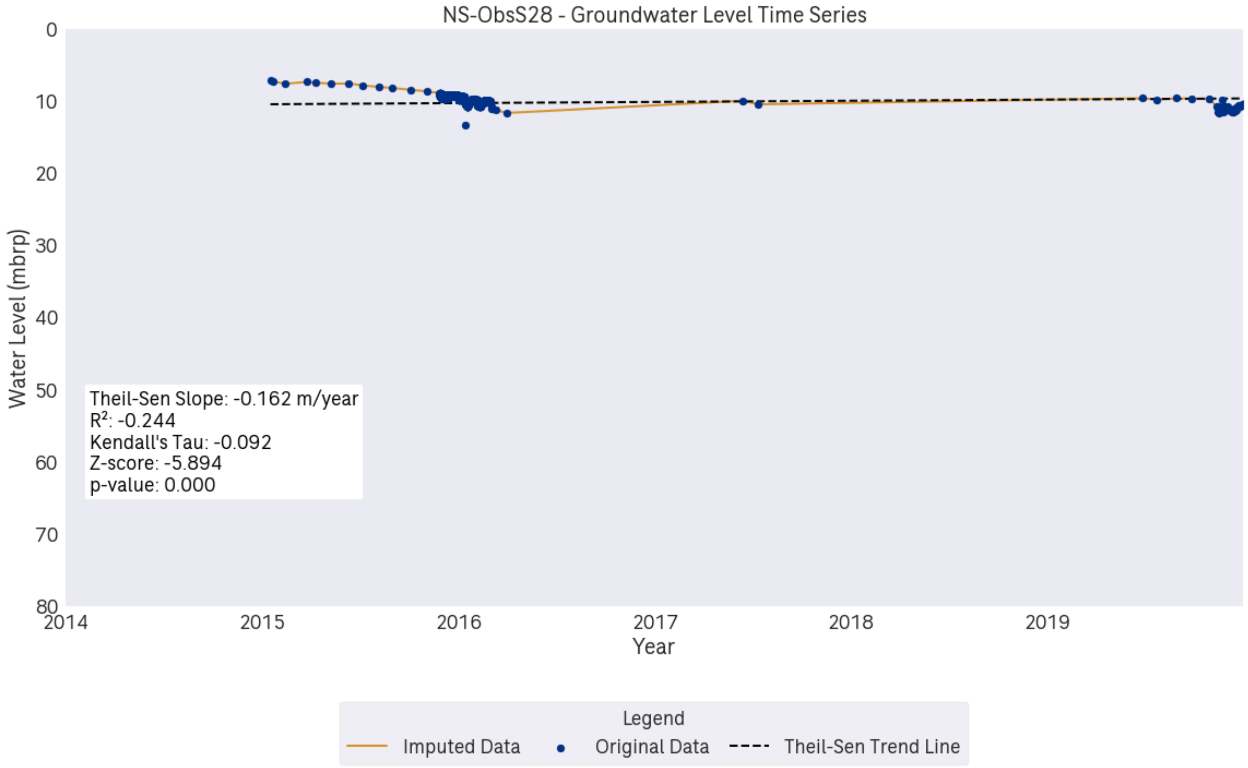

NS-EXS31 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2014
2015
2016
2017
2018
2019
Year
Theil-Sen Slope: -0.157 m/year
R²: -0.128
Kendall's Tau: -0.445
Z-score: -28.053
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line

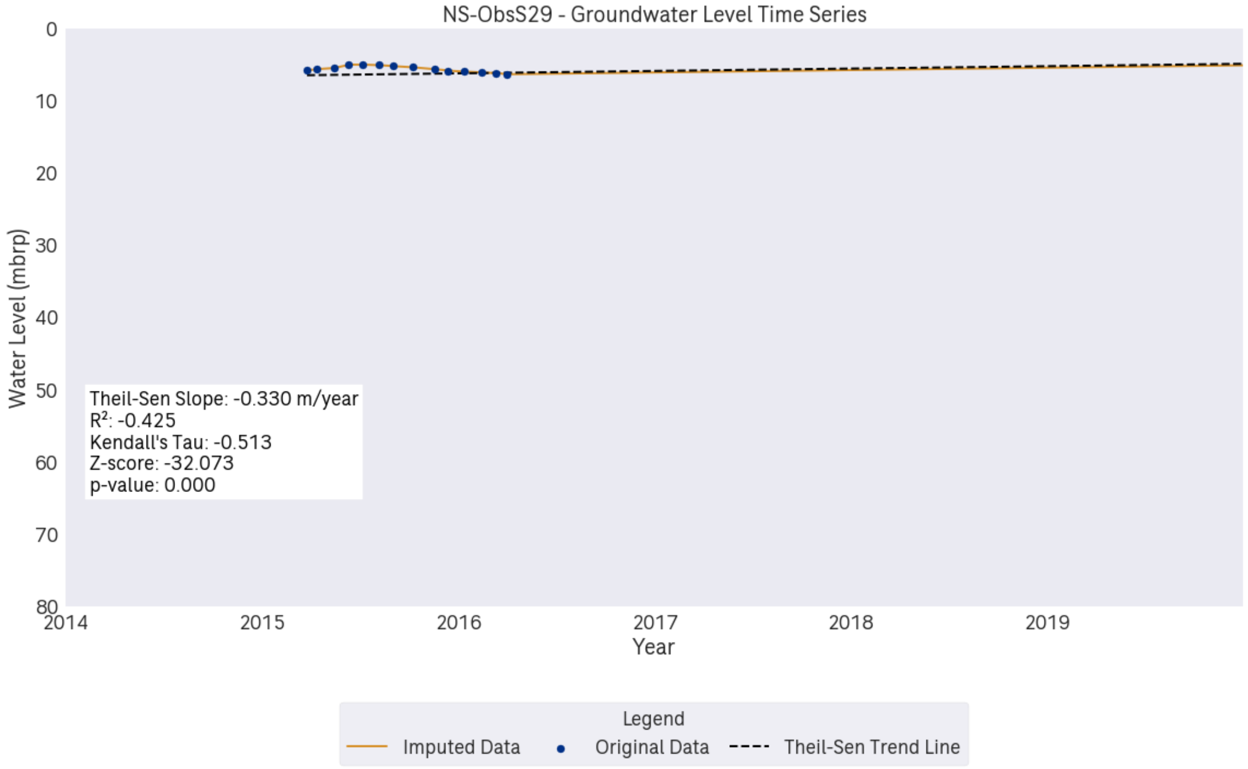

NS-ObsS09 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2014
2015
2016
2017
2018
2019
Year
Theil-Sen Slope: -1.522 m/year
R²: -0.109
Kendall's Tau: -0.307
Z-score: -19.917
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line

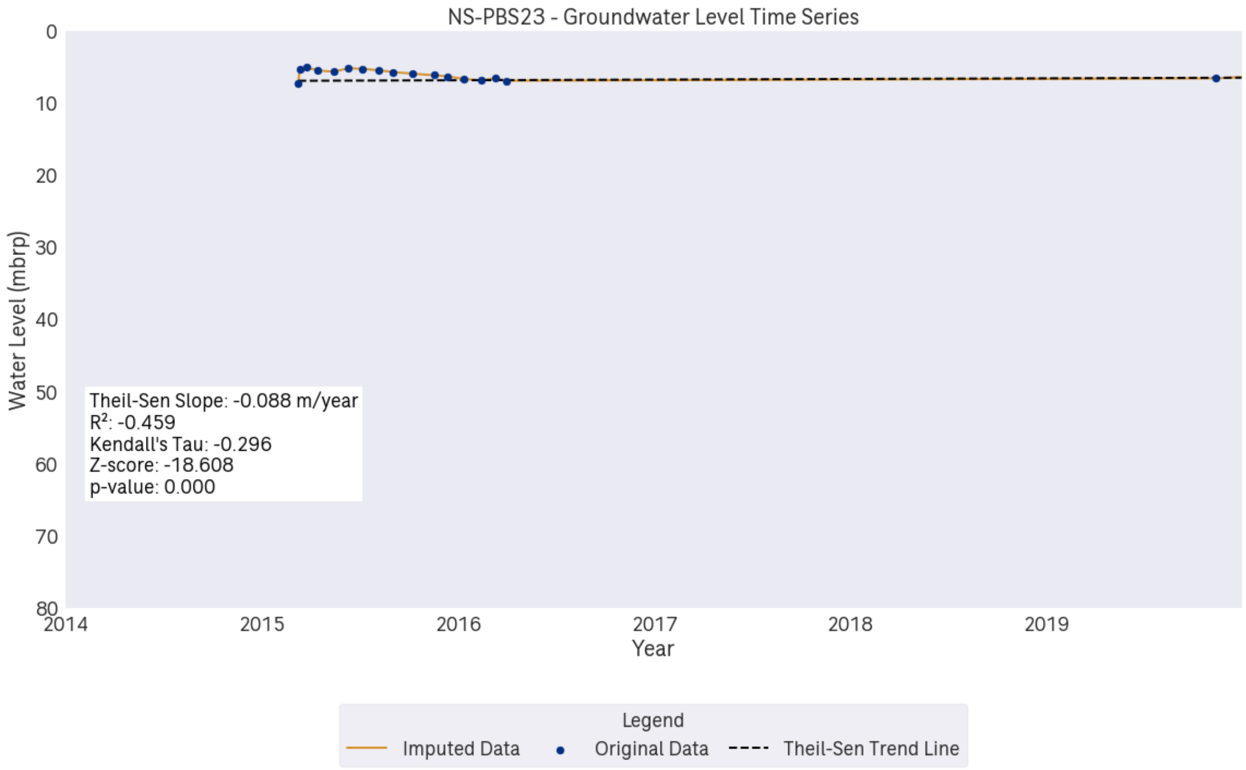

NS-ObsS10 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2014
2015
2016
2017
2018
2019
Year
Theil-Sen Slope: -0.819 m/year
R²: -0.271
Kendall's Tau: -0.546
Z-score: -35.398
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line


NS-ObsS12 - Groundwater Level Time Series


NS-ObsS13 - Groundwater Level Time Series

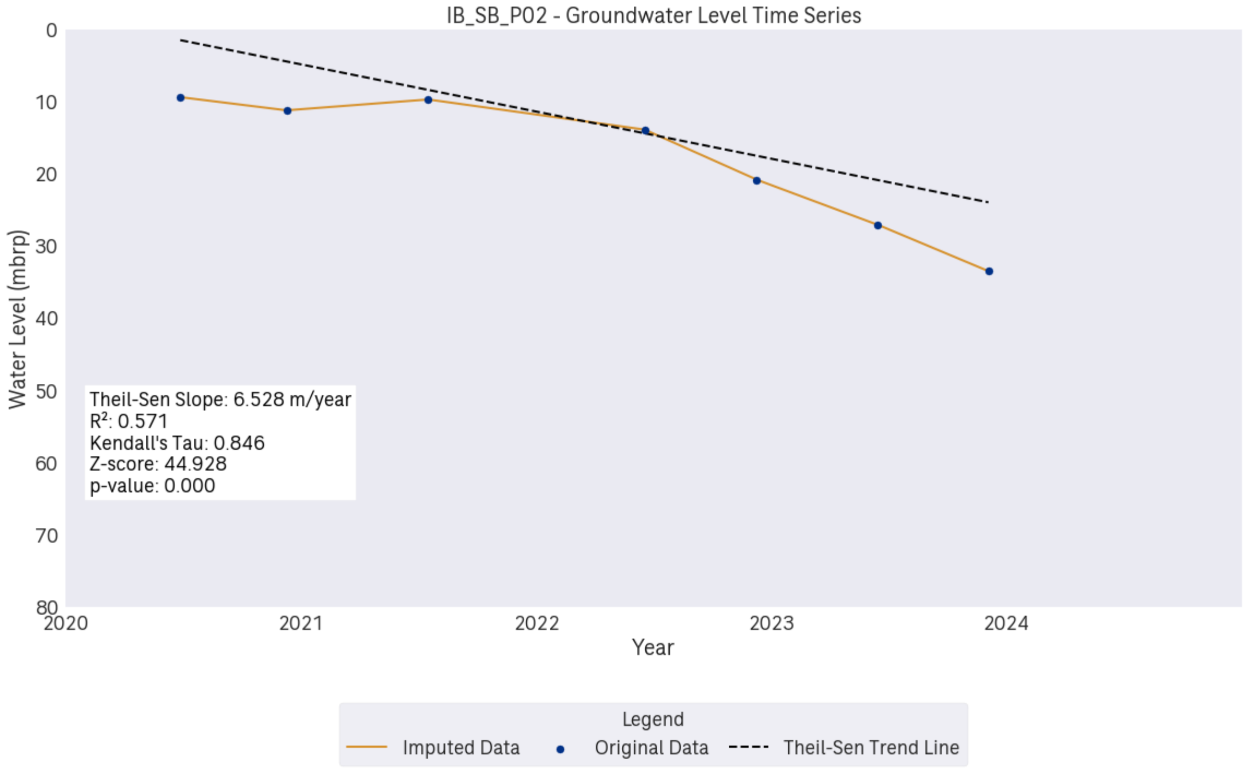

NS-ObsS28 - Groundwater Level Time Series
0
10
20
30
40
50
60
70
80
Water Level (mbrp)
2014
2015
2016
2017
2018
2019
Year
Theil-Sen Slope: -0.162 m/year
R²: -0.244
Kendall's Tau: -0.092
Z-score: -5.894
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line

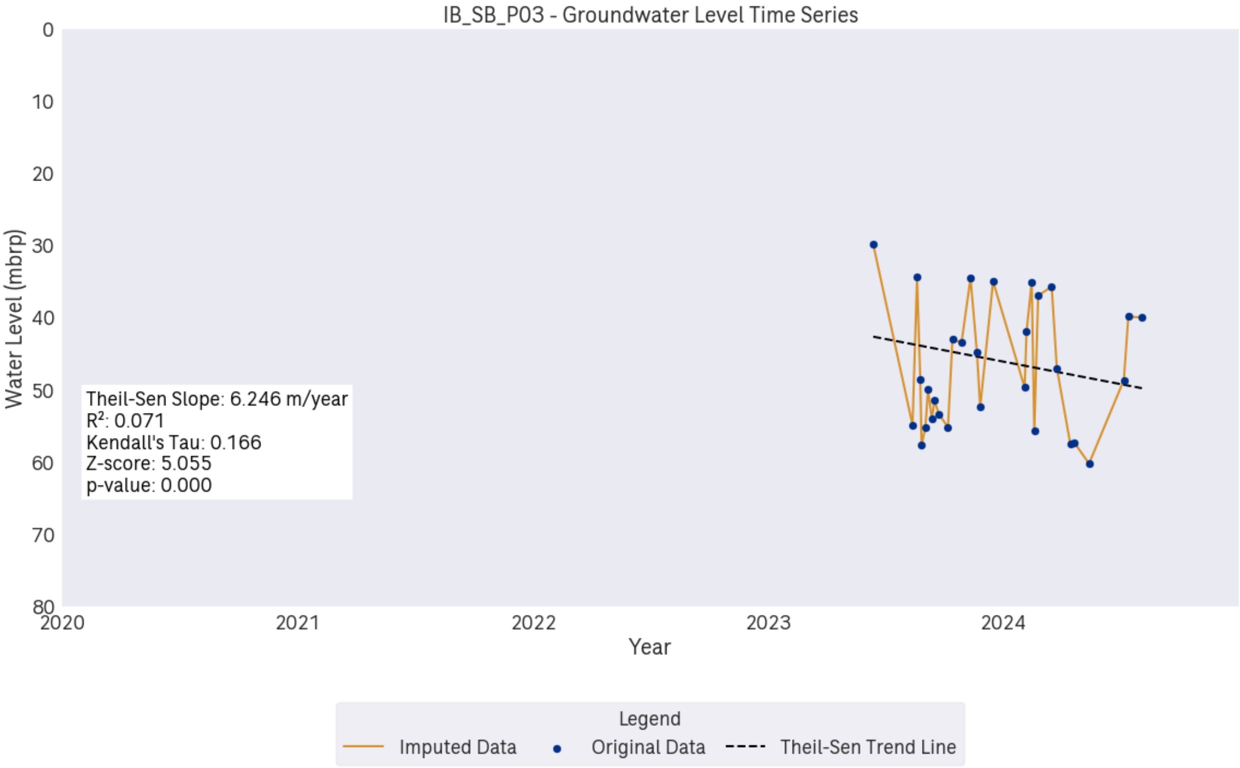

NS-ObsS29 - Groundwater Level Time Series
0
10
20
30
40
50
60
70
80
Water Level (mbrp)
2014
2015
2016
2017
2018
2019
Year
Theil-Sen Slope: -0.330 m/year
R²: -0.425
Kendall's Tau: -0.513
Z-score: -32.073
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line

