CENTRAL LAND COUNCIL

Submission to the Northern Territory Environmental Protection Agency

SINGLETON HORTICULTURE PROJECT

Referral of proposed action submitted by Fortune Agribusiness Funds Management Pty Ltd and published by the NTEPA on 23 November 2022

PART 1

ACKNOWLEDGEMENT

*The Central Land Council (**CLC**) acknowledges the traditional owners of the Northern Territory who, with their ancestors, have been custodians and stewards of the Territory and its resources for tens of thousands of years.*

INTRODUCTION

1. The Central Land Council (**CLC**) welcomes the opportunity to respond to the referral documents submitted by Fortune Agribusiness Funds Management Pty Ltd (**Fortune**) to the Northern Territory Environmental Protection Agency (**NT EPA**) under the *Environment Protection Act 2019* (NT) (**EP Act**). These documents have been submitted to determine the appropriate environmental impact assessment (**EIA**) method for the proposed Singleton Station agricultural development (**Proposed Development**) under the EP Act and *Environmental Protection Regulations 2020* (NT) (**EP Regulations**).

2. The Proposed Development is located at Singleton Station in the arid zone and falls within the Western Davenport Water Control District, which is in turn divided into three 'Management Zones' under the relevant Water Allocation Plan or **WAP**.[1]

3. The Proposed Development's ultimate objective is the cultivation of 3,300 hectares of irrigated fruit and vegetables. This objective being underpinned by the following elements:

    a. a water extraction licence[2] for up to 40,000 ML year extracted with 144 bores[3] (**Singleton Licence**) from aquifers underlying the Central Plains Management Zone. It is well-documented that the Singleton Licence is the largest groundwater licence ever granted in the NT and in all likelihood the entire country;

    b. an application and proposed application to clear 4,037 hectares of native vegetation (with this being additional to the loss of groundwater dependent ecosystems or **GDEs** caused by drawdown of aquifers);[4]

    c. infrastructure, accommodation and a solar farm.

4. The CLC is a Commonwealth Statutory Authority established under the *Aboriginal Land Rights (Northern Territory) Act* (Cth) 1976 (**ALRA**), with statutory responsibilities for approximately 780,000 square kilometres of land in the southern half of the Northern Territory (**NT**). The CLC has functions including:

    a. ascertaining and expressing the wishes and opinion of Aboriginals living in the area of the CLC as to the management of Aboriginal land in the area;[5]

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[1] Western Davenport WAP 2021-22. The Draft Western Davenport WAP 2022-2032 will soon be released for public comment.
[2] The Singleton Licence has been granted (Licence No WDCP10358), but is currently subject to legal proceedings in the NT Supreme Court.
[3] A total of 144 bores have been approved: 2 for domestic use and 142 for horticulture.
[4] Fortune has submitted both a Land Clearing Application (**LCA**) and application for a Non-Pastoral Use (**NPU**) permit under the *Pastoral Land Act 1992* (NT) (**PL Act**), which are yet to be determined.
[5] ALRA, s. 23(1)(a)

b. protecting the interests of traditional Aboriginal owners of Aboriginal land;[6]

c. assisting Aboriginal people to take measures likely to assist in the protection of sacred sites on land (whether or not Aboriginal land);[7] and

d. consulting with traditional Aboriginal owners of Aboriginal land about any proposals relating to the use of that land.[8]

5. The CLC also administers a range of programs for the benefit of constituents in relation to environmental management, community development, governance, economic participation, cultural heritage, and customary practices.

6. The CLC is the recognised representative Aboriginal/Torres Strait Islander body for the southern region of the NT pursuant to section 203AD of the *Native Title Act 1993* (Cth) (**NTA**). The CLC's area includes Singleton Station.

7. Singleton Station is subject to a Native Title consent determination by the Federal Court in *Rex on behalf of the Akwerlpe-Waake, Iliyarne, Lyentyawel Ileparranem and Arrawatyen People v Northern Territory of Australia* (2010) FCA 911, as varied by Orders made in 2020 in *Mpwerempwer Aboriginal Corporation RNTBC (ICN 7316) v Northern Territory of Australia and Ors NTD42/2018*. Mpwerempwer Aboriginal Corporation RNTBC (Mpwerempwer) is the prescribed body corporate for the purposes of section 57(2) of the Native Title Act. The CLC provides assistance and facilitation to Mpwerempwer.

8. Sacred sites exist on Singleton Station and on adjoining land which Fortune's modelling shows will be affected by groundwater drawdown from the Singleton Licence. Aboriginal people have rights to access and protect those sites under the *Northern Territory Sacred Sites Act* 1989 (NT) (**Sacred Sites Act**), NTA and ALRA.

9. In matters concerning Singleton Station, the CLC acts for Mpwerempwer. The CLC also acts for:

a. Kaytetye Tywerate Arenge Aboriginal Corporation RNTBC, the prescribed body corporate for the northern portion of Neutral Junction Station, which Fortune's modelling shows will be affected by groundwater drawdown from the Singleton Licence;

b. the Iliyarne, Warrabri and Karlantijpa South Aboriginal Land Trusts, each of which Fortune's modelling shows will be affected by groundwater drawdown from the Singleton Licence; and

[6] ALRA, s. 23(1)(b)
[7] ALRA, s. 23(1)(ba)
[8] ALRA, ss. 23(1)(c).

c. Aboriginal people in surrounding communities and nearby outstations affected by the Proposed Development.

10. This submission is made on behalf of those groups.

EXECUTIVE SUMMARY

11. Expert analysis commissioned by the CLC across key areas indicates that the Proposed Development is likely to have a significant impact on groundwater resources, sandplain habitat, culturally-significant GDEs and other sacred sites and values.

12. Further, deficiencies in the analysis, monitoring, modelling and surveying to date by both the NT Government and Fortune has increased the level of uncertainty regarding precisely how significant these impacts will be over time. Flawed and ill-conceived mitigation measures – in particular the 'adaptive management' framework linked to the Singleton Licence – are cause for serious concern. These shortcomings have resulted in Fortune erroneously assigning a 'low' or 'medium' residual risk rating to all affected areas,[9] which is itself indicative of a general failure to undertake sufficiently rigorous up-front EIA.

13. The aforementioned matters, all of which are explored in more detail in the body of this submission and in attached expert reports, trigger, in the view of the CLC, a legal requirement to subject the Proposed Development to a full Environmental Impact Statement (**EIS**) (also known as a 'Tier 3 Assessment').[10] Failure to do so would arguably be inconsistent with the applicable decision-making framework under the EP Act and EP Regulation, which could potentially give rise to judicial review proceedings in the NT Supreme Court.

SCOPE OF SUBMISSION

14. This submission is divided into the following 8 parts which together support the CLC's assertion that the Proposed Development must be assessed by way of a full EIS:

- **Part 1** sets out the relevant legal framework under the EP Act and EP Regulations, and provides commentary on the application of this framework to the EIA process for the Proposed Development.

[9] GHD, EP Act 2019 Referral Report – Singleton Horticulture Project, 8 November 2022, p. 96 (summary); pp. 93-139 (**Referral Report**).
[10] NT Dept of Environment, Parks and Water Security, Environmental impact assessment and environmental approval in the Northern Territory - Environmental impact assessment guidance (**EIA Guidelines**), pg. 22.

- **Part 2** discusses groundwater and GDEs and associated monitoring, modelling and adaptive management. Supporting expert evidence is included as **Attachments A, B, C and D** to this submission, while supporting peer-reviewed literature is included at **Attachment E**.

- **Part 3** discusses salinity and associated assessment and management actions. Supporting expert evidence is included at **Attachment F.**

- **Part 4** discusses terrestrial ecosystems and associated assessment and management actions. Supporting peer-reviewed literature is included at **Attachments G**, **H, I and J.**

- **Part 5** discusses the nature of, and impacts on, sacred sites and Aboriginal cultural heritage. Supporting expert evidence is included at **Attachments K, L and M**.

- **Part 6** discusses aquatic ecosystems, and in particular stygofauna.

- **Part 7** discusses the purported socio-economic benefits linked to the Proposed Development. Supporting expert evidence is included at **Attachments N, O and P**.

- **Part 8** discusses greenhouse gas emissions.

- **Part 9** applies the relevant legal framework to the evidence and provides concluding remarks.

PART 1: LEGAL FRAMEWORK

15. The Proposed Development is subject to a range of provisions in the EP Act and EP Regulations. These provisions may be divided into the following three areas:

    a. the circumstances in which some form of EIA is required and associated processes and methods;

    b. matters that must be considered and/or applied when making a decision about the appropriate EIA method; and

    c. additional duties incumbent on proponents.

Each of these will be addressed in turn.

1.1 – Circumstances in which EIA required; processes and methods

16. The EP Act specifies that EIA is required for a referred ‘action’ where that action has the ‘potential’ to have a significant impact on the environment.[11] Where this is the case, the NT EPA must ensure that the EIA is carried out in accordance with the regulations.[12] The regulations may provide for the ‘processes and methods’ for the EIA of affected referred actions.[13]

17. Relevantly, ‘action’ is defined to include any of the following: (a) a project; (b) a development; (c) an undertaking; (d) an activity or series of activities; (e) works; (f) a material alteration of any of the things mentioned in paragraphs (a) to (e).[14] ‘Significant impact’ is defined as ‘an impact of major consequence having regard to: (a) the context and intensity of the impact; and (b) the sensitivity, value and quality of the environment impacted on and the duration, magnitude and geographic extent of the impact.’[15]

18. There are four main EIA ‘methods’: assessment by referral information; assessment by supplementary environmental report; assessment by environmental impact statement; or assessment by inquiry.[16] These are also referred to as EIA ‘tiers’ in the EIA Guidelines.

1.2 – Matters that must be considered and/or applied when making a decision about the appropriate EIA method

19. Second, and assuming an action has the potential to have a significant impact on the environment,[17] the NT EPA must choose which of these four EIA methods or ‘tiers’ ought to be applied to the referred action. In making this determination, it must have regard to the following five criteria:

    a. the significance of the potential impact of the proposed action or the strategic proposal;

    b. the level of confidence in predicting potential significant impacts of the proposed action or strategic proposal taking into account the extent and currency of existing knowledge;

    c. the level of confidence in the effectiveness of any proposed measures identified in the referral to avoid, mitigate or manage potential significant impacts of the proposed action or strategic proposal;

[11] EP Act, s.55.
[12] EP Act, s. 57(1).
[13] EP Act, s. 57(2).
[14] EP Act, s.5 (a) – (f).
[15] EP Act, s.11.
[16] EP Regulation, reg. 5.
[17] EP Act, s. 55; EP Regulation, regulation 57(2)(b).