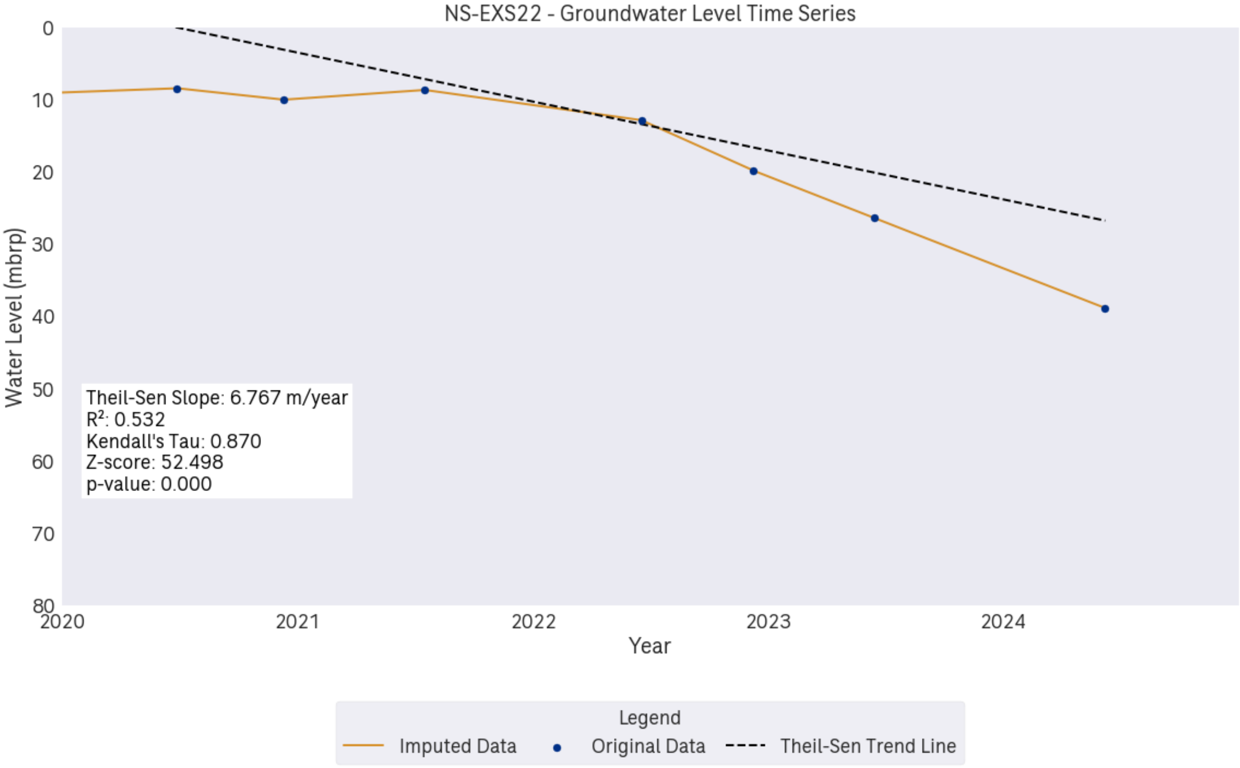


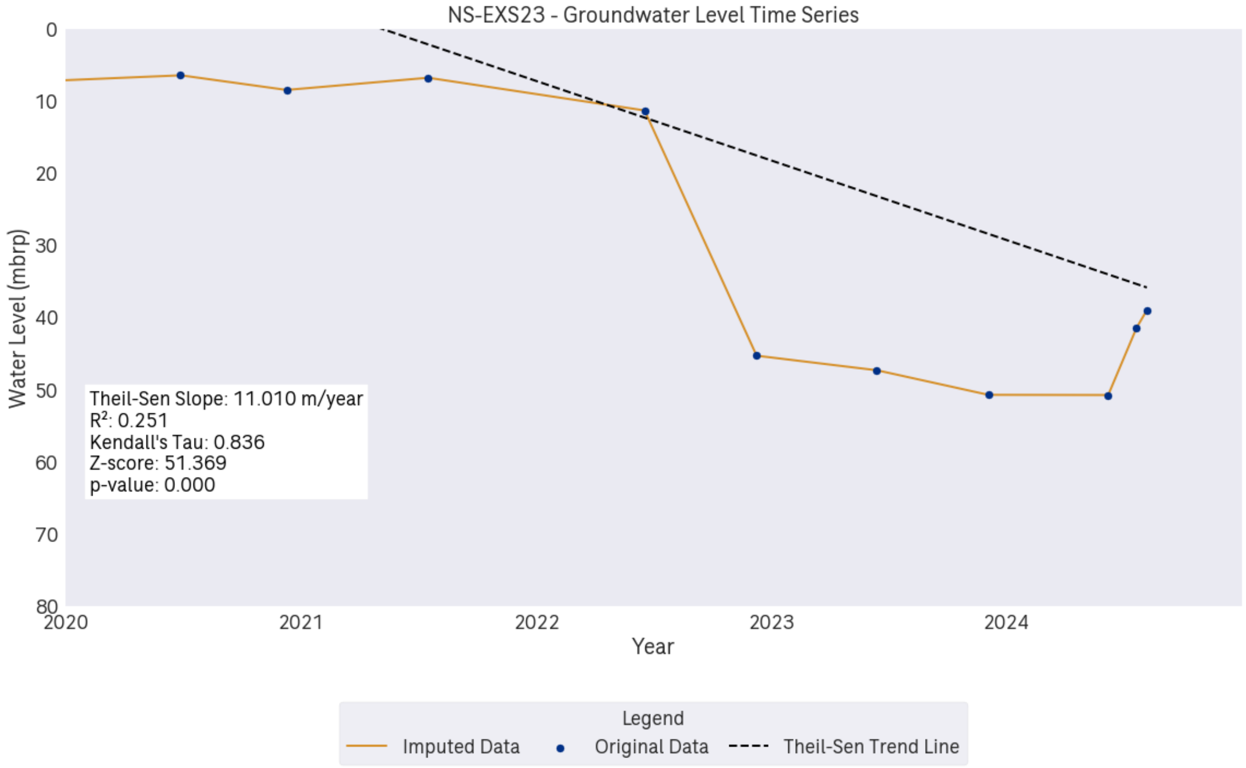
A.6 Southern Borefield

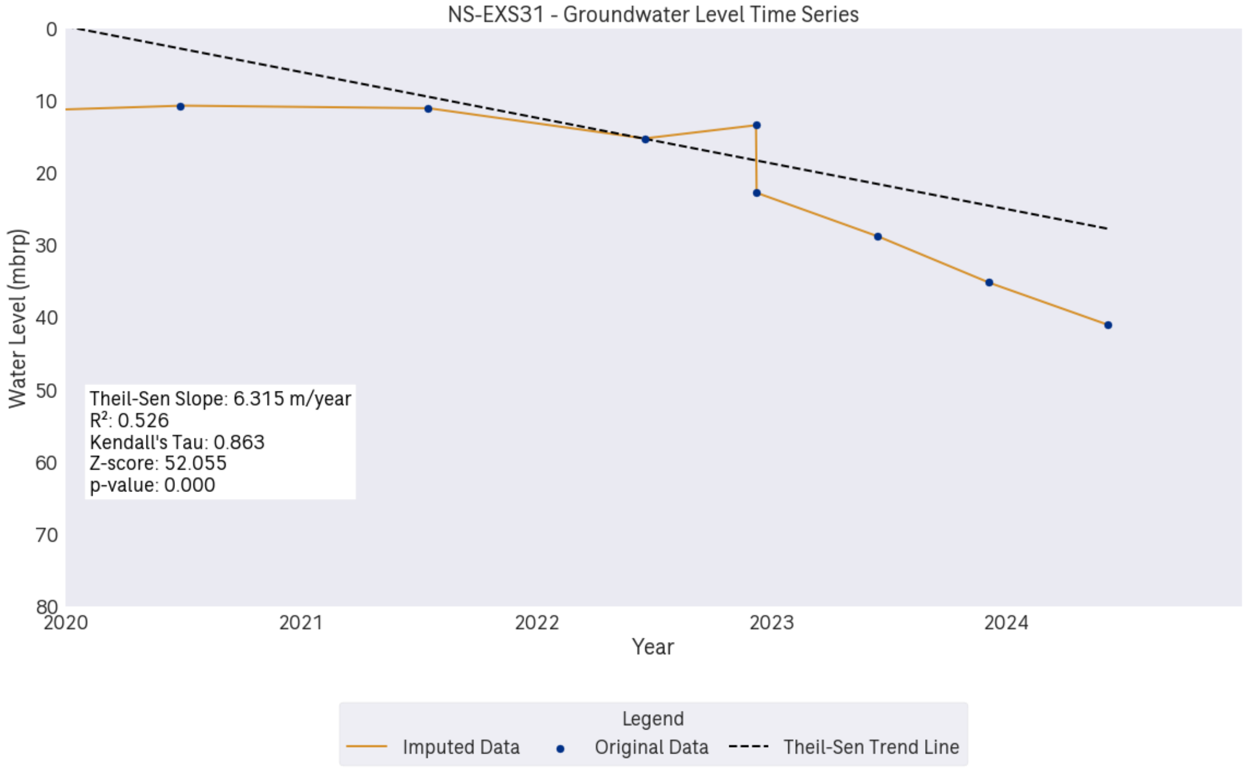
A.6.1 Impact Period (2020 – 2024)

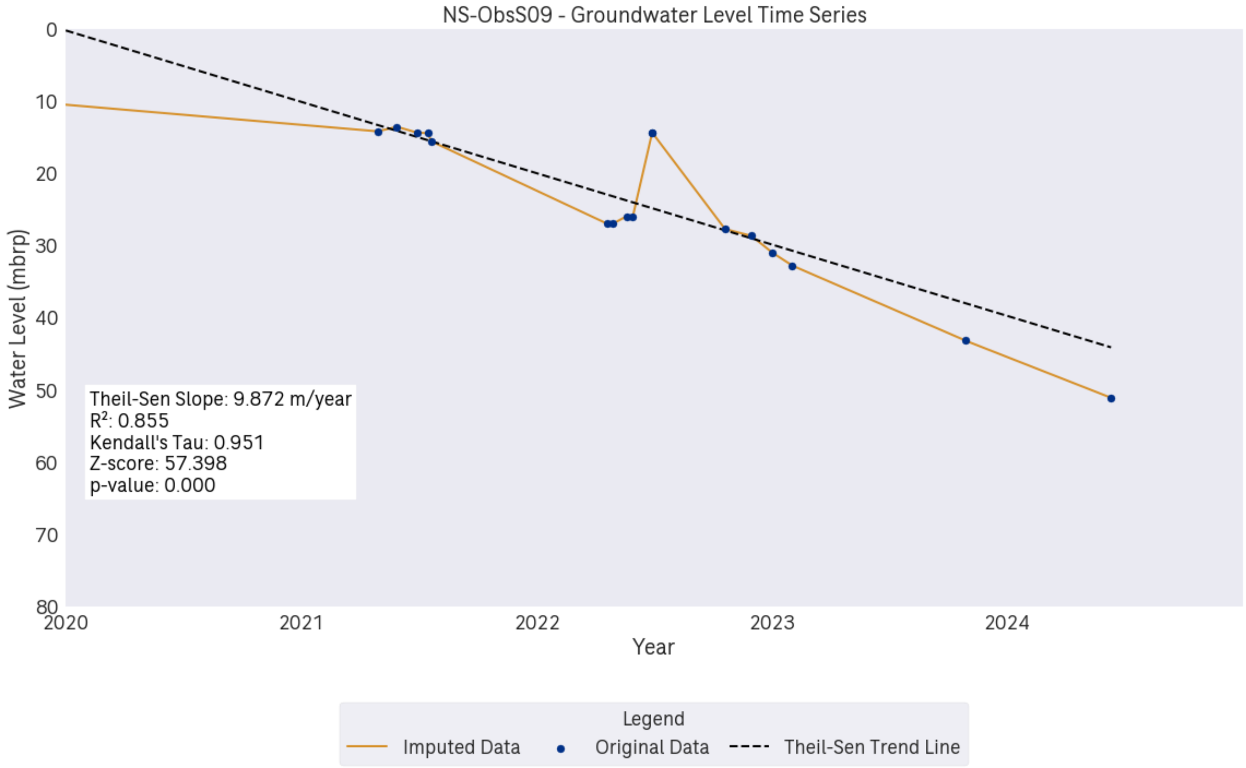


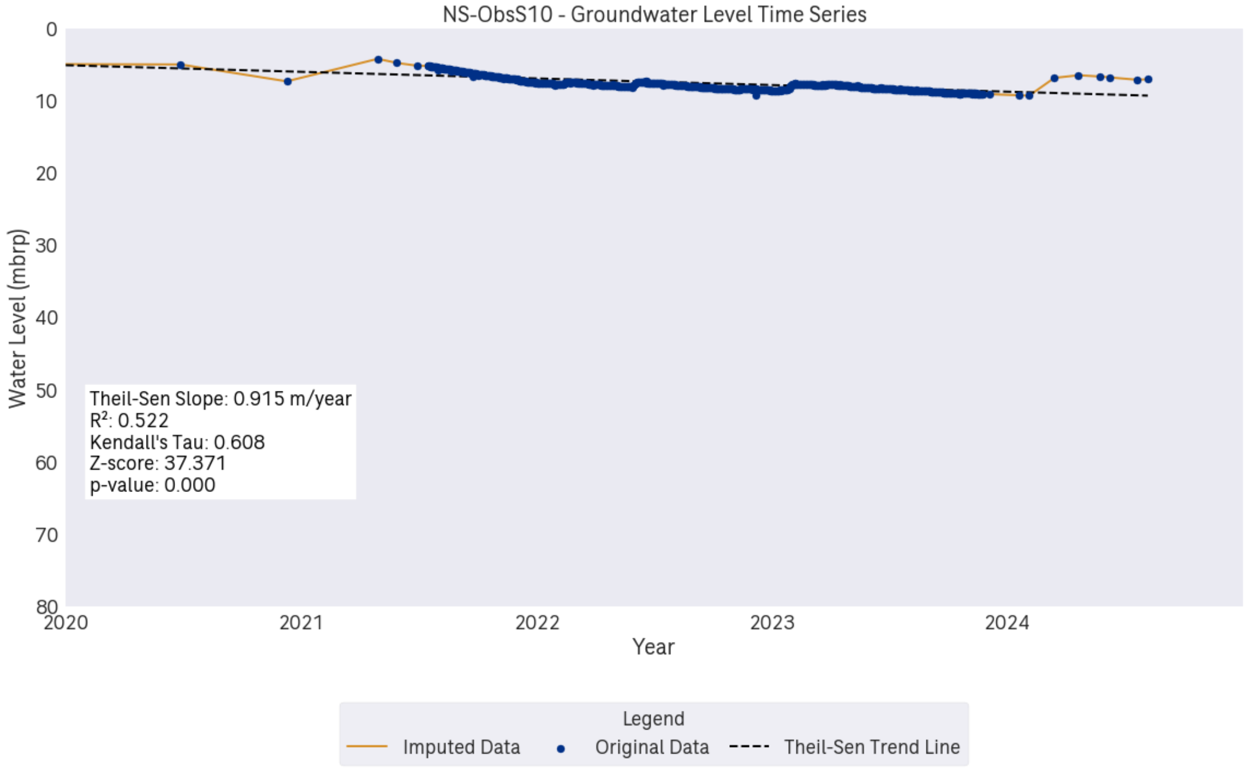

IB_SB_P03 - Groundwater Level Time Series

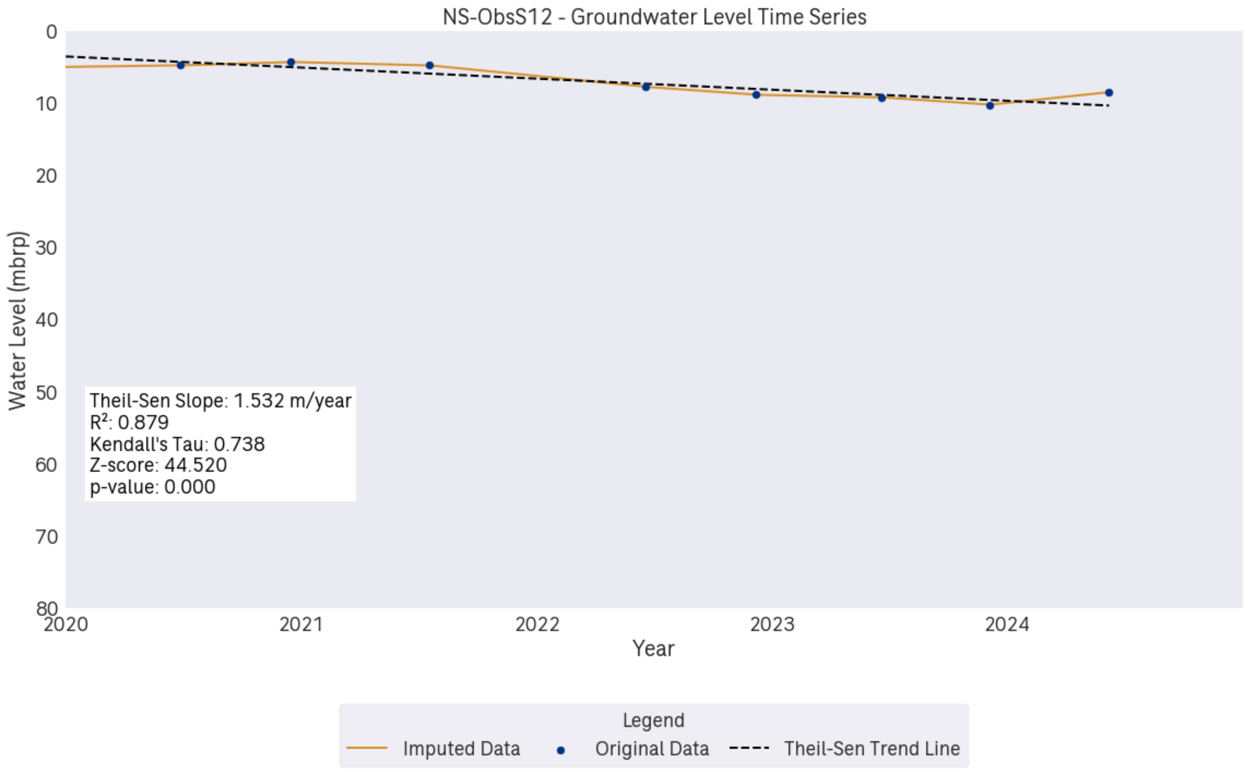

NS-EXS22 - Groundwater Level Time Series

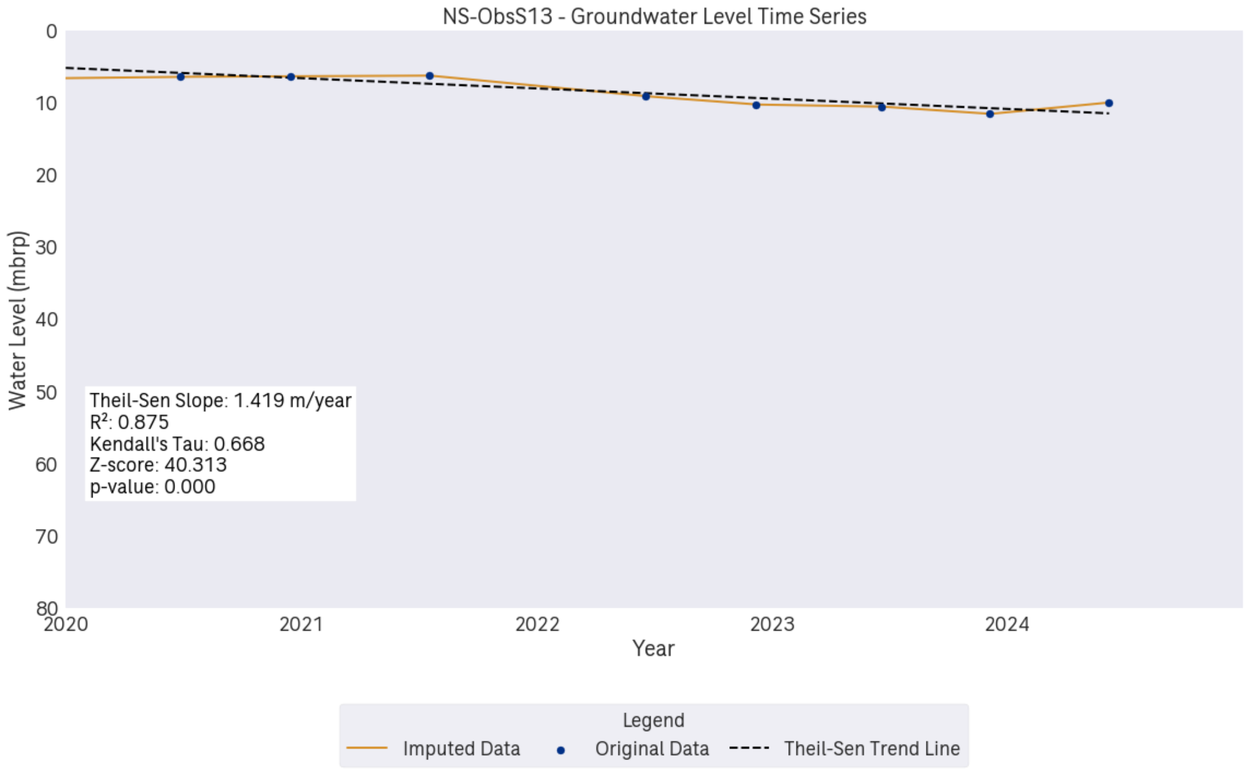

NS-EXS23 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2020
2021
2022
2023
2024
Year
Theil-Sen Slope: 11.010 m/year
R²: 0.251
Kendall's Tau: 0.836
Z-score: 51.369
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line

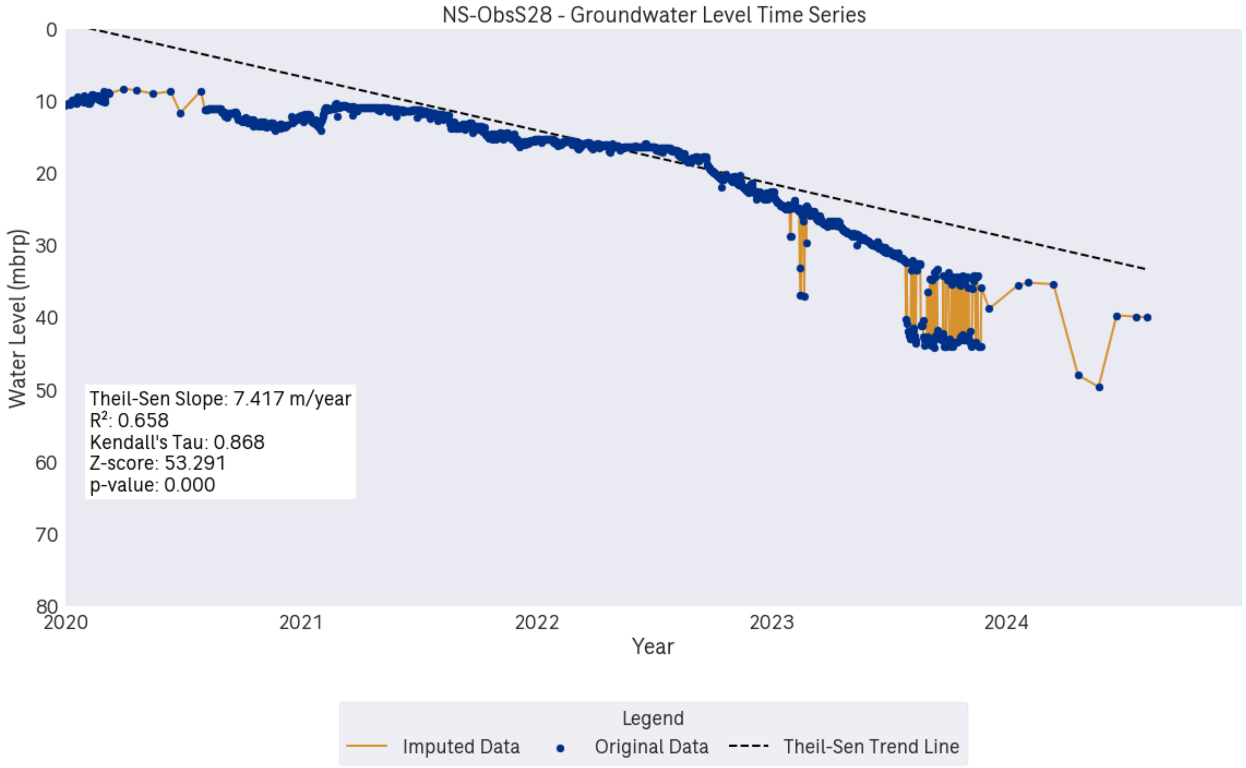

NS-EXS31 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2020
2021
2022
2023
2024
Year
Theil-Sen Slope: 6.315 m/year
R²: 0.526
Kendall's Tau: 0.863
Z-score: 52.055
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line


NS-ObsS09 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2020
2021
2022
2023
2024
Year
Theil-Sen Slope: 9.872 m/year
R²: 0.855
Kendall's Tau: 0.951
Z-score: 57.398
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line


NS-ObsS10 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2020
2021
2022
2023
2024
Year
Theil-Sen Slope: 0.915 m/year
R²: 0.522
Kendall's Tau: 0.608
Z-score: 37.371
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line