d. the extent of community engagement that has occurred in relation to the proposed action or strategic proposal;

e. the capacity of communities and individuals likely to be affected to access and understand information about the proposed action or strategic proposal and its potential significant impacts (**Key Assessment Criteria**).[18]

20. The NT EPA must interpret the Key Assessment Criteria in a manner that promotes the underlying objects and purpose of the EP Act.[19] The objects are as follows:

a. to protect the environment of the Territory; and

b. to promote ecologically sustainable development so that the wellbeing of the people of the Territory is maintained or improved without adverse impact on the environment of the Territory; and

c. to recognise the role of environmental impact assessment and environmental approval in promoting the protection and management of the environment of the Territory; and

d. to provide for broad community involvement during the process of environmental impact assessment and environmental approval; and

e. to recognise the role that Aboriginal people have as stewards of their country as conferred under their traditions and recognised in law, and the importance of participation by Aboriginal people and communities in environmental decision making processes.[20]

21. These objectives are weighted strongly in favour of environmental protection; recognise Aboriginal rights and interests and the importance of Aboriginal people in environmental decision-making processes; and highlight the role of EIA in promoting environmental protection. It is in this light that other, substantive provisions regarding EIA (including the correct EIA method) ought to be interpreted.

22. The NT EPA should further interpret the Key Assessment Criteria in a manner that promotes the stated ‘purpose’ of the EIA process, which is to ‘ensure that’:

a. actions do not have an unacceptable impact on the environment, now or in the future; and

b. all actions that may have a significant impact on the environment are assessed, planned and carried out taking into account:

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[18] EP Regulation, regulation 59

[19] *Interpretation Act 1978*, s.62A.

[20] EP Act, s.3(a)-(e).

i. the principles of ecologically sustainable development (**ESD**); and

ii. the environmental decision-making hierarchy; and

iii. the waste management hierarchy; and

iv. ecosystem-based management;[21] and

v. the impacts of a changing climate; and

c. the potential for less environmentally damaging alternative approaches, methodologies or technologies for actions is considered; and

d. the community is provided with an opportunity to participate, and have its views considered, in decisions on proposed actions; and

e. the potential for actions to enhance or restore environmental quality through restoration or rehabilitation is identified and provided for to the extent practicable.[22]

23. Of further relevance to the decision-making process undertaken by the NT EPA in relation to the correct EIA method for the Proposed Development are the principles of ESD. Specifically, [a] decision-maker must consider and apply these principles in making a decision under this Act.'[23] Note that 'under this Act' extends to decision-making under the EP Regulations.[24] The principles of ESD that must be both considered *and* applied are as follows:

a. The decision-making principle. First, decision-making processes should effectively integrate both long-term and short-term environmental and equitable considerations. Second, decision-making processes should allow for community involvement in relation to decisions and actions that affect the community.[25]

b. The precautionary principle. Decision-making should be guided by (a) a careful evaluation to avoid serious or irreversible damage to the environment wherever practicable; and (b) an assessment of the risk-weighted consequences of various options.[26]

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[21] Defined in s.4 of the EP Act as 'management that recognises all interactions in an ecosystem, including ecological and human interactions.'
[22] EP Act, s.42(a) – (e).
[23] EP Act, s. 17(1), (2).
[24] *Interpretations Act 1978* (NT), s. 21.
[25] EP Act, s.18(1), (2).
[26] EP Act, s. 19(1), (2).

c. Evidence-based decision-making. Decisions should be based on the best available evidence in the circumstances that is relevant and reliable.[27]

d. Inter-generational and intra-generational equity. The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of present and future generations.[28]

e. Principle of sustainable use. Natural resources should be used in a manner that is sustainable, prudent, rational, wise and appropriate.[29]

f. Principle of conservation of biological diversity and ecological integrity. Biological diversity and ecological integrity should be conserved and maintained.[30]

g. Principle of improved valuation, pricing and incentive mechanisms.[31]

24. In making a decision 'in relation to actions that affect the environment', decision-makers (as well as proponents and approval holders) must apply the 'environmental decision-making hierarchy.' This hierarchy consists of three elements which must be applied in the following order: first, ensure that actions are designed to avoid adverse impacts on the environment; second, identify management options to mitigate adverse impacts on the environment to the greatest extent practicable; third, if appropriate, provide for environmental offsets in accordance with this Act for residual adverse impacts on the environment that cannot be avoided or mitigated.[32]

1.3 – Additional duties incumbent on proponents

25. As a proponent of an 'action', Fortune is subject to the following 'general duties' under an EIA process:

a. to provide communities that may be affected by a proposed action with information and opportunities for consultation to assist each community's understanding of the proposed action and its potential impacts and benefits;

b. to consult with affected communities, including Aboriginal communities, in a culturally appropriate manner;

c. to seek and document community knowledge and understanding (including scientific and traditional knowledge and understanding) of the natural and cultural values of areas that may be impacted by the proposed action;

d. to address Aboriginal values and the rights and interests of Aboriginal communities

[27] EP Act, s. 20.
[28] EP Act, s. 21.
[29] EP Act, s. 22.
[30] EP Act, s. 23.
[31] EP Act, s. 24, (1)-(4).
[32] EP Act, s. 26(1)(a)-(c).

in relation to areas that may be impacted by the proposed action;

e. to consider the principles of ecologically sustainable development in the design of the proposed action;

f. to apply the environmental decision-making hierarchy in the design of the proposed action;

g. to consider the waste management hierarchy in the design of the proposed action.[33]

26. In summary, the decision-making framework contains multiple elements. However, the Key Assessment Criteria set out in regulation 59 must be read in light of the EP Act's objects (which are strongly weighted in favour of environmental protection) and the stated 'purpose' of the EIA process (which seeks to ensure that an EIA under the Act is sufficiently rigorous to maximise environmental protection). Additionally, as an administrative decision-maker, the NT EPA must both consider *and* apply the principles of ESD, as well as the environmental decision-making hierarchy.