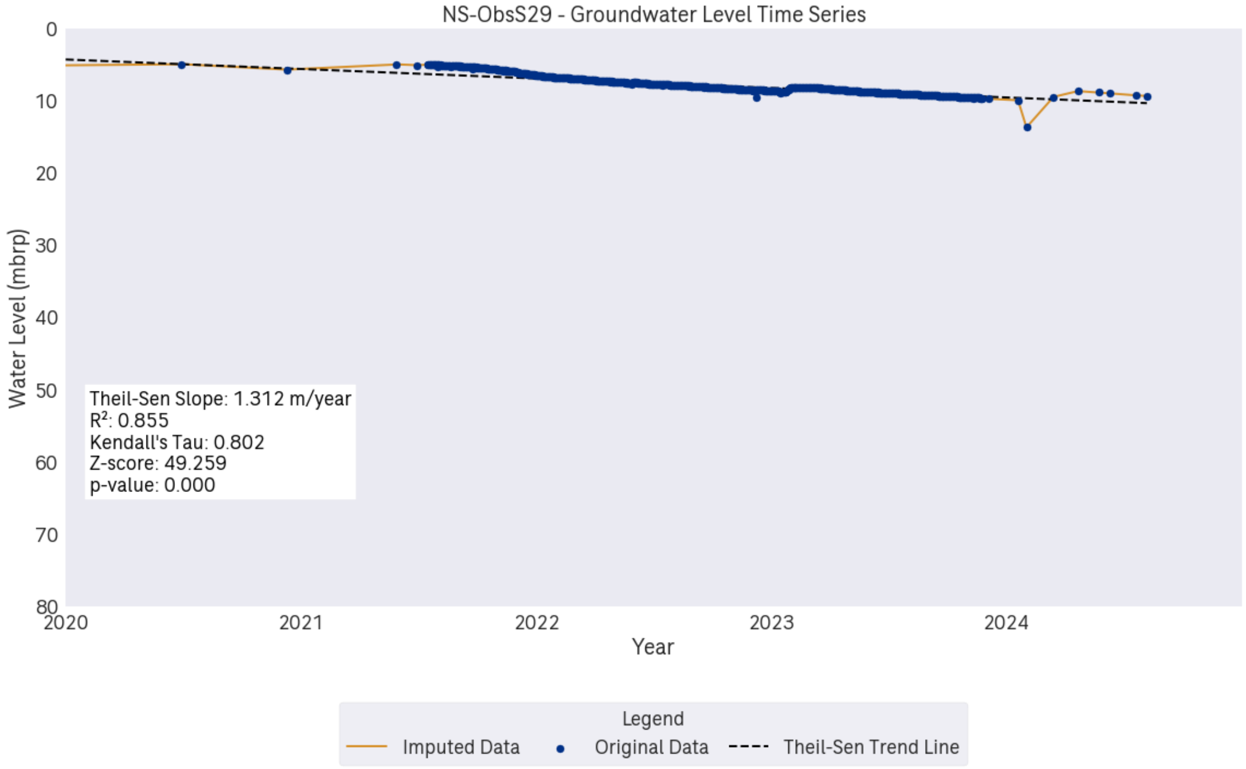

NS-ObsS12 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2020
2021
2022
2023
2024
Year
Theil-Sen Slope: 1.532 m/year
R²: 0.879
Kendall's Tau: 0.738
Z-score: 44.520
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line


NS-ObsS13 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2020
2021
2022
2023
2024
Year
Theil-Sen Slope: 1.419 m/year
R²: 0.875
Kendall's Tau: 0.668
Z-score: 40.313
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line



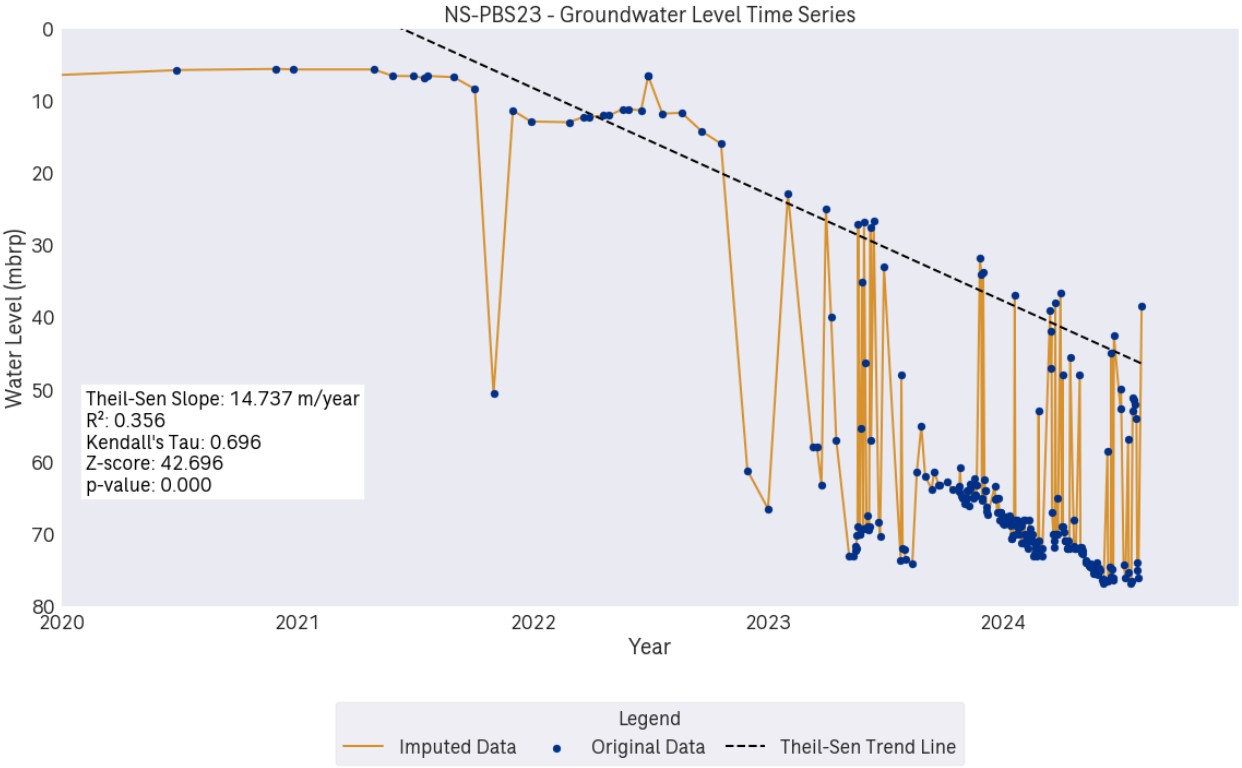
NS-ObsS28 - Groundwater Level Time Series

Theil-Sen Slope: 7.417 m/year
R^2: 0.658
Kendall's Tau: 0.868
Z-score: 53.291
p-value: 0.000



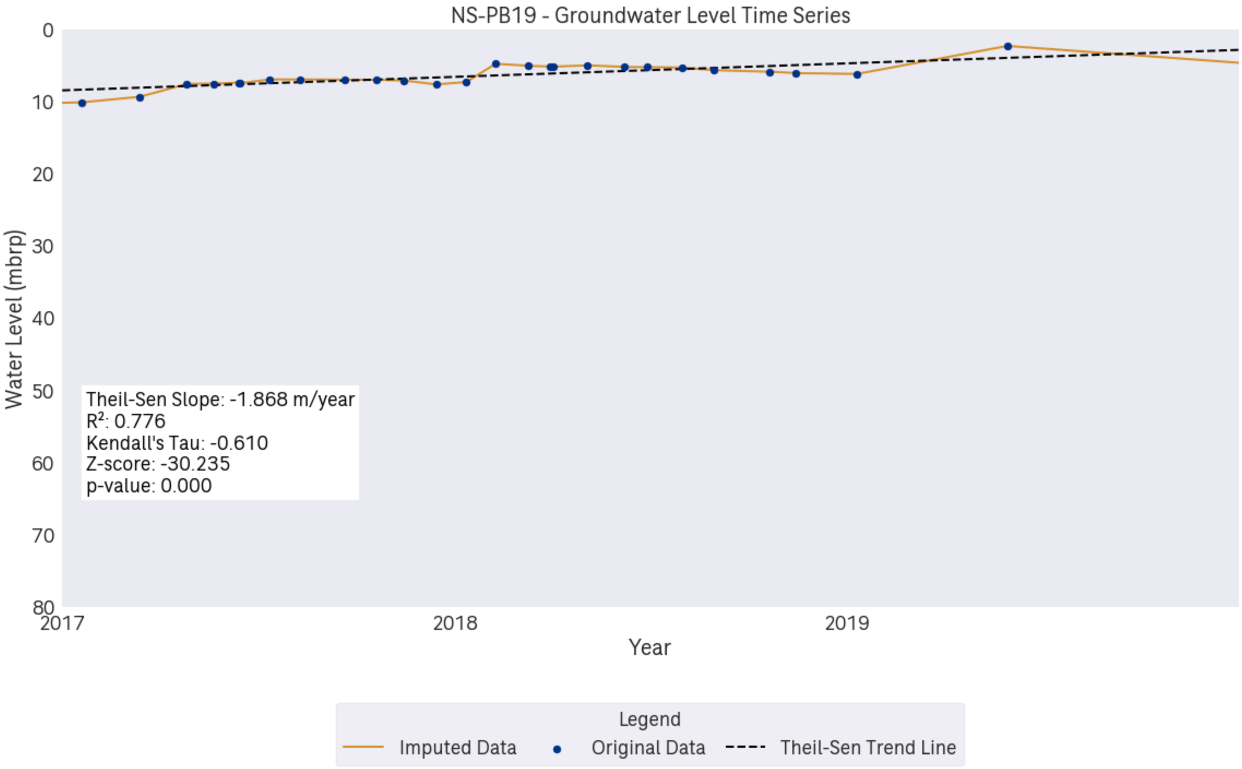
NS-ObsS29 - Groundwater Level Time Series

Theil-Sen Slope: 1.312 m/year
R^2: 0.855
Kendall's Tau: 0.802
Z-score: 49.259
p-value: 0.000



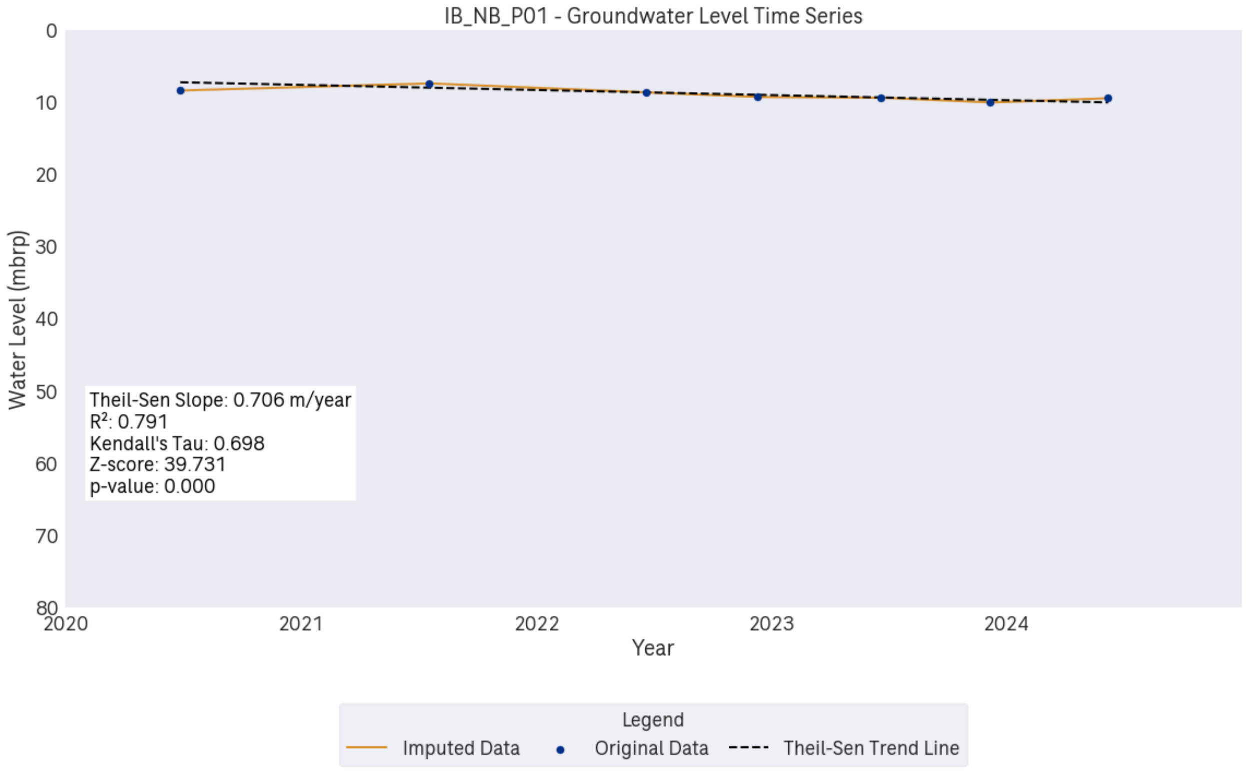
A.7 Northern Borefield

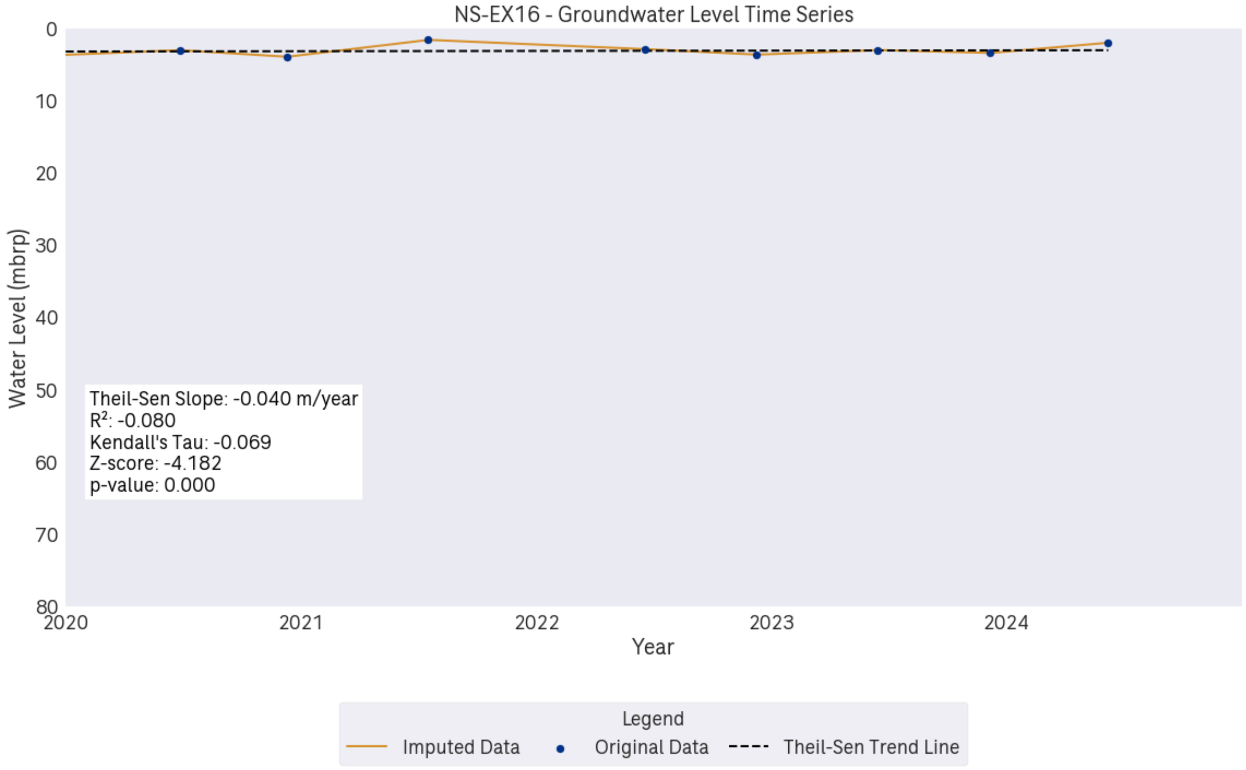
A.7.1 Baseline Period (2017 – 2020)

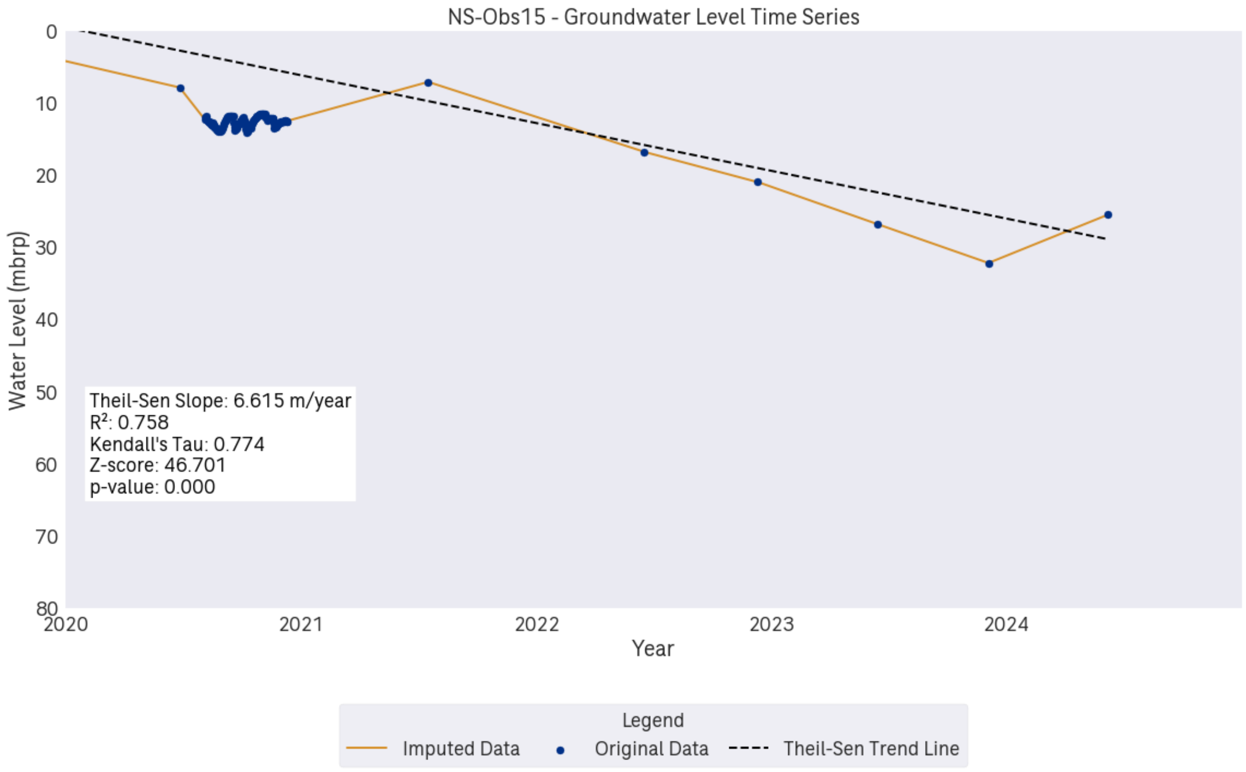


A.8 Northern Borefield

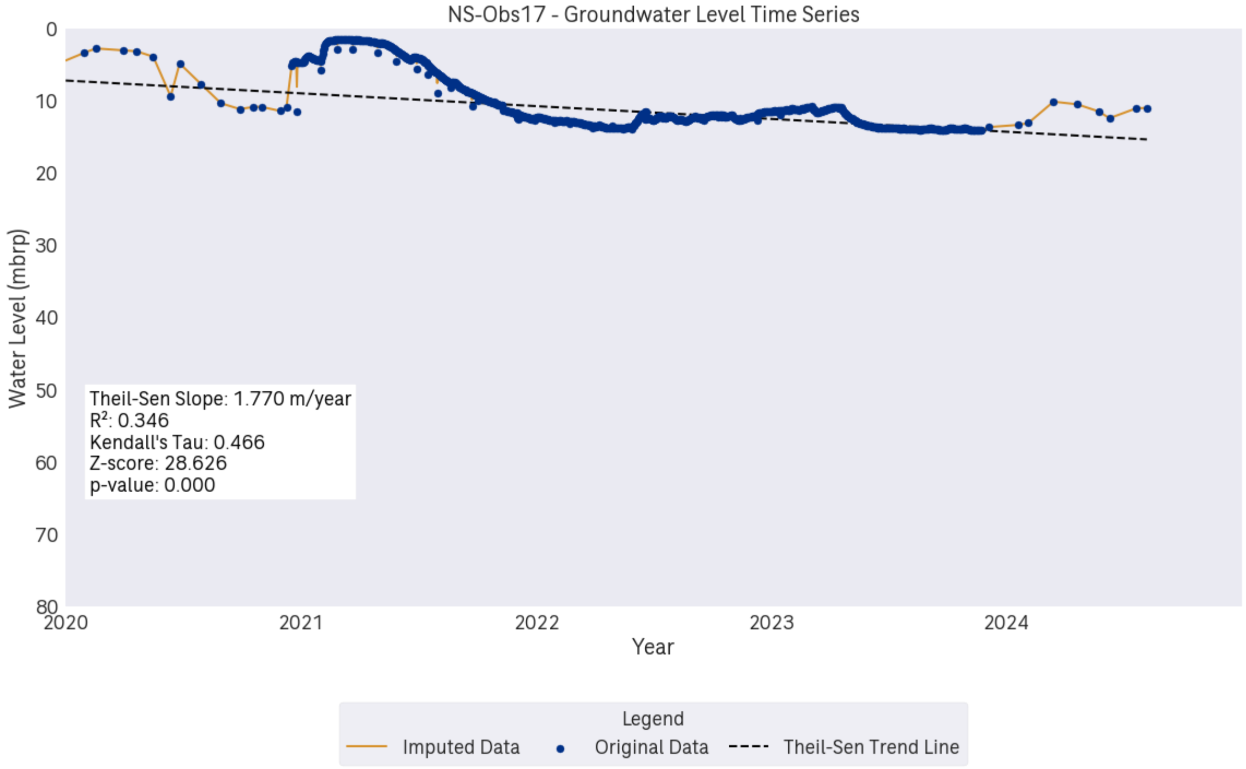
A.8.1 Impact Period (2020 – 2024)