27. When considered together, the various provisions that comprise the applicable decision-making framework impose a requirement on the NT EPA to ensure that EIA is commensurate with the scale, complexity and potential impacts of a given 'action', with this being designed to maximise environmental protection and the rights and interests of Aboriginal peoples. Actions that are large and impactful, designed to operate over decades, about which there are large knowledge gaps (including due to inadequate underlying monitoring, modelling and surveying) will invariably require more detailed EIA to meet the obligations set out in the EP Act.

PART 2: GROUNDWATER AND GDES

28. Part 2 of this submission will provide commentary on:

a. the scale of the Proposed Development and its likely impacts on groundwater resources and GDEs;

b. deficiencies of first, the groundwater modelling and monitoring undertaken by the NT Government in the Western Davenport region and second, the groundwater modelling undertaken by Fortune for the Proposed Development itself;

c. flaws in Fortune's proposed mitigation strategy, in particular in relation to the 'adaptive management framework' that applies to the Singleton Licence.

29. Our commentary in this section is based on three expert reports, a submission and peer-reviewed literature (which are included at **Attachments A, B, C, D and E** to this submission.

[33] EP Act, s.43(a)-(g).

30. These submissions are also in accordance with the alternative course proposed by the Water Resources Review Panel appointed by the Minister following applications to review the water licence granted to Fortune by the Water Controller:

> *Alternatively, the Review Panel suggests that these factors may be better informed by a comprehensive assessment process that is enabled through referral under the EP Act and therefore set aside the groundwater extraction licence WDPCC10000 and substitute a decision refusing the Licence.*[34]

2.1 – Scale and impacts

31. It is now well-documented that the Singleton Licence is the largest groundwater licence ever granted in the NT and in all likelihood the entire country. Indeed, the CLC and its experts have been unable to find any direct comparison with other large-scale developments (that is, we have been unable to identify any other development extracting or diverting up to 40GL/year from groundwater resources). This highlights the unusual nature of the Proposed Development and potential for significant, and potentially unpredictable and irreversible, impacts.[35]

32. To put its scale in perspective, it has been noted that:

> *the ten largest groundwater licences in the state of NSW range from approximately 7GL to 15GL with these licences being spread across three different catchments. The number of bores associated with these individual licences ranges from 3 to 11*.[36]

33. Comparisons between the volume of water that will be diverted under the Singleton Licence and mining developments reveal that even large-scale open cut coal mines divert a fraction of the water authorised under this Licence. By way of example:

> *…the proposed McPhillamys Gold Mine in the Lachlan Catchment in south-western NSW, which will comprise a pit of some 450 metres in depth, is projected to divert a maximum of 580ML/year or 0.58GL/year from the aquifers through which it will be cut. This is 0.0145% of the Singleton Licence. The proponents of McPhillamy's Gold Mine, like most mining proponents, are required to undertake environmental impact assessment* [by way of a full EIS][37] *in accordance with the relevant statutory framework.*[38]

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[34] Water Resources Review Panel report to Minister dated 14.10.2021, at [93]. Available online at: https://depws.nt.gov.au/__data/assets/pdf_file/0007/1069657/wrrp-advice-to-minister-wdpcc10000.pdf (accessed 13.02.2023)
[35] See Attachments A, B, C and D to this submission.
[36] Submissions by the Environmental Defenders Office on behalf of the Arid Lands Environment Centre and Environment Centre NT to the Panel reviewing the Singleton Licence under s.30 of the *Water Act 1992* (NT), pg. 3. Available online at: https://www.edo.org.au/publication/submissions-to-the-water-resources-review-panel-singleton-licence/ (accessed 08.02.2023).
[37] https://pp.planningportal.nsw.gov.au/major-projects/projects/mcphillamys-gold-project (accessed 08.02.2023).
[38] Submissions by the Environmental Defenders Office on behalf of the Arid Lands Environment Centre and Environment Centre NT to the Panel reviewing the Singleton Licence under s.30 of the *Water Act 1992* (NT), pg.

34. The likely impacts of the Singleton Licence on affected groundwater resources in the Central Plains Management Zone include:

    a. significant drawdown, including in areas where GDEs are located (up to 50 metres in certain areas over 30 years);[39]

    b. where the baseline depth to groundwater is less than 15 metres:

        i. 26% of alluvial GDEs and 13% of sandplain GDEs on the Singleton Station may be impacted; and

        ii. 25% of alluvial GDEs and 15% of sandplain GDEs on the Central Plains Management Zone may be impacted after 40 years.[40]

35. These impacts must be considered within the context of rules that, in the absence of a declared water allocation plan (the current scenario), allow up to 80% of total aquifer storage to be extracted over a 100-year period, which is in essence a form of 'managed depletion' rather than 'sustainable management.'[41] Even with a declared water allocation plan, rules based on recharge rather than ***net*** recharge lead to drawdown of the aquifer, and it is that drawdown which can have a significant impact upon GDEs.

36. In summary, and despite uncertainties arising from deficiencies in the underlying monitoring and modelling undertaken in relation to the affected aquifers and Proposed Development (discussed below), it is highly likely that the impacts on groundwater will be significant due to the sheer volume proposed to be extracted over multiple decades.

2.2 – Deficiencies in monitoring and modelling

37. Expert analysis of the Western Davenport WAP water allocation framework and associated model development is included at **Attachment A** to this submission.[42] In summary, this analysis indicates that the water allocation framework and modelling for the Western Davenport WAP area is undermined by a range of problems, including:

    a. a lack of spatially distributed data on aquifer geometry, lithology, hydraulic properties, water levels and water quality;

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3. Available online at: https://www.edo.org.au/publication/submissions-to-the-water-resources-review-panel-singleton-licence/ (accessed 08.02.2023).

[39] Paragraph 66 of the Statement of Decision by the Water Controller for the Singleton Licence dated 08.04.2021 (**Statement of Decision**). In her decision to grant the Singleton Licence on 15.11.2021, Minister Worden relied on the Statement of Decision.

[40] Paragraph 101 of the Statement of Decision.

[41] Northern Territory Water Allocation Planning Framework (Arid Zone – Aquifers), p.2.

[42] Western Davenport Plan, Associated Documents and Groundwater Model Review, dated 16.07.21. Note this is based on an analysis of the modelling underpinning the Western Davenport WAP 2018 – 2021 which was the WAP that was in force at the time the Singleton Licence was approved. The replacement WAP will be released in draft form shortly. However, we are advised that in the absence of significant, additional monitoring of groundwater resources in the WAP area (over a minimum of five years), any replacement modelling will not rectify the underlying deficiencies identified by the CLC and its experts. Until such time as a new WAP is declared, the Arid Zone rules apply, which permit the managed depletion of the aquifer by 80% of the stored resource over 100 years.

b. a dearth of water level data and associated time series (within the context of long-term predictive modelling) for much of the model domain (especially for the regolith, which is only inferred rather than based on measured data); and

c. aquifer testing data is sparse and generally restricted to short duration, single borehole tests which cannot determine aquifer storage properties.

38. This means that key baseline data regarding the characteristics of the affected aquifers is absent, which in turn exacerbates the level of uncertainty regarding the impacts associated with the extraction of such a large volume of water over time.

39. Additionally, the Western Davenport WAP 2011-2021 itself identifies key limitations in the underlying modelling. These are articulated in a submission prepared by the CLC in 2021 seeking Ministerial review of the Singleton Station Licence.[43] This submission is included at **Attachment B** to this submission.

40. **Attachment C** to this submission is an expert sensitivity analysis with indications of predictive uncertainty of the groundwater modelling relied on for the purpose of the Proposed Development. It highlights a range of serious problems, including:

a. The baseline data available to construct a reliable groundwater model describing the impacts of the project is limited. The datasets are lacking in several areas including: spatial coverage, detail of geological classifications (types of soil/rock, depths of soil/rock, thickness of aquifers etc.), and field measurement of parameters that would assist in parameterising a groundwater model.

b. Building/configuring any model requires a degree of data interpretation by the modeller. Since the available baseline datasets are limited (as per subparagraph a, above), the application of the data to build a model is open to interpretation by the modeller e.g. the area, depth and volume of aquifer layers. The model that Fortune is relying on has one plausible interpretation of the datasets, but there could be other reasonable interpretations. The model results could be affected by this interpretation.

c. The accuracy and range (referred to in the document as 'uncertainty' usually expressed as a median value +/- a range e.g. for groundwater levels 10m AHD +/- 5m) of plausible model results can be significantly influenced by the numerical parameters chosen for the model. The choice of these model parameters can be guided by calibration to measured historical data (e.g. variations in depth to groundwater). In a sophisticated model like MIKEShe, there are numerous model parameters. A criticism of Fortune's model is that they have adopted one combination of model parameters amongst many possible parameter combinations which might reproduce the historical data.

[43] Submission seeking ministerial review of Water Controller's decision to grant the new water extraction licence WDPCC10000 to Fortune Agribusiness, 7 May 2021, pp 5 to 9 inclusive.

d. The numerical uncertainty of a model can be tested by varying the model parameters - known as model sensitivity analysis. A key criticism of Fortune's model is that the sensitivity analysis presented in the EIA is limited. The CLC's experts have conducted a broader sensitivity analysis and demonstrated that Fortune's model could be far more sensitive to the choice of model parameters than reported.

e. The CLC's experts have indicated that the predicted impacts of water extraction by the project could have been underestimated by up to 30m in groundwater depth with an associated large increase in the spatial footprint of potentially impacted areas. The potential underestimation of modelled groundwater impacts has significant implications for potential underestimation of impacts to GDEs, vegetation, stygofauna etc.

41. Furthermore, the CLC and its experts have identified serious legal, ecological and cultural deficiencies in the assumption that 30% of GDEs in the Western Davenport Water Control District can be impacted.[44] For example, this figure has no discernible scientific basis; nor does it take into account the potential, relative value of a particular landform (meaning that 30% of the most ecologically and culturally significant GDEs could in theory be degraded or destroyed). It does not take into account that GDEs are frequently associated with cultural values in general and sacred sites in particular. No damage to sacred sites (be they GDEs or otherwise) is permitted under the Sacred Sites Act. The CLC asserts that Fortune's assessment of interconnected cultural values is flawed (see **Part 5** of this submission for further details).