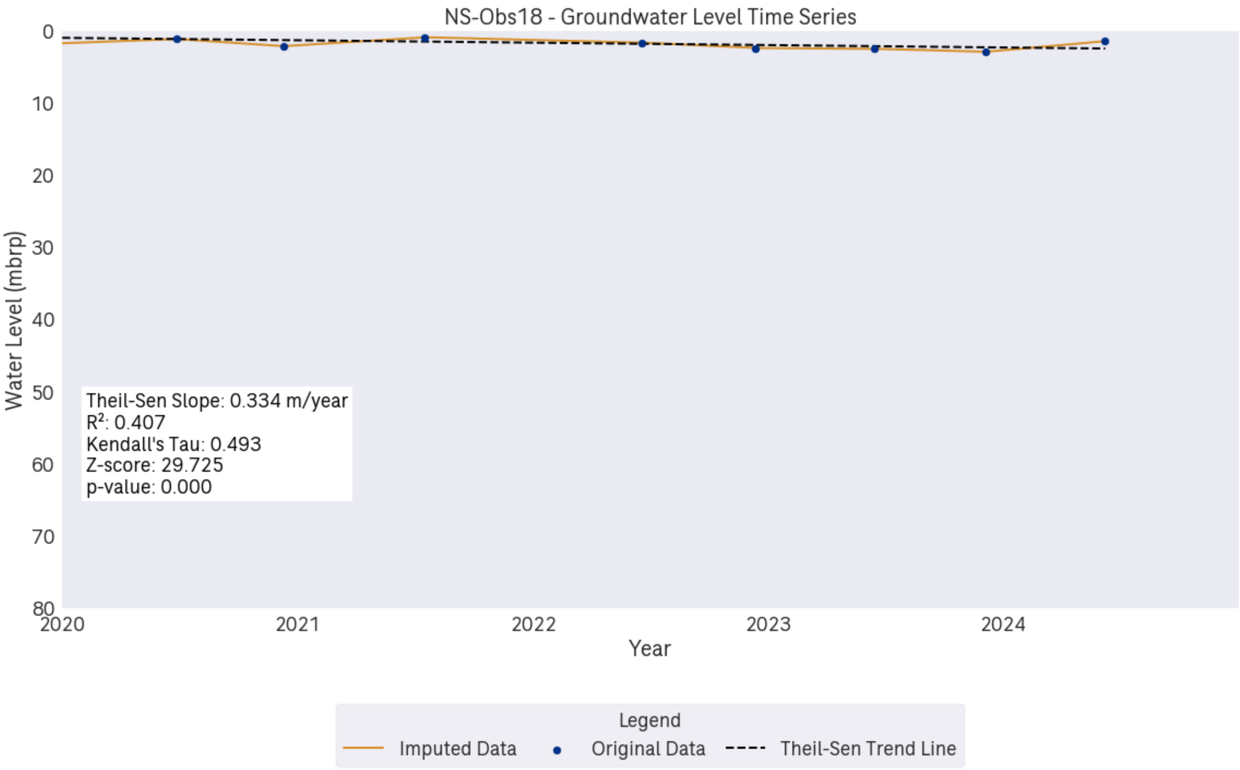


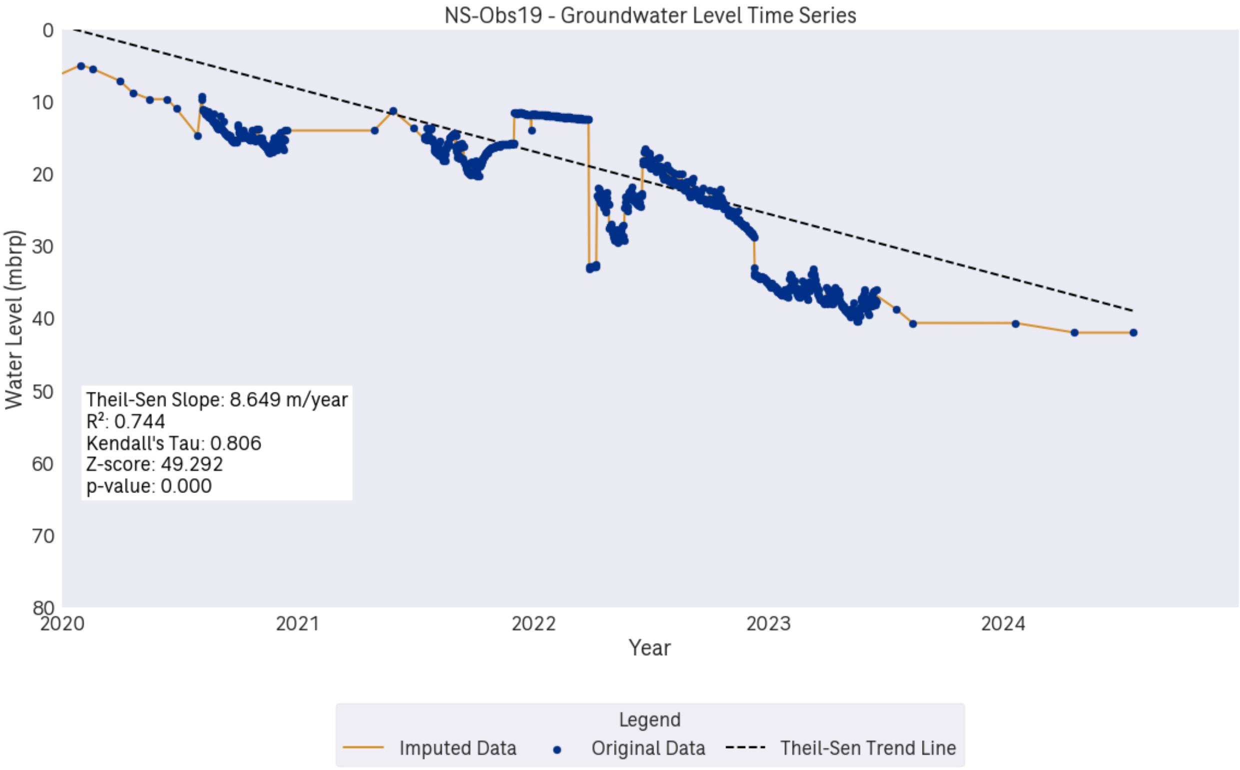


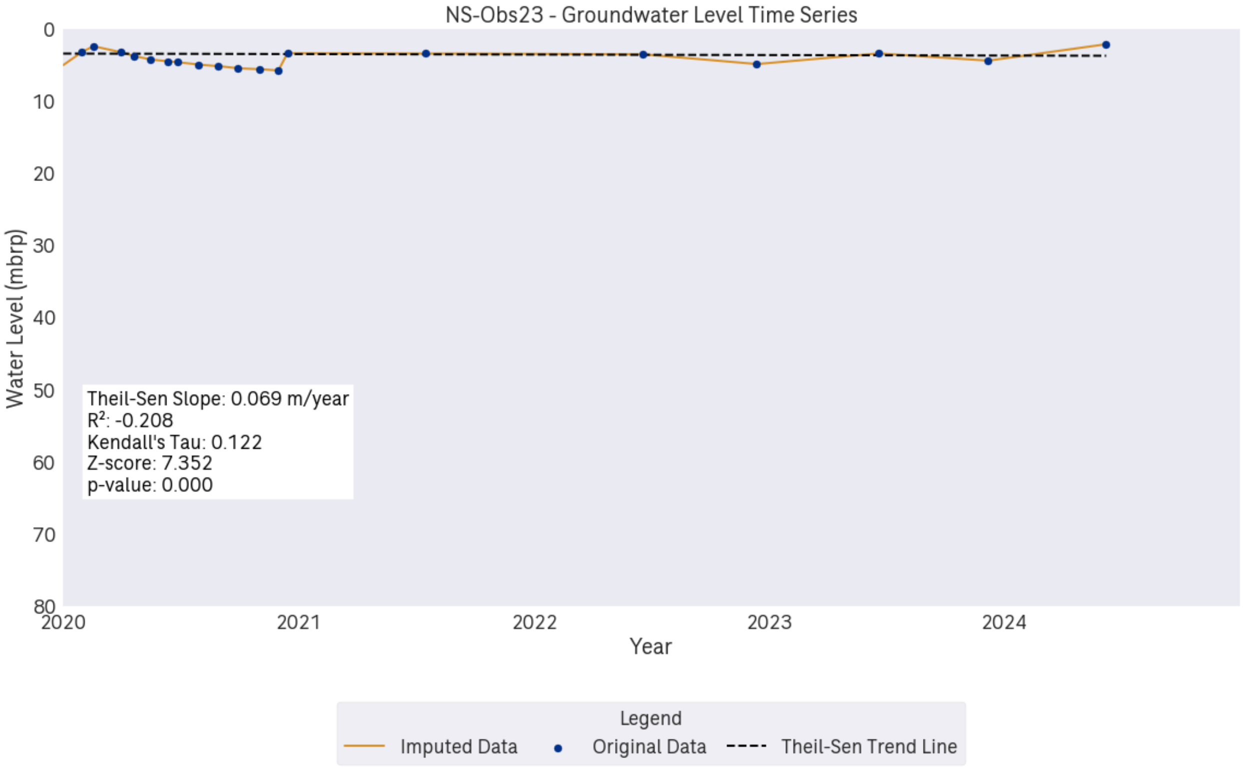
NS-Obs15 - Groundwater Level Time Series

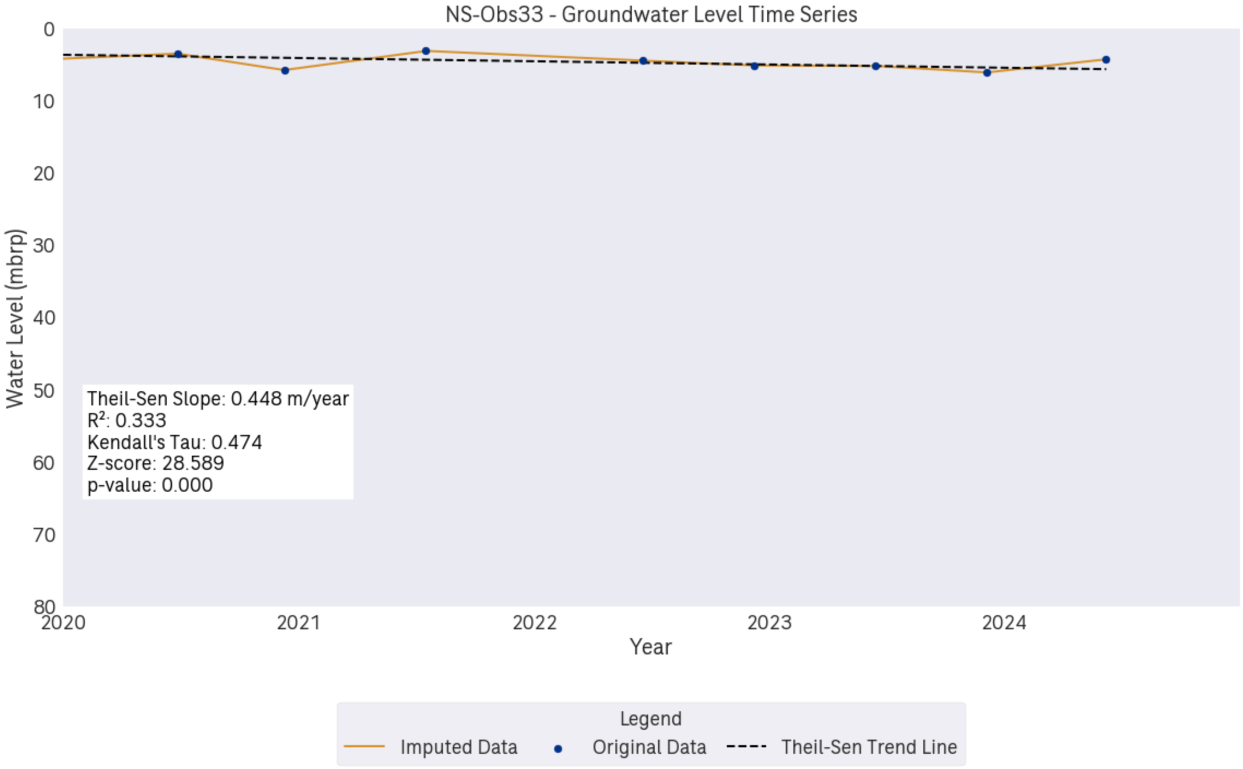


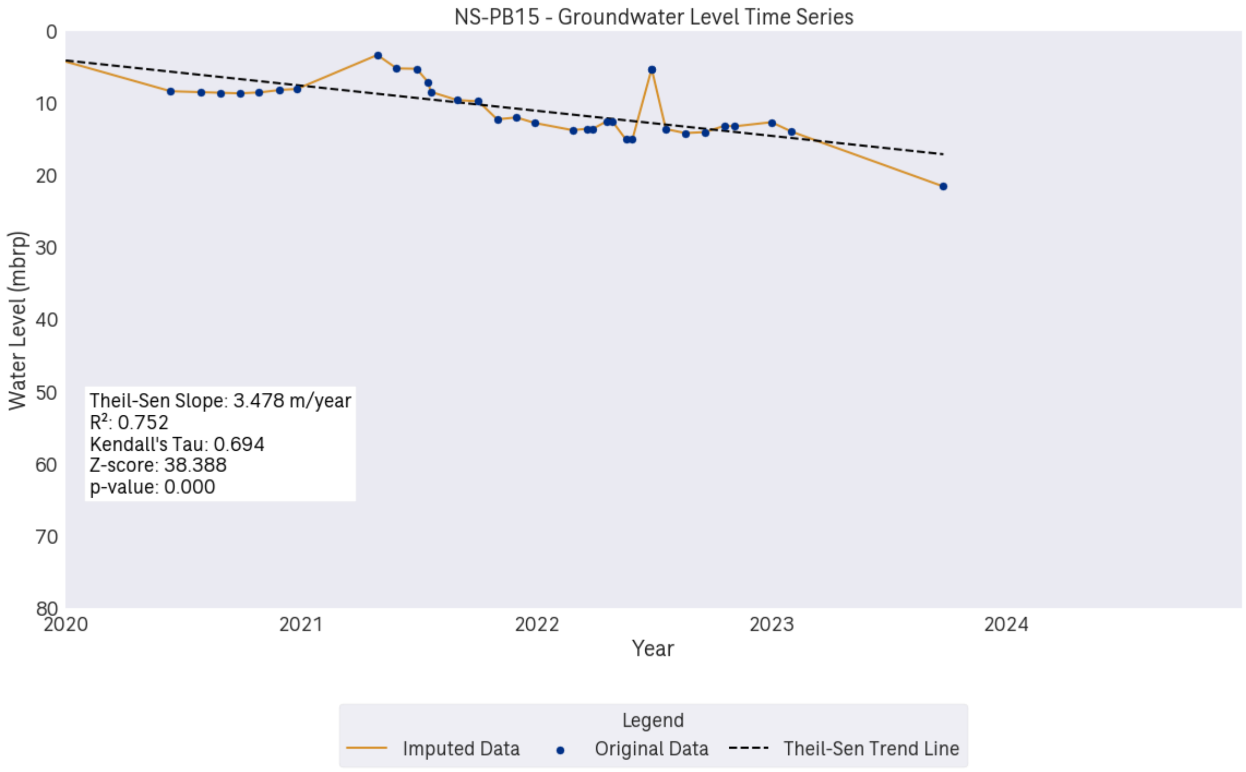
NS-Obs17 - Groundwater Level Time Series

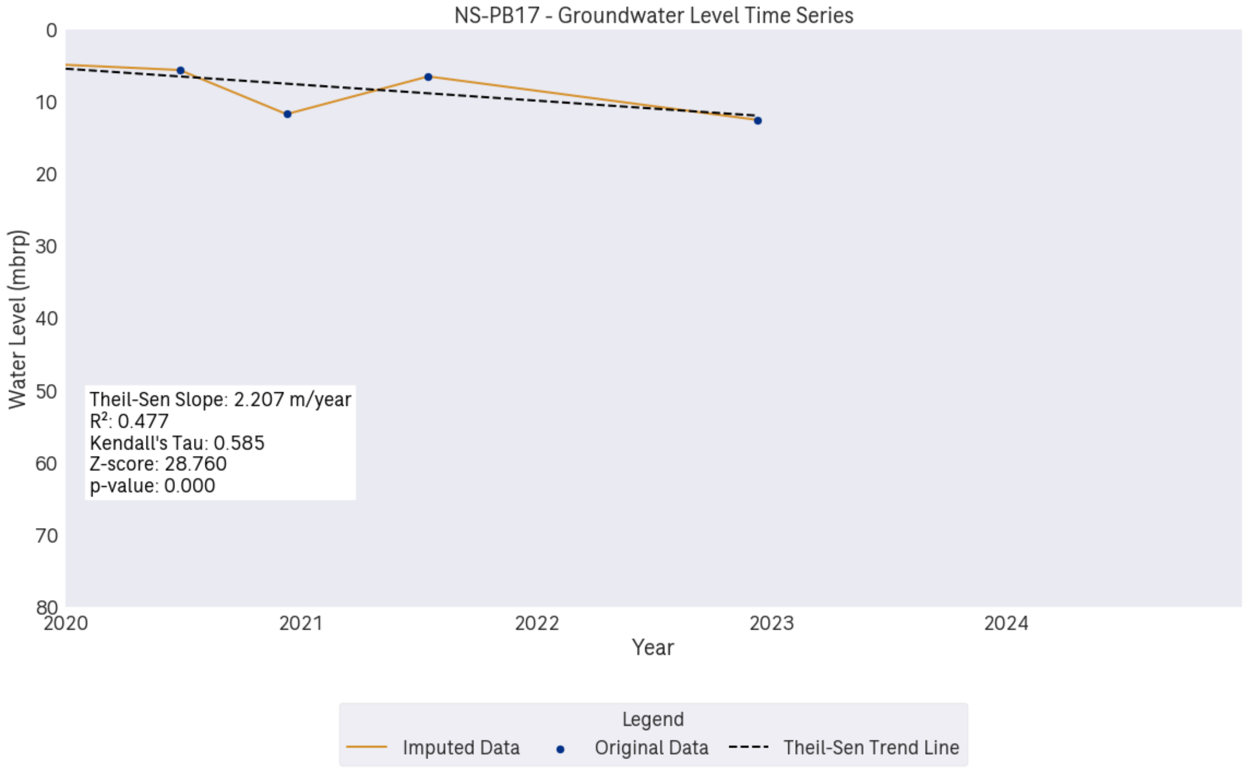

NS-Obs18 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2020
2021
2022
2023
2024
Year
Theil-Sen Slope: 0.334 m/year
R²: 0.407
Kendall's Tau: 0.493
Z-score: 29.725
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line

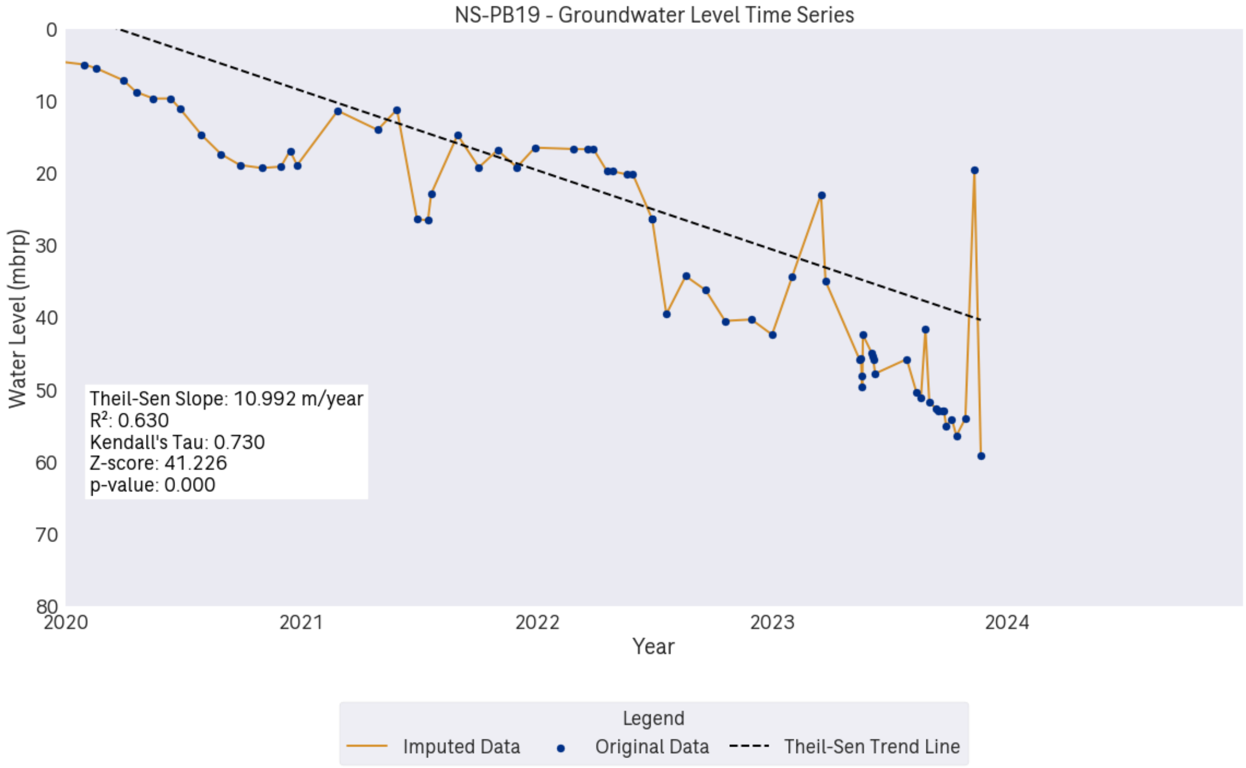

NS-Obs19 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2020
2021
2022
2023
2024
Year
Theil-Sen Slope: 8.649 m/year
R²: 0.744
Kendall's Tau: 0.806
Z-score: 49.292
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line