42. Finally, expert analysis of the materials submitted by Fortune as part of its referral under the EP Act and EP Regulation and included at **Attachment D** to this submission highlight a range of ongoing problems, including that:

a. on balance, there is very little new information pertaining to, *inter alia*, hydrology, hydrogeology and impact assessment, and no new information that would rectify the deficiencies and limitations identified in the expert reports attached to this submission;

b. monitoring and adaptive management plans are generic and lacking in necessary detail; and

c. the risk assessment is not underpinned by good data and analysis, rendering it qualitative and subjective.[45]

43. As a consequence, the expert reviewer recommends that the NT EPA ensure that the Proposed Development is subject to a full EIS (Tier 3 assessment). This is particularly important given the assessment undertaken to date by Fortune is, in our view and that of

[44] As per the following policy document: *Limits of acceptable change to groundwater dependent vegetation in the Western Davenport Water Control District.*
[45] Singleton Station Horticulture Project – EIS and Appendices, Focussed Review

our advising experts, more consistent with a pre-feasibility study than proper EIA.

2.3 – Mitigation measures – adaptive management

44. The CLC, on the evidence of experts engaged by it, has persistently argued that the uncertainty around the possible impacts of the Proposed Development on groundwater, and GDEs in particular, could and should be reduced by undertaking more fulsome monitoring and modelling and a full EIS. However, and as a substitute for these necessary steps, Fortune has sought to rely on so-called 'adaptive management' to purportedly mitigate the inherent uncertainty and possible magnitude of the impacts on groundwater and GDEs. Indeed, 'adaptive management' provisions have been built into the conditions for the Singleton Licence.

45. Expert evidence commissioned by the CLC (**Attachments A and D**) makes it abundantly clear that this 'adaptive management' regime is fundamentally flawed for the following (non-exhaustive) list of reasons:

    a. adaptive management is often inappropriately relied upon to justify approval of complex projects for which there is insufficient understanding of risks to the environment;

    b. adaptive management requires a strong understanding of the affected water resource(s), biodiversity, GDEs and cultural values to be potentially successful. However, the monitoring, modelling and surveying work undertaken in relation to these matters by Fortune is manifestly deficient; and

    c. given the infrequent and small amount of groundwater recharge in the area, if impacts occur that are deemed unsuitable, groundwater recovery may take decades - if it occurs at all. Fortune's own groundwater modelling predicts almost no recharge for nearly 60 years.

46. We would further note that the use of an 'adaptive management' framework for water being extracted to grow perennials has been queried by a number of experts.[46] Specifically, once planted, perennials require ongoing watering to stay alive. The notion that Fortune would invest millions of dollars in planting vines and trees – and then agree to reduce extractions and lose part of their investment because impacts had exceeded certain thresholds – seems unrealistic.

47. This is exemplified by the fact that the current draft of the adaptive management plan at Schedule G of Fortune's referral documents does not envisage 'turning the taps off' in response to any trigger. Rather, the identified management actions include relocating bores and artificially watering or off-setting GDEs.[47] The triggers for implementation of those management action remain largely undefined, but may include the spatial extent of

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[46] See for example: Submissions by the Environmental Defenders Office on behalf of the Arid Lands Environment Centre and Environment Centre NT to the Panel reviewing the Singleton Licence under s.30 of the *Water Act 1992* (NT), pp. 4-5. Available online at: https://www.edo.org.au/publication/submissions-to-the-water-resources-review-panel-singleton-licence/ (accessed 08.02.2023).

[47] Schedule G: Groundwater Monitoring Program & Adaptive Management Plan, pp 42 – 43

drawdown being 20% greater than anticipated by modelling or 5% destruction of GDEs.[48] Without sufficient baseline studies, triggers defined in that manner will always be vague and open to interpretation. Advice given to the CLC is that once a GDE's health declines visually, it is usually too late to save that GDE. Particularly for GDEs that are also sacred sites, off-setting is an inappropriate response and would not meet Fortune's obligations under the Sacred Sites Act.

48. Finally, peer-reviewed literature regarding the use of adaptive management in relation to groundwater resources (**Attachment E**) has highlighted the vital importance of strong predictive modelling to, *inter alia*, guide management alternatives. It has also reinforced the role of rigorous data collection (drilling, monitoring, geophysical surveys etc.) in addressing 'critical data gaps and the main sources of uncertainty in estimates of project effects and predictions of the efficacy of AGM [adaptive groundwater management] strategies.'[49]

49. We note that these two critical elements – fit-for-purpose modelling and sufficient baseline data about the affected aquifers – are precisely what have been identified as missing from the underlying work undertaken by Fortune and the NT Government in relation to the wider Western Davenport WAP.

PART 3: SALINITY

50. A CLC note of expert analysis (**Attachment F**) of Fortune's Salinity Impact Assessment Report (Appendix L of the referral materials) identified a number of problems. These include a failure to:

    a. report on or model environmental impacts of salinity beyond changes in the groundwater extracted from the pumping bores;

    b. report on salinity at the water table and maximum potential salinity increases; and

    c. report on original soil salinity which could greatly increase salinity levels above predictions.

51. These gaps mean that the risk of increased salinity is much higher than predicted. They also leave critical questions unanswered, including the following:

    a. What is the salinity at the top of the water table?

    b. What are the potential maximum salinity levels due to the development?

    c. Why is a salinity concentration of 1500mg/L assumed as the maximum when initial salinity levels are assumed to be 900mg/L?

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[48] Schedule G: Groundwater Monitoring Program & Adaptive Management Plan, pp 39 – 40
[49] Pg. 7.

d. What are the soil salinity levels below 2-3m and how might they impact on increased salinity risks?

52. The aforementioned gaps and uncertainties in turn undermine the suitability of the mitigation measures proposed by Fortune in its Salinity Impact Assessment Report.

PART 4: TERRESTRIAL BIODIVERSITY

53. This part provides commentary on Fortune's Biodiversity Assessment Report (Appendix C of referred materials), and in particular methodological flaws and limitations in the surveying and assessment work conducted to date. We note that the work underpinning the Biodiversity Report was undertaken within the context of Fortune's proposal to clear over 4,000 hectares of native vegetation (sandplain habitat) to facilitate the Proposed Development.

54. The Biodiversity Assessment Report (**Biodiversity Report**) is a desktop analysis,[50] relying on literature reviews and biodiversity surveys conducted in 2019 as part of the 'Mapping the Future' survey,[51] as well as online mapping tools including the Protected Matters Search Tool (**PMST**) and The NT Government Department of Environment and Natural Resources – Natural Resource Maps database (**NR Maps database**).

55. The Biodiversity Report itself notes the limits of this approach, including the fact that:

> *[n]o trapping or targeted threatened species survey was conducted. The level of confidence surrounding the likelihood of occurrence and potential impact on threatened species is limited by the findings of the Mapping the Future Survey (DEPWS, 2022) and advice provided by the NT government dated September 18, 2020 recommending that targeted threatened species surveys were not necessarily required to assess potential impact.*[52]

56. We further note that the Mapping the Future survey is critically limited by the fact that the relevant flora and fauna surveys were conducted during a period of extreme water scarcity (March to October 2019). As noted in the Biodiversity Report, '…unfortunately, the timing of the flora surveys coincided with a period of prolonged severe drought, meaning that only the perennial subset of the herbaceous flora was sampled'.[53]

57. The Biodiversity Report also acknowledges that the extreme climatic conditions that typified the survey period may have affected the detection of certain species, including the Greater Bilby and the Spectacled Hare-Wallaby.[54] For example, the Report states that:

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[50] Biodiversity Report, pp.2, 6.
[51] https://depws.nt.gov.au/programs-and-strategies/mapping-the-future (accessed 10.02.23).
[52] Biodiversity Report, p.2.
[53] Biodiversity Report, p.2.
[54] Biodiversity Report, pp. 50; Appendix C, Table 5, p. 12 (of Appendix). Table 5 notes that 'Range and distribution [of the Spectacled Hare-Wallaby] possibly expands and contracts with resource availability and climactic conditions.'

> *the Mapping the Future survey was conducted in October 2019, at the time of prolonged dry periods, which coincided with very high temperatures over the summer of 2019/20 (BOM, 2022). This would have contributed to poorer ecological conditions and potentially lower detectability of several species of potential threatened flora and fauna, including Greater bilby.*[55]

58. Extensive peer-reviewed literature (see **Attachments G, H, I and J** to this submission) assessing the presence of flora and fauna during climatic 'boom and bust' periods in arid environments confirms that trends regarding species cannot be determined by limited surveying undertaken during 'bust' (or dry) spells. As a consequence, best-practice dictates that surveying must be undertaken over longer timescales that also incorporate 'boom' conditions, which can be brief but significant for biodiversity. Failure to do so will invariably skew survey results.[56] Indeed, this is consistent with the Australian Government's 'Survey guidelines for Australia's threatened mammals – Guidelines for detecting mammals listed as threatened under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth)',[57] as well as the NT EPA's Guidelines for Assessment of Impacts on Terrestrial Biodiversity.[58]

59. This is particularly true for the Greater Bilby, the numbers for which can increase significantly in a given region during 'boom' periods caused by high rainfall. For example, the Australian Wildlife Conservancy (**AWC**) observed that:

> *From 2021 to 2022, Bilby populations increased across AWC sanctuaries from an estimated 1,230 individuals to 1,480. AWC protects at least 10% of Australia's remaining Bilby*[59] *population which is estimated at around 10,000 individuals.*

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[55] Biodiversity Report, p. 50.

[56] See for example: Pavey, C.R. and Nano, C.E., 2013. Changes in richness and abundance of rodents and native predators in response to extreme rainfall in arid Australia. *Austral Ecology*, 38(7), pp.777-785; Pavey, C. R., Nano, C. E., Cole, J. R., McDonald, P. J., Nunn, P., Silcocks, A., & Clarke, R. H. (2014). The breeding and foraging ecology and abundance of the Princess Parrot (Polytelis alexandrae) during a population irruption. *Emu-Austral Ornithology*, 114(2), 106-115.Pavey, C.R., Nano, C.E.M., Waltert, M, 2020. Population dynamics of dasyurid marsupials in dryland Australia: Variation across habitat and time, *Austral Ecology*, 45, 283–290.

[57] Australia Government, *Survey guidelines for Australia's threatened mammals – Guidelines for detecting mammals listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999 (Cth)*, p.6. https://www.dcceew.gov.au/sites/default/files/documents/survey-guidelines-mammals.pdf (accessed 10.02.23).