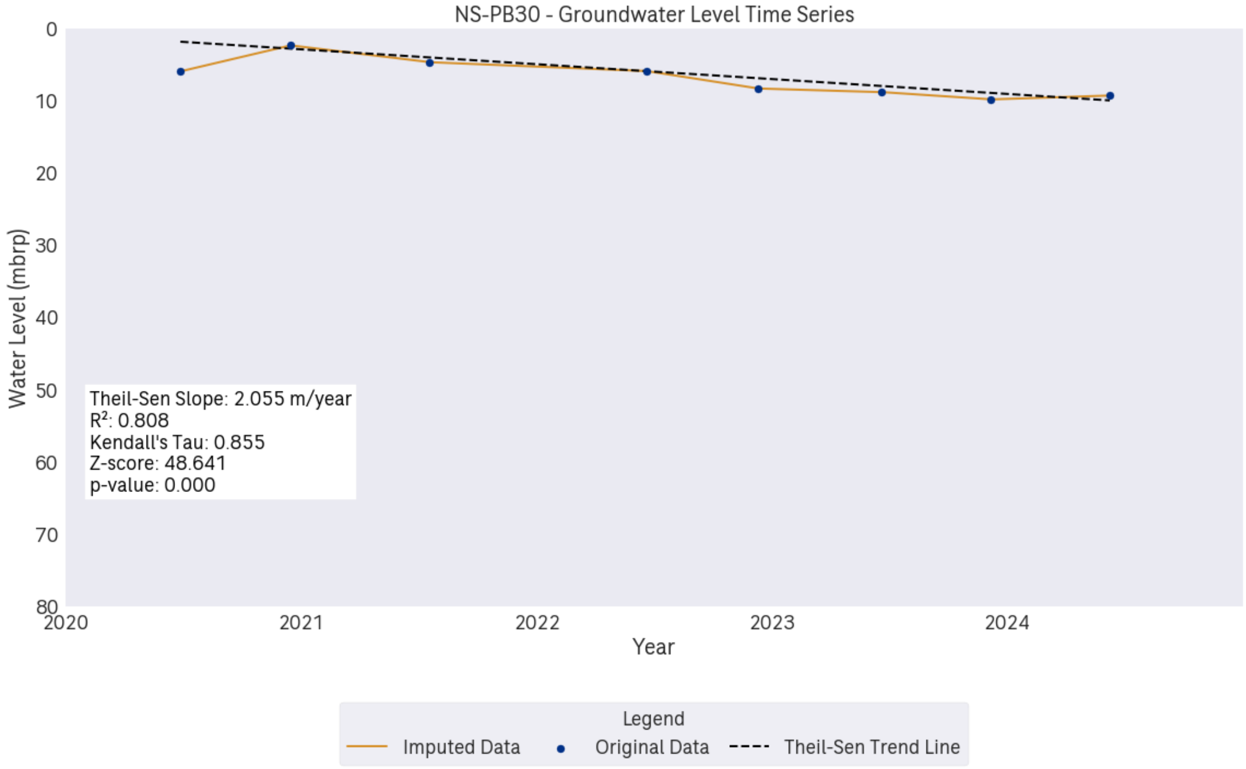

NS-Obs23 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2020
2021
2022
2023
2024
Year
Theil-Sen Slope: 0.069 m/year
R²: -0.208
Kendall's Tau: 0.122
Z-score: 7.352
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line

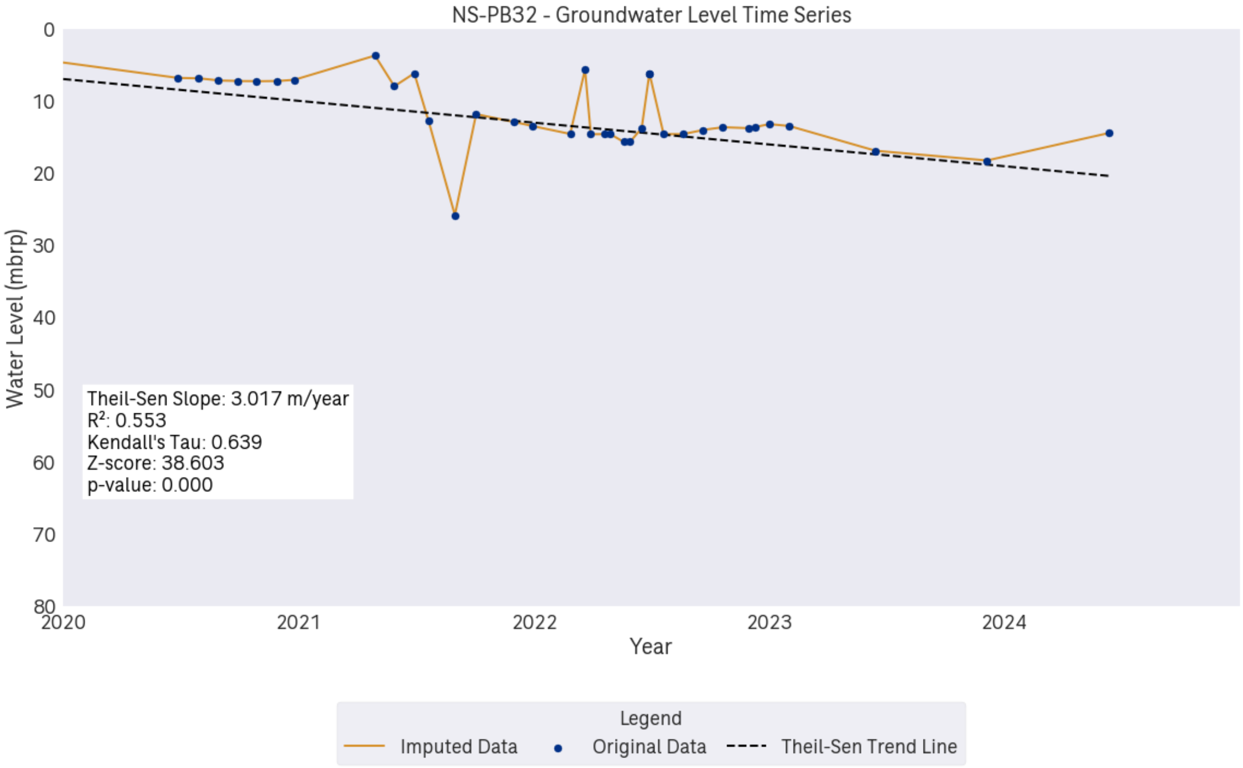

NS-Obs33 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2020
2021
2022
2023
2024
Year
Theil-Sen Slope: 0.448 m/year
R²: 0.333
Kendall's Tau: 0.474
Z-score: 28.589
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line

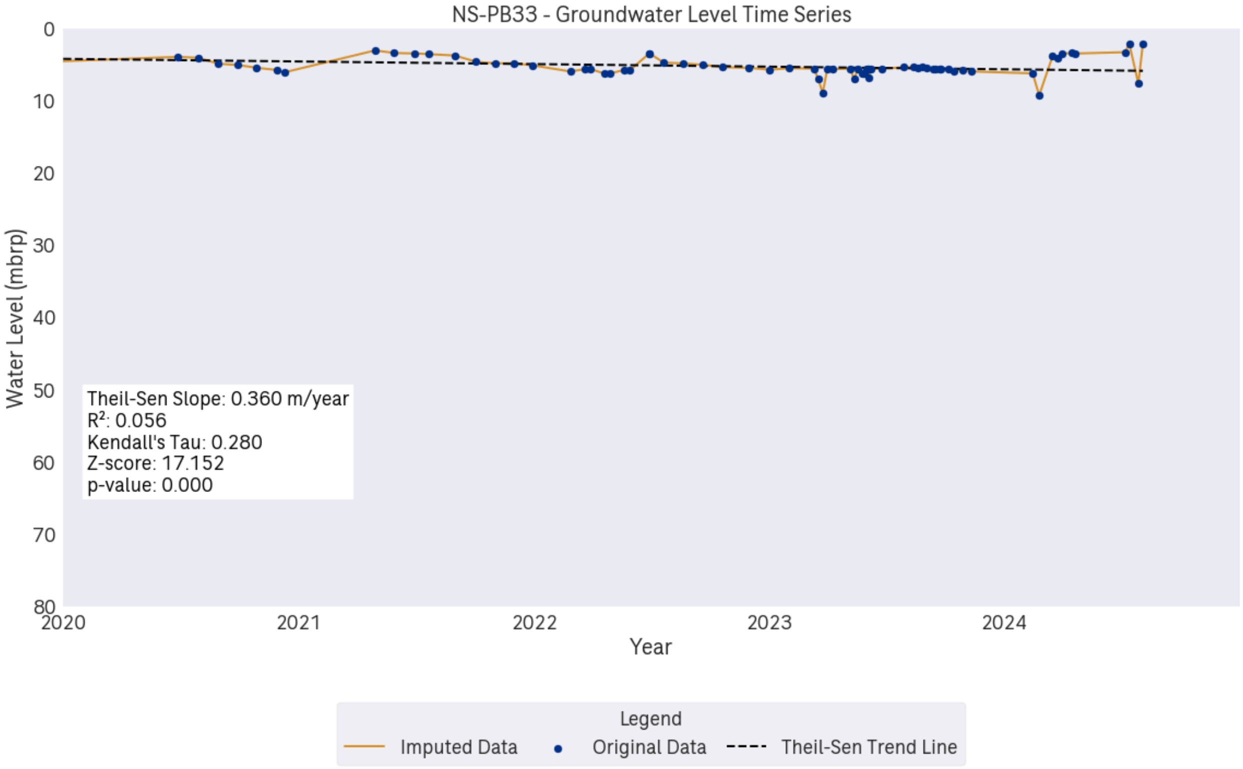

NS-PB15 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2020
2021
2022
2023
2024
Year
Theil-Sen Slope: 3.478 m/year
R²: 0.752
Kendall's Tau: 0.694
Z-score: 38.388
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line


NS-PB17 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2020
2021
2022
2023
2024
Year
Theil-Sen Slope: 2.207 m/year
R²: 0.477
Kendall's Tau: 0.585
Z-score: 28.760
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line


NS-PB19 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2020
2021
2022
2023
2024
Year
Theil-Sen Slope: 10.992 m/year
R²: 0.630
Kendall's Tau: 0.730
Z-score: 41.226
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line

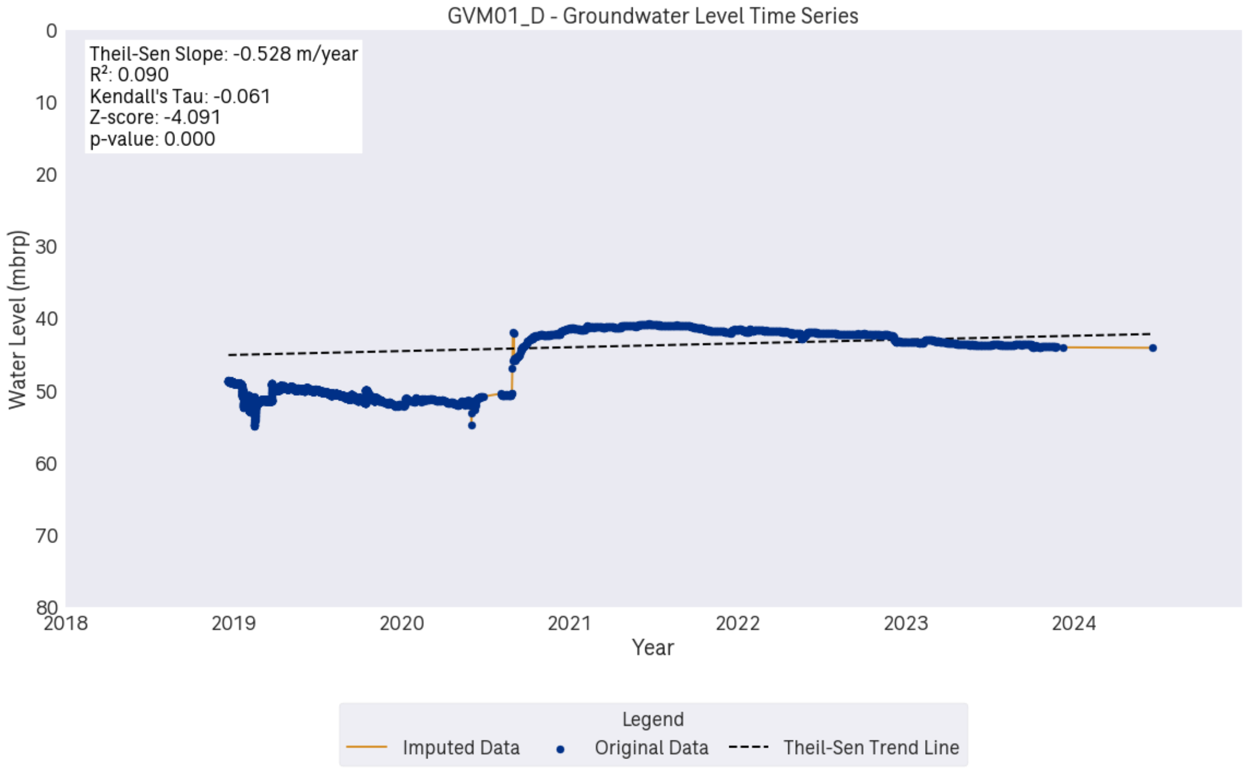

NS-PB30 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2020
2021
2022
2023
2024
Year
Theil-Sen Slope: 2.055 m/year
R²: 0.808
Kendall's Tau: 0.855
Z-score: 48.641
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line

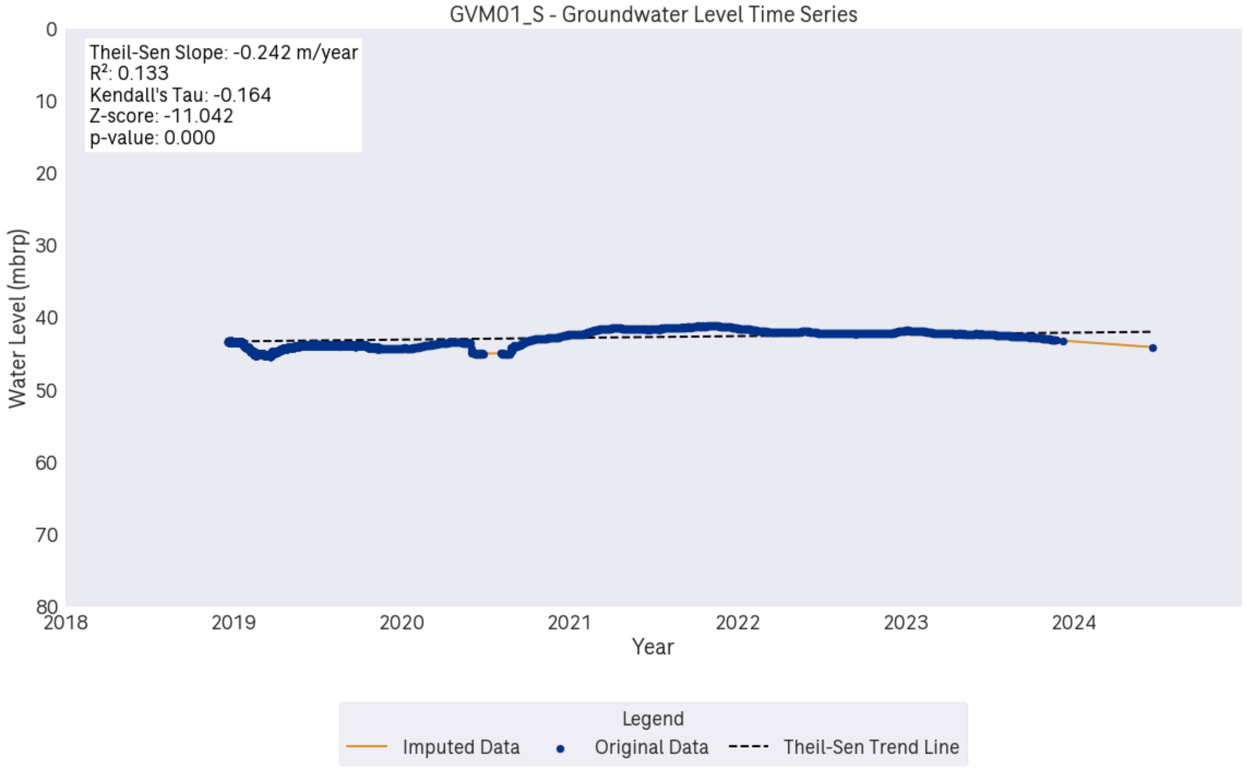

NS-PB32 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2020
2021
2022
2023
2024
Year
Theil-Sen Slope: 3.017 m/year
R²: 0.553
Kendall's Tau: 0.639
Z-score: 38.603
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line

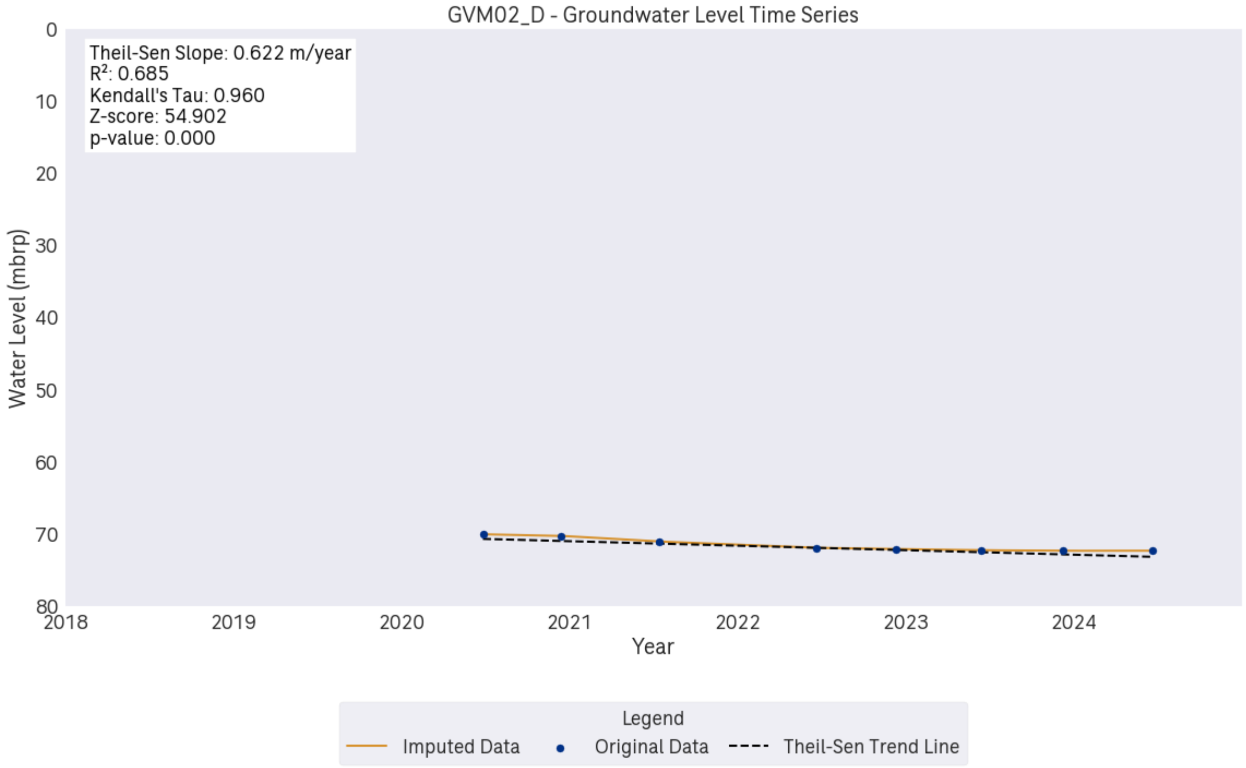

NS-PB33 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2020
2021
2022
2023
2024
Year
Theil-Sen Slope: 0.360 m/year
R²: 0.056
Kendall's Tau: 0.280
Z-score: 17.152
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line

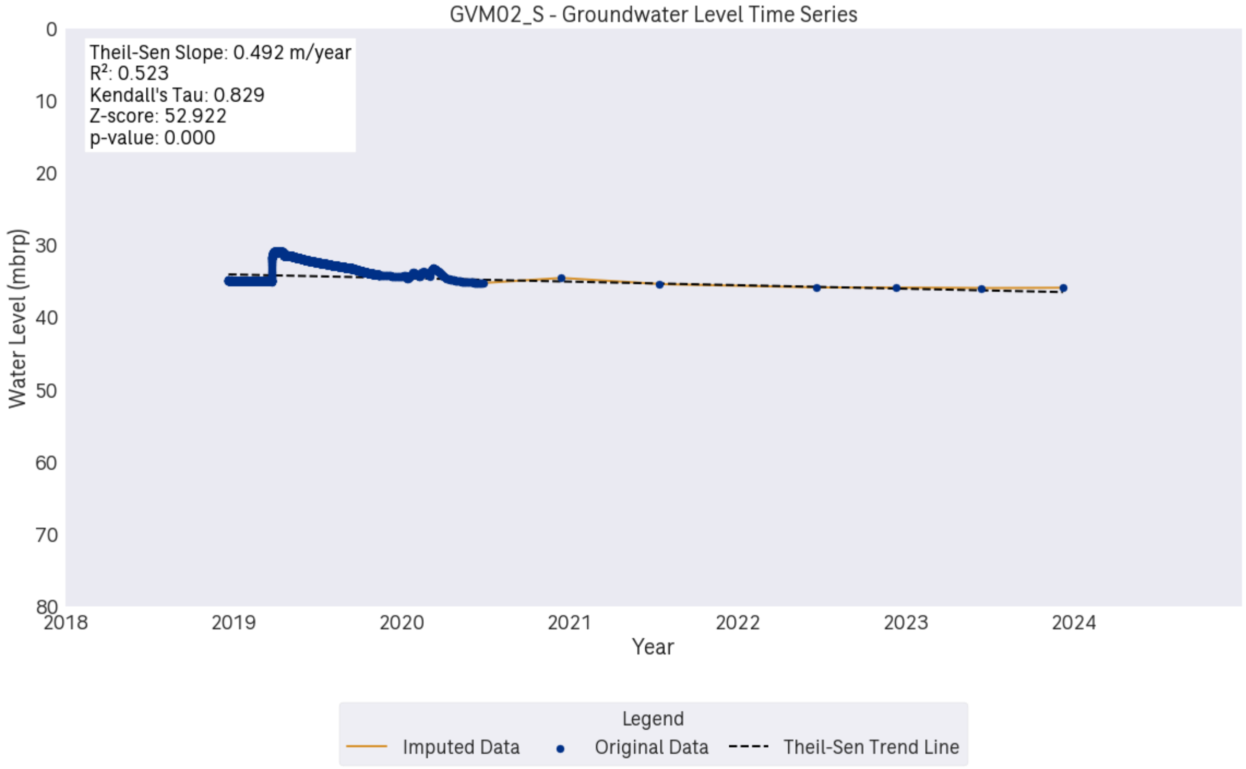
A.9 Glacier Valley Pit Area

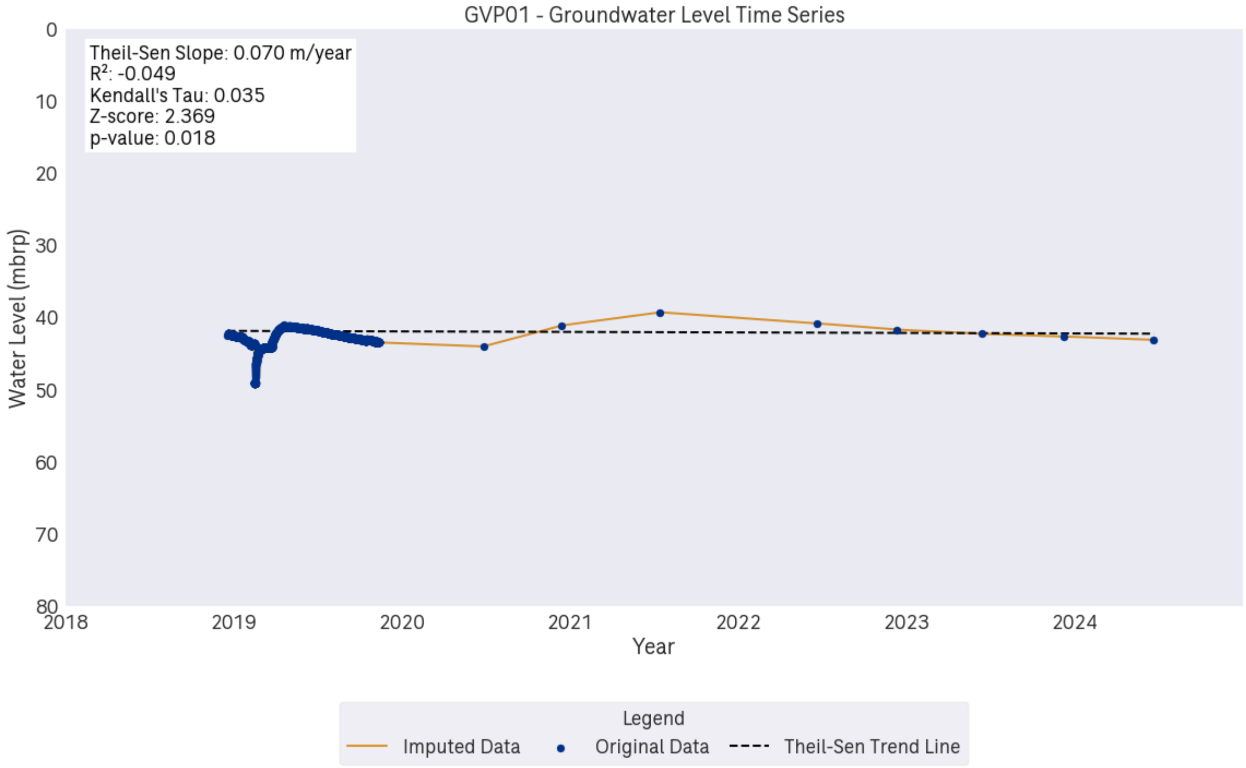
A.9.1 Baseline Period (2018 – 2024)

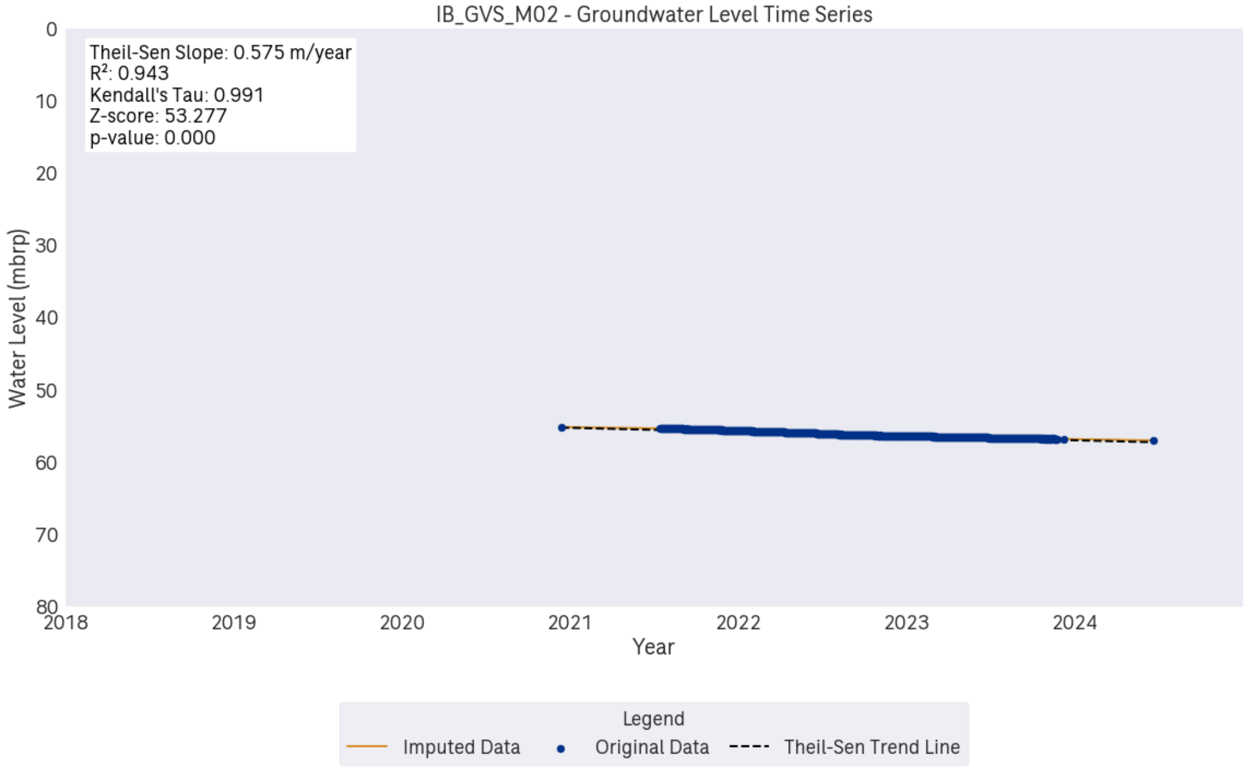





GVM02_D - Groundwater Level Time Series
Theil-Sen Slope: 0.622 m/year
R^2: 0.685
Kendall's Tau: 0.960
Z-score: 54.902
p-value: 0.000
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2018
2019
2020
2021
2022
2023
2024
Year
Legend
Imputed Data
Original Data
Theil-Sen Trend Line

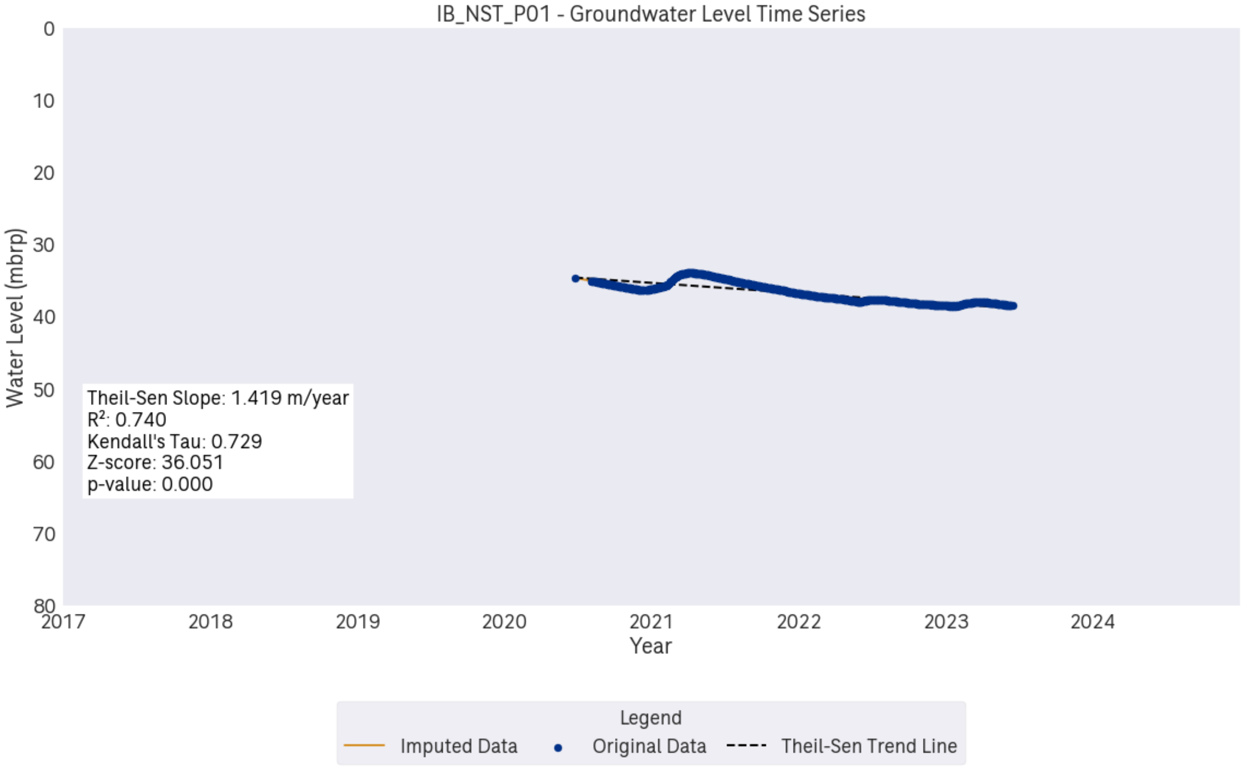

GVM02_S - Groundwater Level Time Series
Theil-Sen Slope: 0.492 m/year
R^2: 0.523
Kendall's Tau: 0.829
Z-score: 52.922
p-value: 0.000
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2018
2019
2020
2021
2022
2023
2024
Year
Legend
Imputed Data
Original Data
Theil-Sen Trend Line

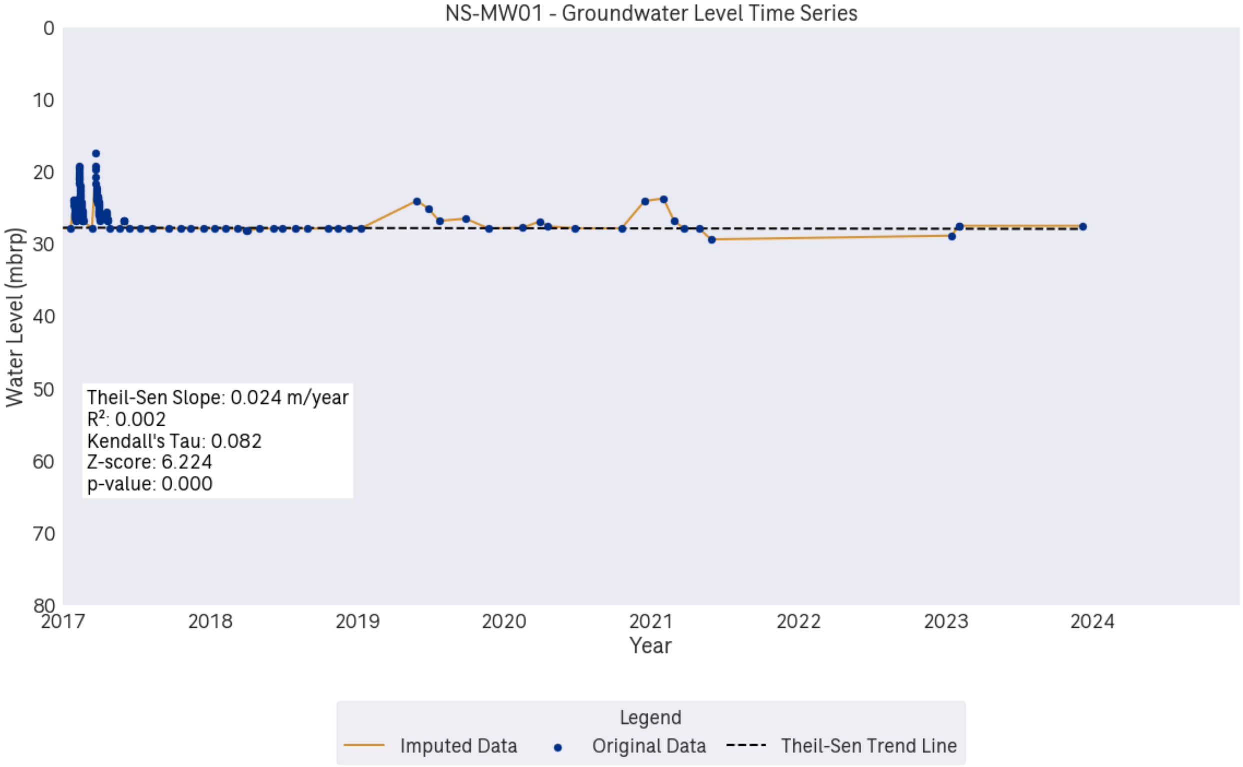

GVP01 - Groundwater Level Time Series
Theil-Sen Slope: 0.070 m/year
R²: -0.049
Kendall's Tau: 0.035
Z-score: 2.369
p-value: 0.018
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2018
2019
2020
2021
2022
2023
2024
Year
Legend
Imputed Data
Original Data
Theil-Sen Trend Line

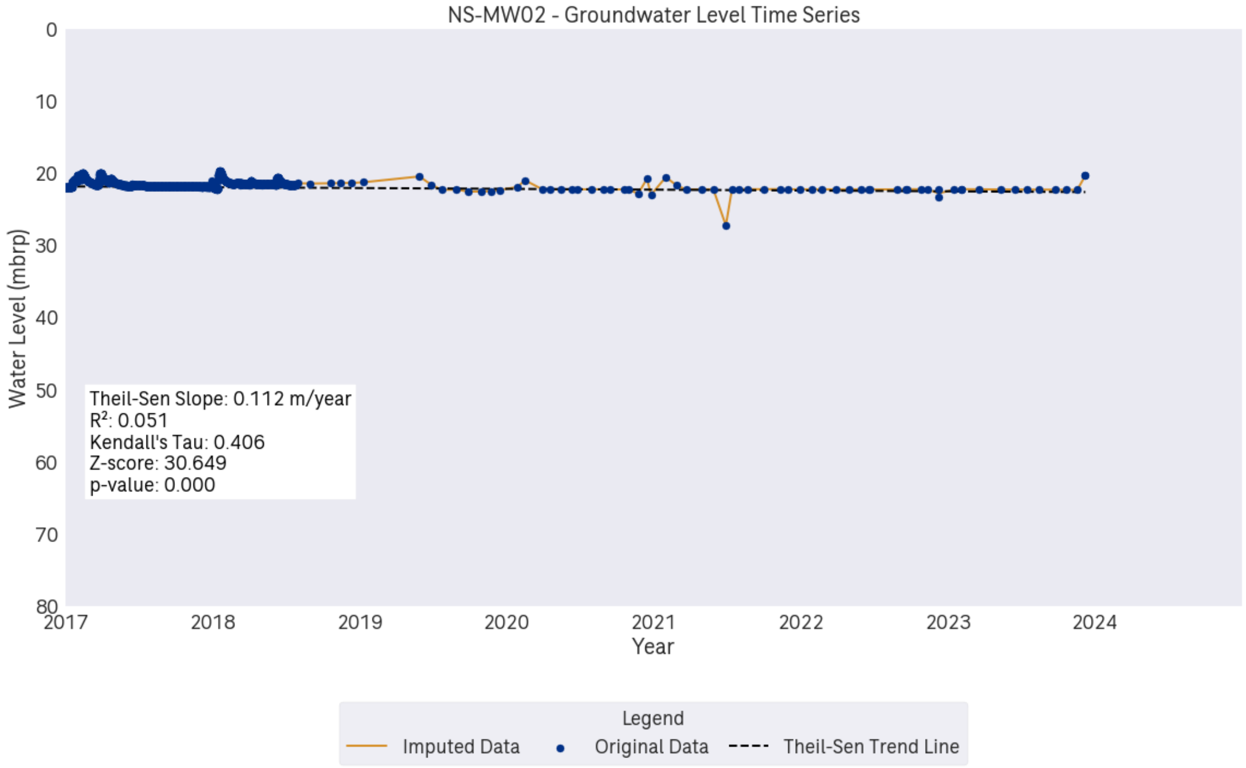

IB_GVS_M02 - Groundwater Level Time Series
Theil-Sen Slope: 0.575 m/year
R²: 0.943
Kendall's Tau: 0.991
Z-score: 53.277
p-value: 0.000
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2018
2019
2020
2021
2022
2023
2024
Year
Legend
Imputed Data
Original Data
Theil-Sen Trend Line

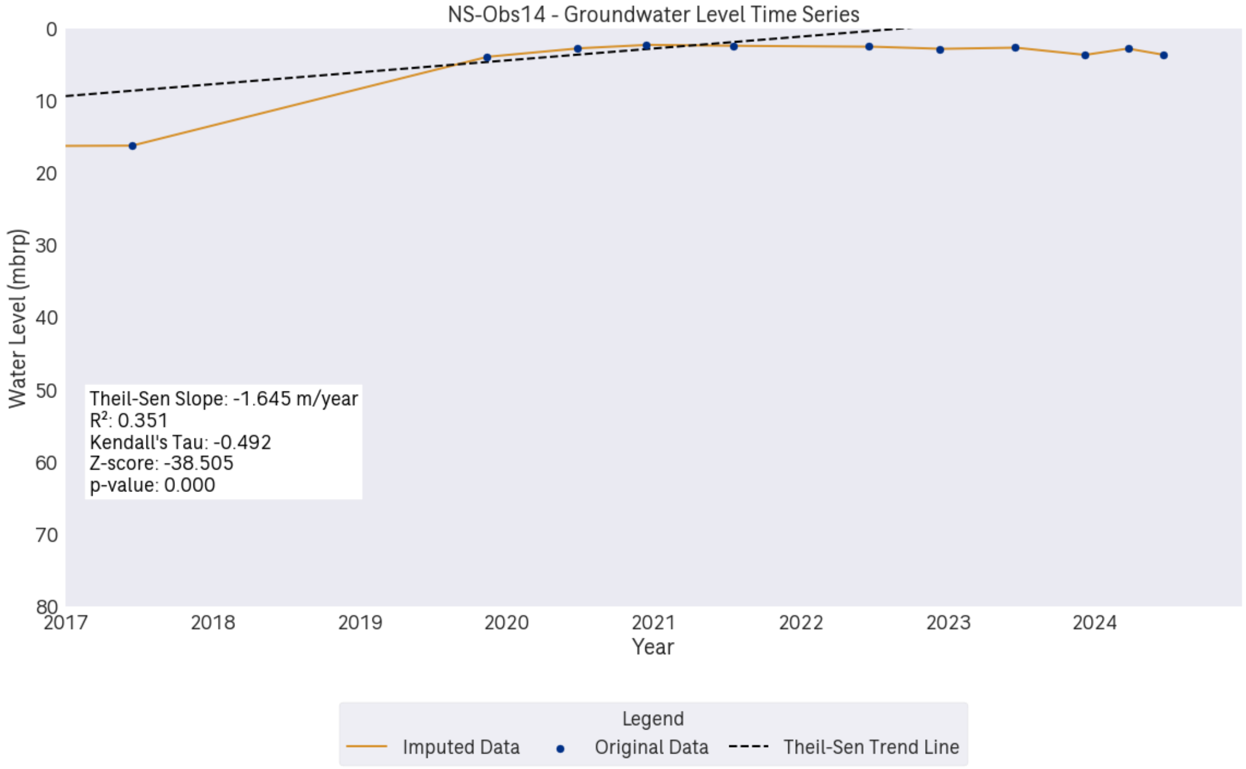
A.10 North Star Pit Area

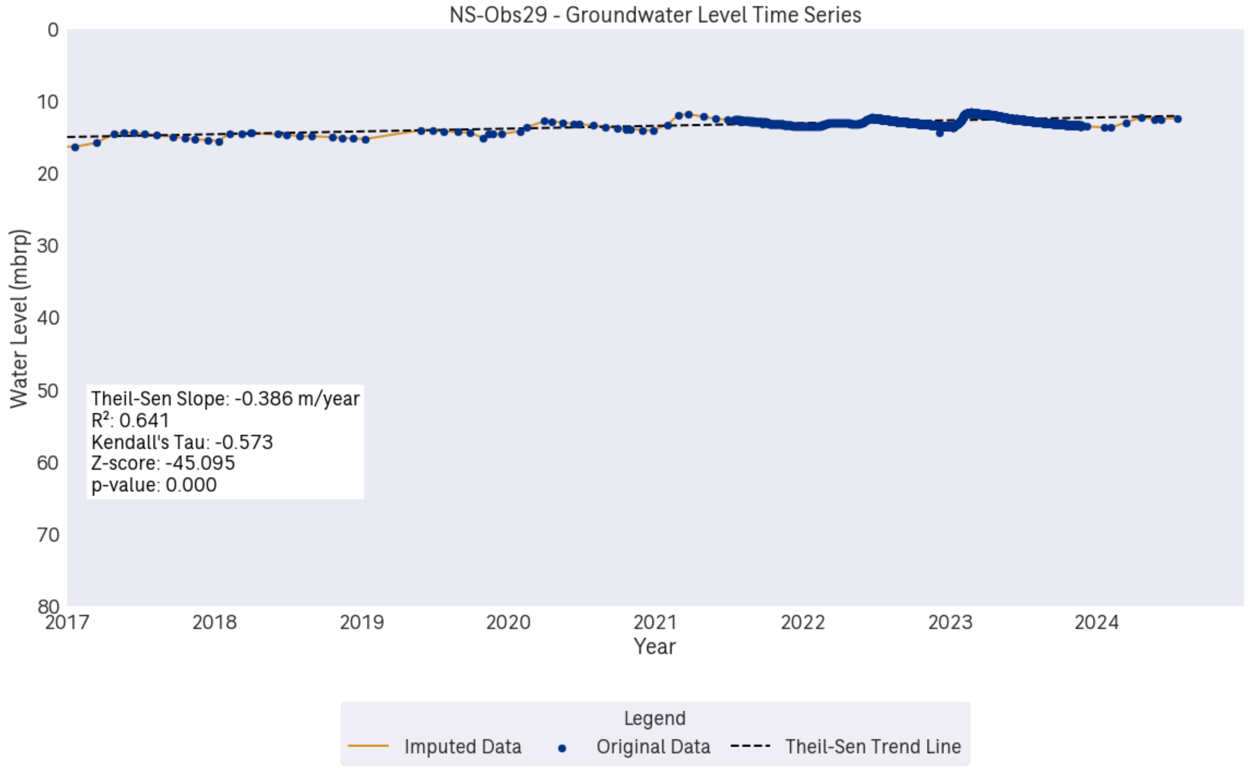
A.10.1 Baseline Period (2017 – 2024)





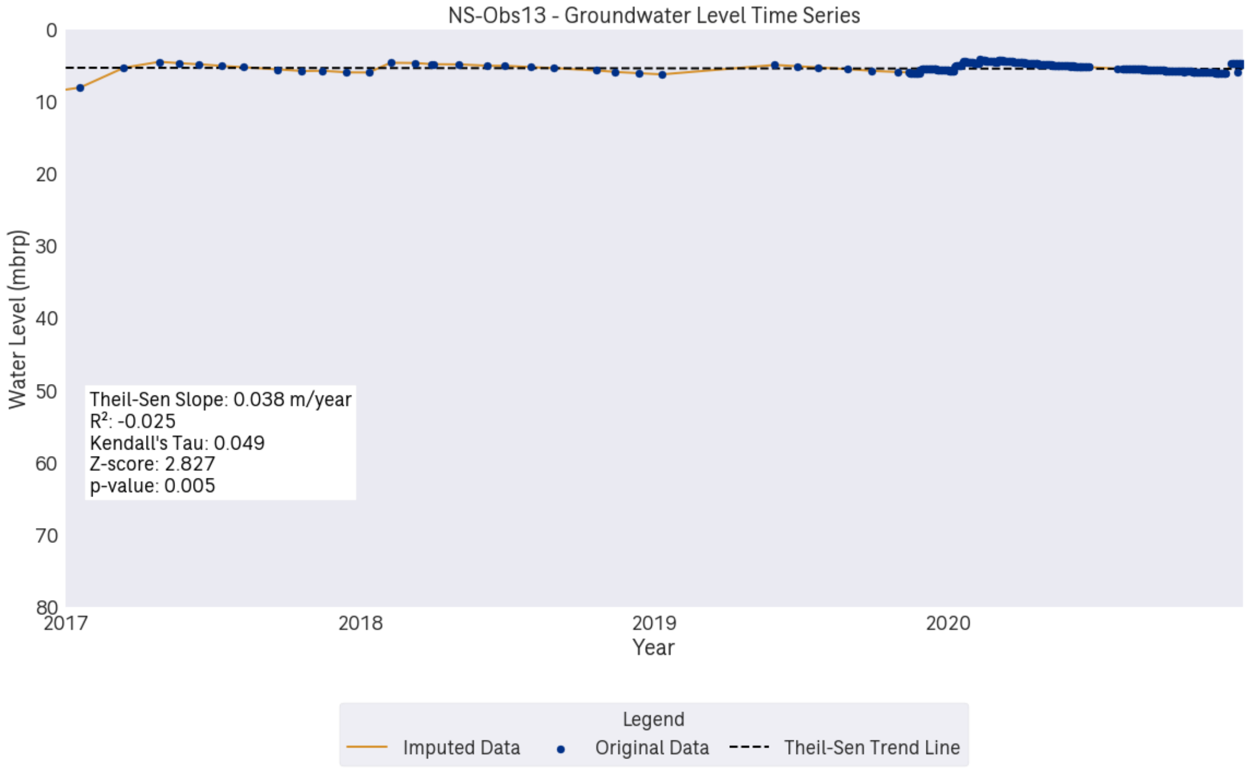

NS-MW02 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
Theil-Sen Slope: 0.112 m/year
R²: 0.051
Kendall's Tau: 0.406
Z-score: 30.649
p-value: 0.000
2017
2018
2019
2020
2021
2022
2023
2024
Year
Legend
Imputed Data
Original Data
Theil-Sen Trend Line

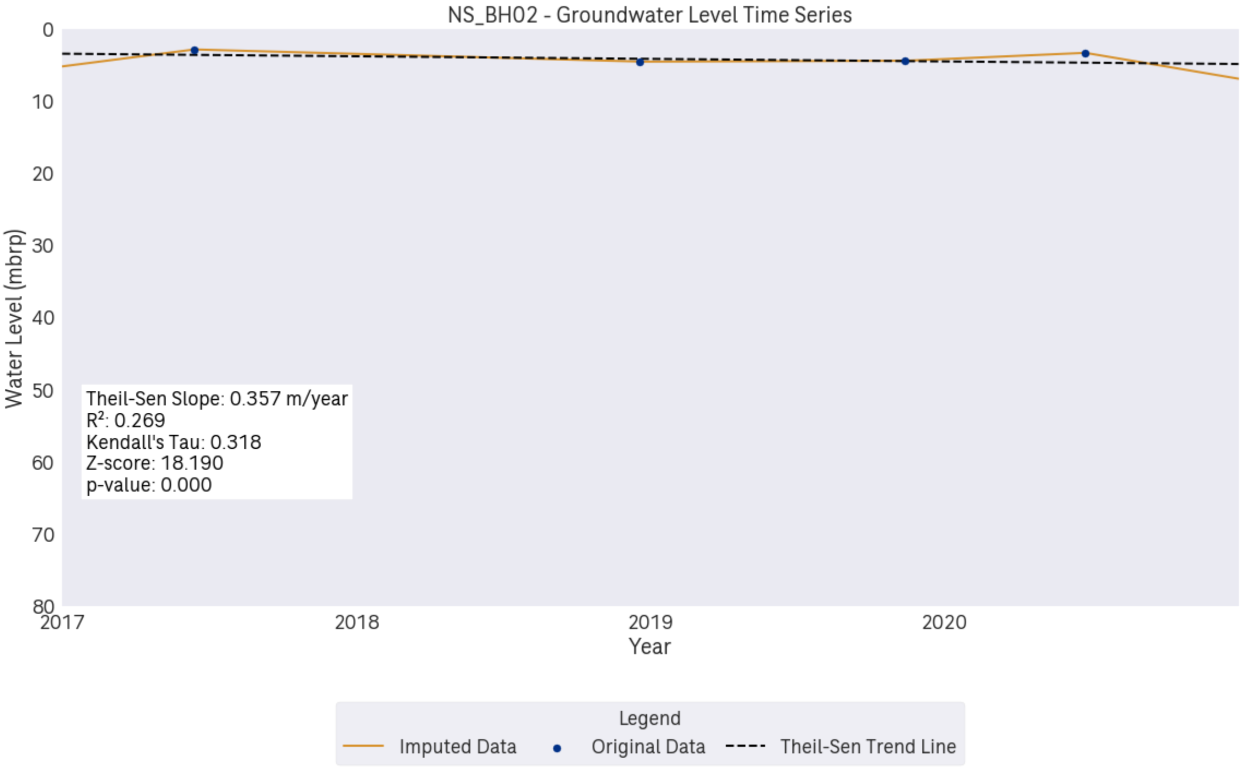

NS-Obs14 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
Theil-Sen Slope: -1.645 m/year
R²: 0.351
Kendall's Tau: -0.492
Z-score: -38.505
p-value: 0.000
2017
2018
2019
2020
2021
2022
2023
2024
Year
Legend
Imputed Data
Original Data
Theil-Sen Trend Line

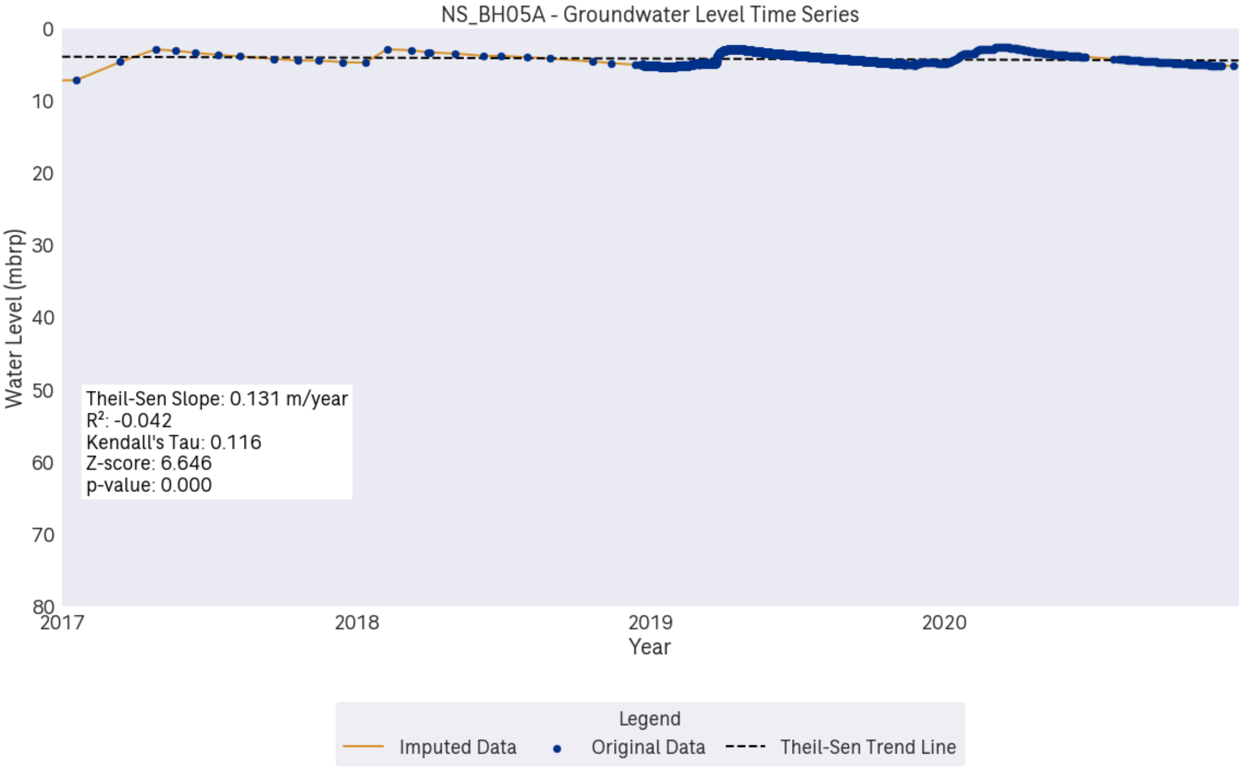


A.11 TSF and RWP Area

A.11.1 Baseline Period (2017 – 2021)

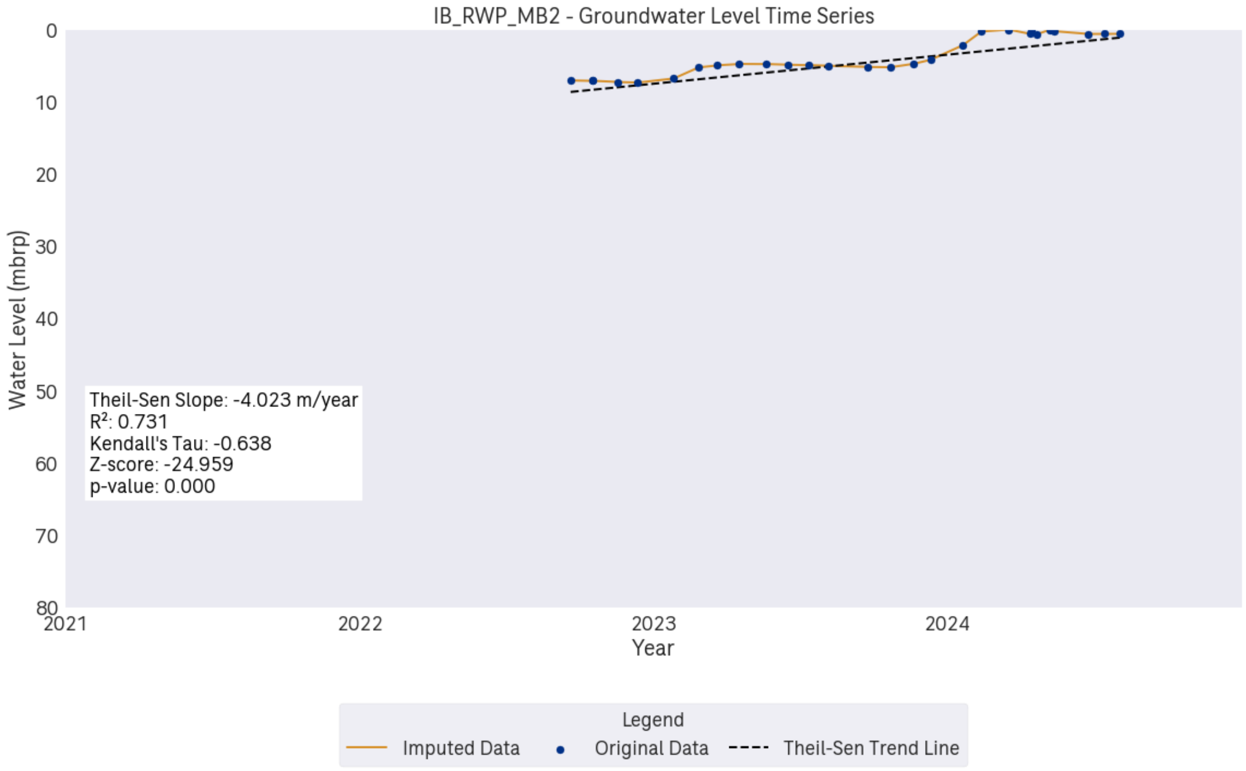


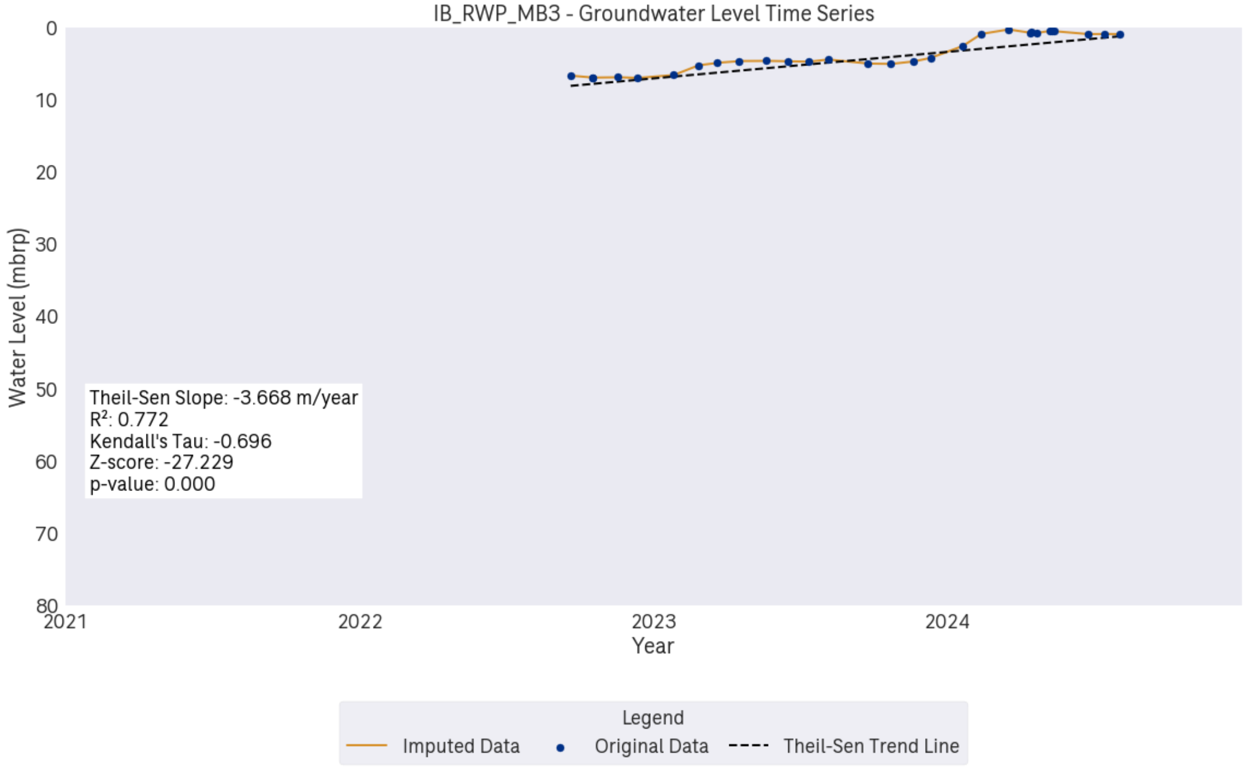

NS_BH02 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2017
2018
2019
2020
Year
Theil-Sen Slope: 0.357 m/year
R²: 0.269
Kendall's Tau: 0.318
Z-score: 18.190
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line

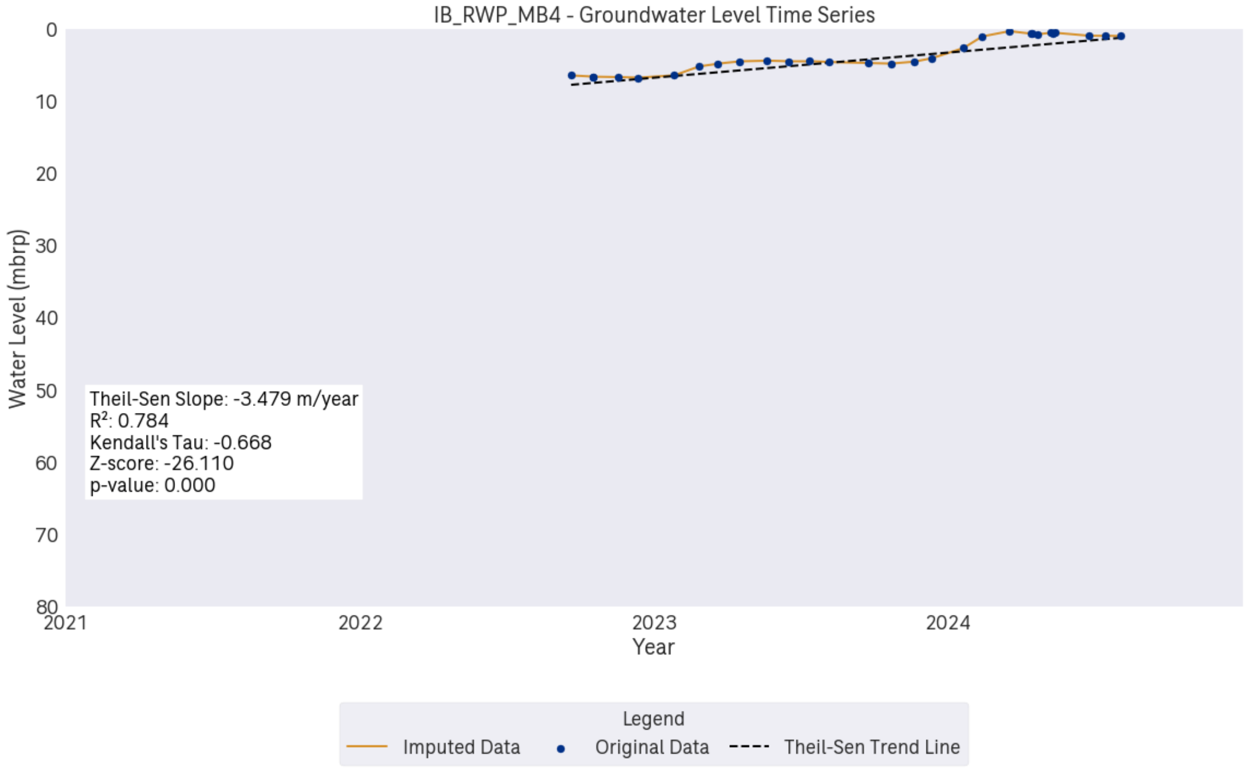

NS_BH05A - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2017
2018
2019
2020
Year
Theil-Sen Slope: 0.131 m/year
R²: -0.042
Kendall's Tau: 0.116
Z-score: 6.646
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line

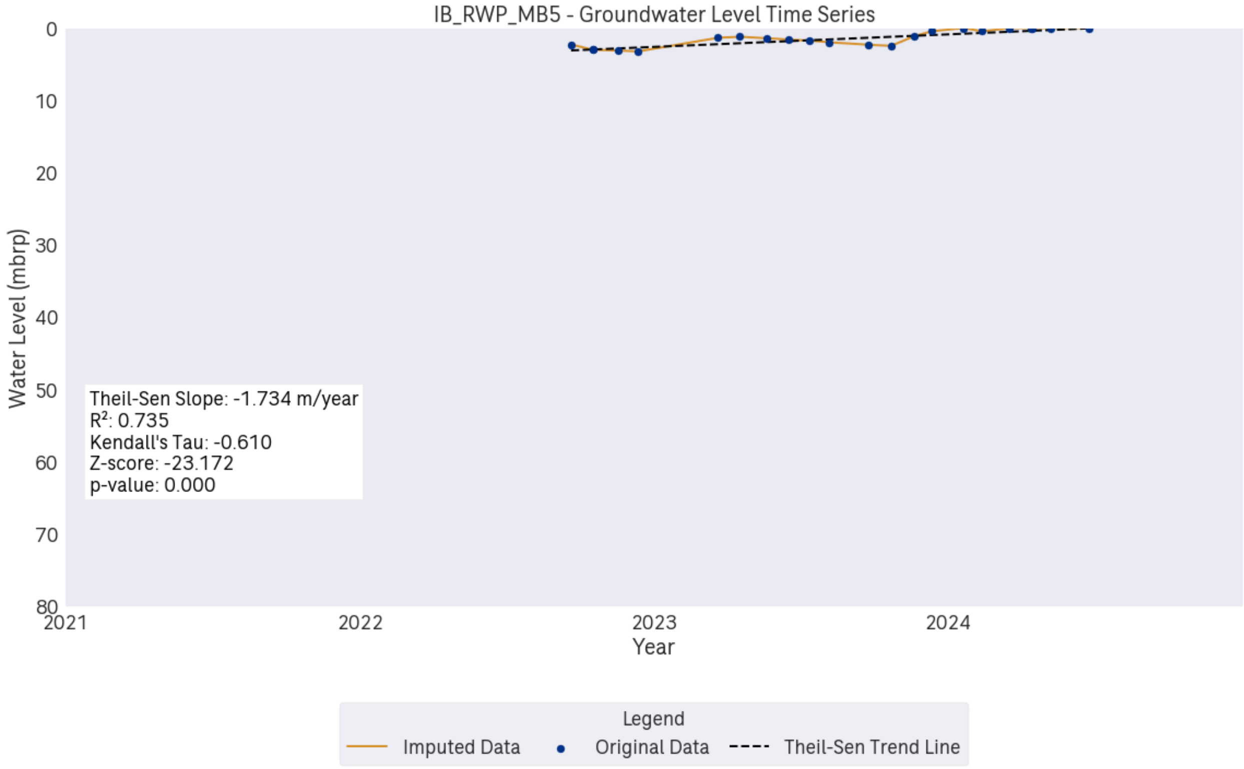
A.12 TSF and RWP Area

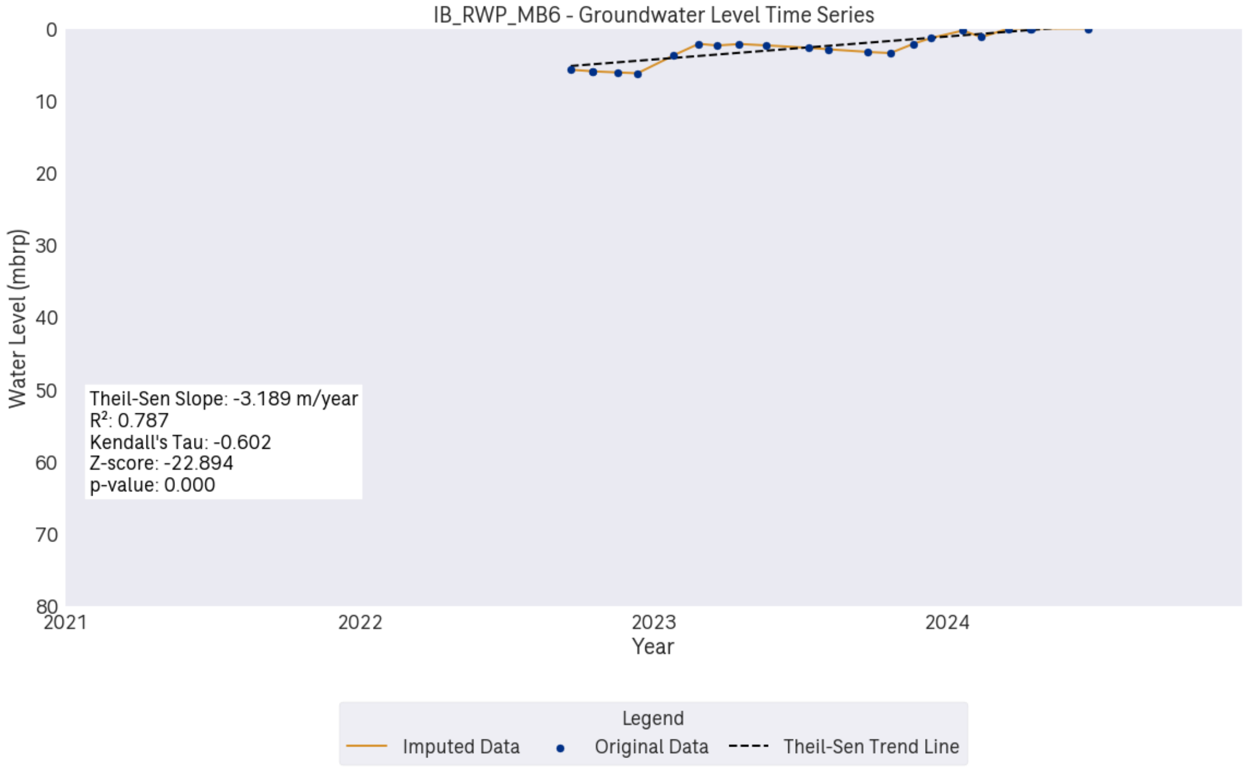
A.12.1 Impact Period (2021 – 2024)

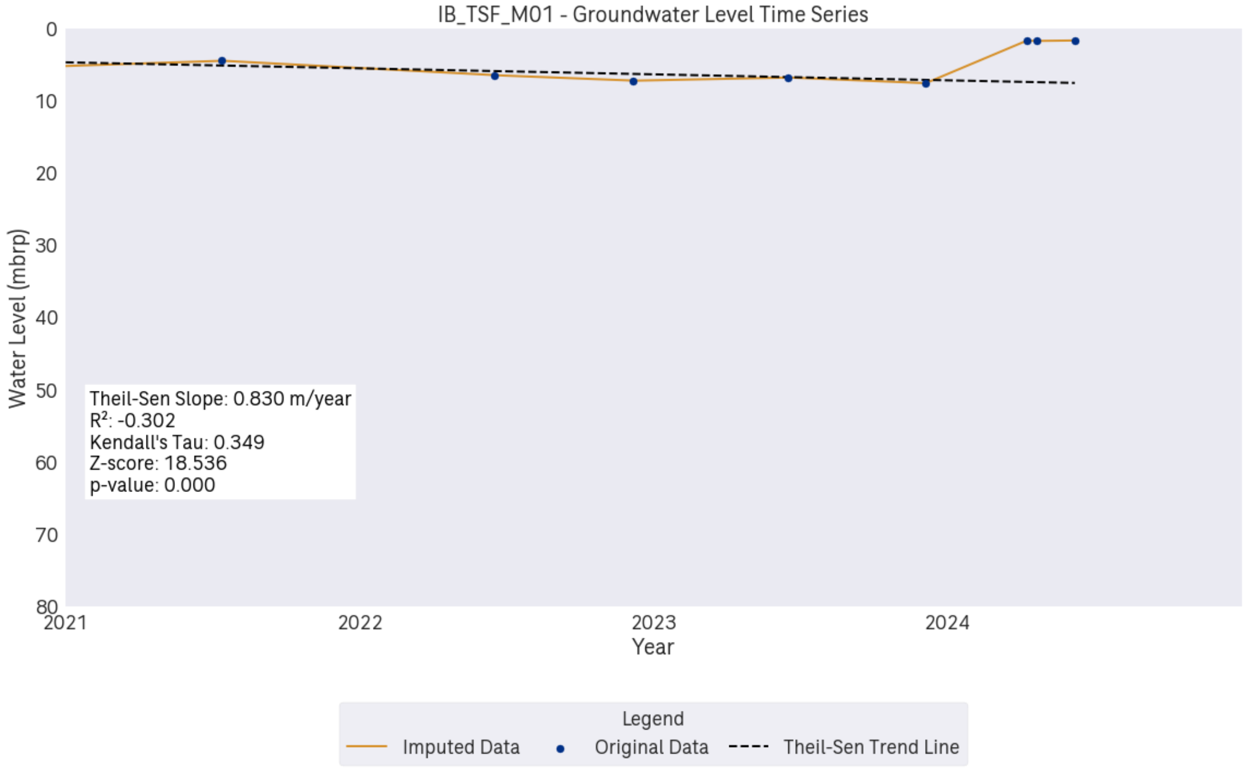


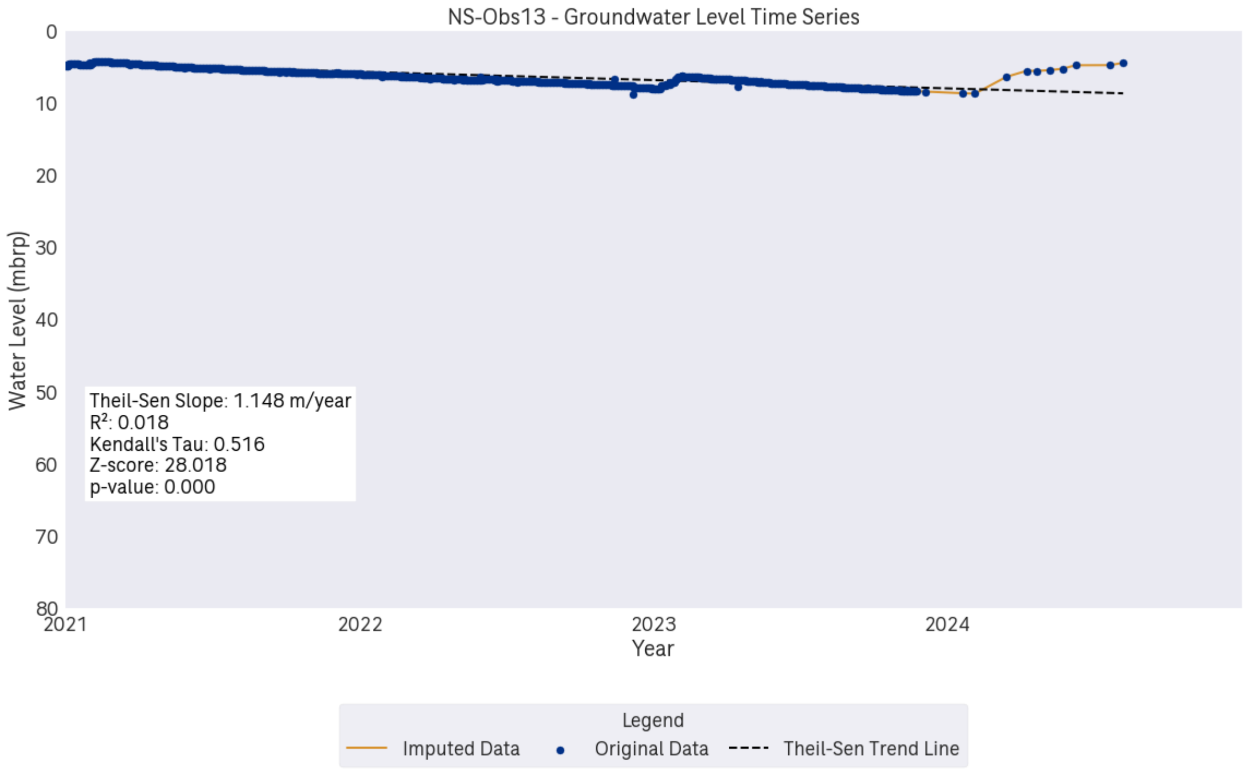


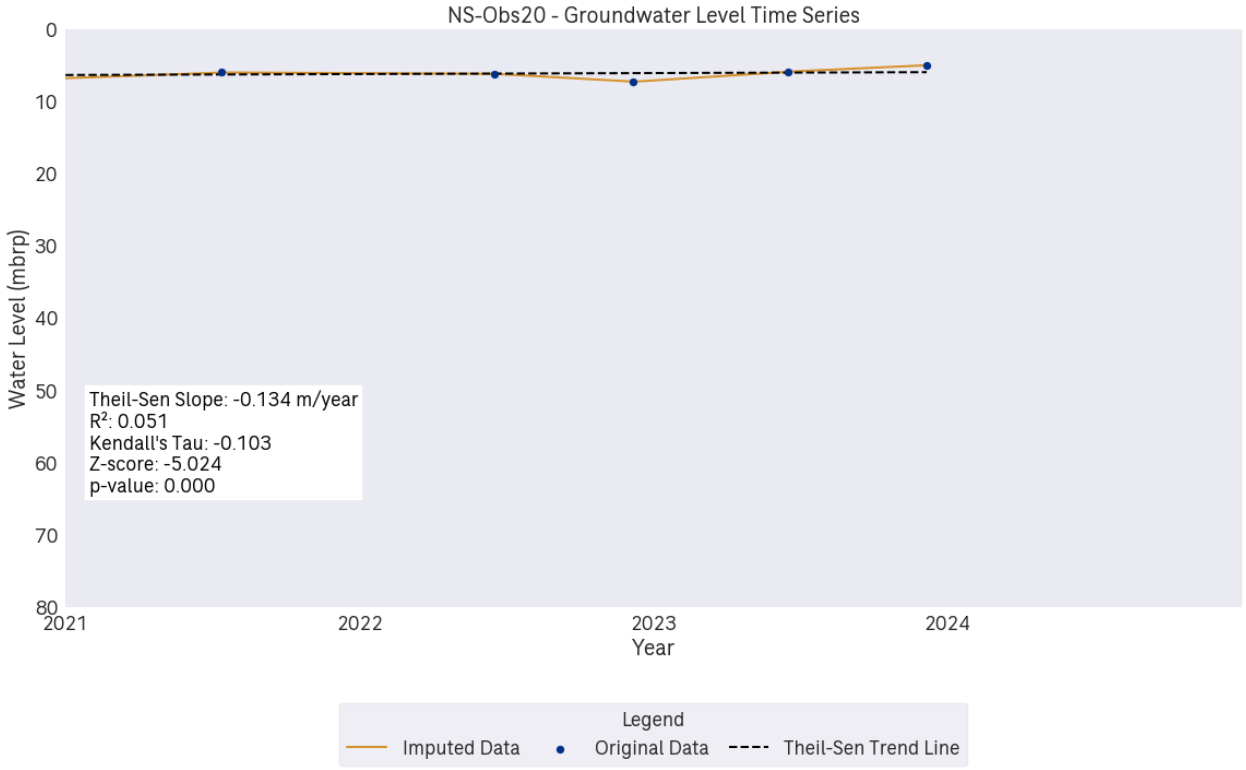

IB_RWP_MB4 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
Theil-Sen Slope: -3.479 m/year
R²: 0.784
Kendall's Tau: -0.668
Z-score: -26.110
p-value: 0.000
2021
2022
2023
2024
Year
Legend
Imputed Data
Original Data
Theil-Sen Trend Line

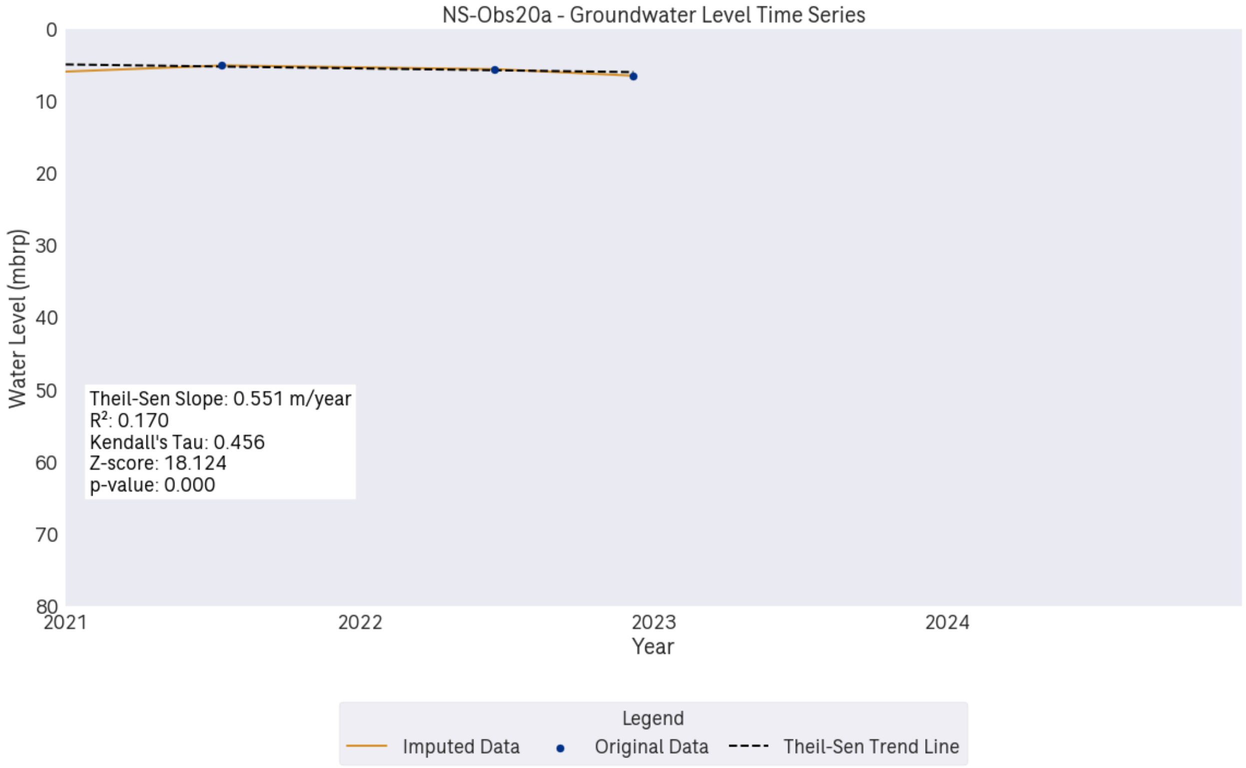

IB_RWP_MB5 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
Theil-Sen Slope: -1.734 m/year
R²: 0.735
Kendall's Tau: -0.610
Z-score: -23.172
p-value: 0.000
2021
2022
2023
2024
Year
Legend
Imputed Data
Original Data
Theil-Sen Trend Line


IB_RWP_MB6 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2021
2022
2023
2024
Year
Theil-Sen Slope: -3.189 m/year
R²: 0.787
Kendall's Tau: -0.602
Z-score: -22.894
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line


IB_TSF_M01 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2021
2022
2023
2024
Year
Theil-Sen Slope: 0.830 m/year
R²: -0.302
Kendall's Tau: 0.349
Z-score: 18.536
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line


NS-Obs13 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2021
2022
2023
2024
Year
Theil-Sen Slope: 1.148 m/year
R²: 0.018
Kendall's Tau: 0.516
Z-score: 28.018
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line


NS-Obs20 - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2021
2022
2023
2024
Year
Theil-Sen Slope: -0.134 m/year
R²: 0.051
Kendall's Tau: -0.103
Z-score: -5.024
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line


NS-Obs20a - Groundwater Level Time Series
Water Level (mbrp)
0
10
20
30
40
50
60
70
80
2021
2022
2023
2024
Year
Theil-Sen Slope: 0.551 m/year
R²: 0.170
Kendall's Tau: 0.456
Z-score: 18.124
p-value: 0.000
Legend
Imputed Data
Original Data
Theil-Sen Trend Line