[58] These guidelines state (at p.9) that for threatened and migratory fauna, '[s]ampling is to occur at suitable times of year and appropriate intensity to determine the presence of the species and obtain estimates of population abundance where the species occur. Search areas, sampling methods, search time/effort, capture effort as appropriate and results are to be reported for each possible threatened or migratory species. The adequacy of sampling needs to be demonstrated.
https://ntepa.nt.gov.au/__data/assets/pdf_file/0004/287428/guideline_assessment_terrestrial_biodiversity.pdf

[59] Note that the terms 'Greater Bilby' and 'Bilby' refer to the same species.

> *The increase in Bilby populations within AWC sanctuaries can be attributed to the increased rainfall in parts of the country during Australia's second year of La Niña, which replenished the landscape and provided good conditions for breeding.*[60]

60. That is, the primary driver of their population increase during this period was not predator control (noting that these are predator-free zones), but a transition out of Australia's worst drought in recorded history and into a period of significant rainfall.

61. While there is very little research on boom-and-bust populations in the Singleton area, nearby regions (Tanami, Simpson Desert, Uluru) have been well-documented in the literature and confirm the vital importance of properly planning surveying to ensure that it includes boom periods.[61]

62. However, and notwithstanding the significant limitations of the surveying relied upon and/or undertaken by Fortune, the Biodiversity Report concludes that:

> *impacts to threatened species were assessed as 'unlikely' under all criteria. The species assessed are not likely to occupy the Proposal area with any regularity and while the Proposal will remove a large amount of potential habitat, it is not thought to make up core or critical habitat for any species, and the quality and quantity of habitat is somewhat reduced by grazing, weeds and invasive predators such as the feral cat.*[62]

63. The CLC contends that this conclusion is based upon data that is likely to be skewed as a consequence of the period during which it was collected. As such, we'd suggest that it is not possible to definitively conclude that the area to be cleared of native vegetation does not constitute critical habitat for boom-and-bust (threatened) species such as the Greater Bilby. Further, the presence of other threats to these species (grazing, weeds, feral cats) *increases* the need to maintain intact habitat (particularly if it may act as refugia).[63]

64. These methodological flaws – including in relation to potential habitat for a federally-listed species[64] – raise serious concerns about the integrity of the biodiversity assessment undertaken by Fortune to date. They further undermine the mitigation and management actions set out in the Biodiversity Report, [65] including because these

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[60] See: https://www.australianwildlife.org/bilby-census-populations-of-australias-threatened-easter-bunny-are-growing/ (accessed 10.02.2023).
[61] See for example: Pavey, C.R. and Nano, C.E., 2013. Changes in richness and abundance of rodents and native predators in response to extreme rainfall in arid Australia. *Austral Ecology*, 38(7), pp.777-785;
[62] Biodiversity Report, pp.55-56.
[63] Pavey CR, Addison J, Brandle R, Dickman CR, McDonald PJ, Moseby KE, Young LI. The role of refuges in the persistence of Australian dryland mammals. *Biol Rev Camb Philos Soc.* 2017 May;92(2):647-664.
[64] The Greater Bilby is listed as 'vulnerable' under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act).
[65] Biodiversity Report, Appendix C, pp. 15-30 of that Appendix.

actions cannot in any way compensate for the loss of up to 4,000 hectares of potential habitat and refugia for boom-and-bust species such as the Greater Bilby.

65. Finally, we note that the Biodiversity Report acknowledges that Thring Swamp, which is classified as having 'high biodiversity value' and as a 'swamp of botanical significance',[66] will be affected by drawdown associated with the Proposed Development. Given the inherent deficiencies and subsequent uncertainties associated with Fortune's groundwater modelling (as per Part 2 of this submission), we would submit that there is scope for the impact to be greater than predicted. This is significant insofar as swamps are of great cultural significance (see Part 5 of this submission and associated expert reports).

PART 5: SACRED SITES AND ABORIGINAL CULTURAL HERITAGE

5.1 – Comparative legislation

66. It is essential to observe the difference in language and obligation between the EP Act and the Sacred Sites Act.

67. The EP Act acknowledges that there may be environmental impacts which cannot be avoided. In such circumstances the EP Act requires application of the environmental decision-making hierarchy described in paragraph 24. That is: first avoid; second mitigate; third off-set.

68. There is no similar hierarchy in the Sacred Sites Act. Rather, the Sacred Sites Act provides absolute prohibitions,[67] subject only to compliance with conditions on an Aboriginal Areas Protection Authority (**AAPA**) Certificate[68] and related defences.[69]

69. That distinction is important for the Proposed Development where many sacred sites are also GDEs. Mitigating or off-setting damage to 'ordinary' GDEs may be appropriate under the EP Act. It is not for 'sacred' GDEs under the Sacred Sites Act. The NT EPA will see from Fortune's referral documents that no complete sacred site survey has been undertaken on the company's behalf nor has the company comprehensively mapped sacred sites against GDEs. Until that work is done, it is not possible to work out which GDEs cannot be damaged at all (under the Sacred Sites Act) or, alternatively, whether damage must be avoided, mitigated or off-set (under the EP Act). The NT EPA ought to require this work to be done as part of an environmental impact statement so that the NT EPA can have confidence about when and how it should apply the environmental decision making hierarchy as opposed to the prohibitions in the Sacred Sites Act.

[66] Stokeld, D., Leiper, I., Brim Box, J., Jobson, P., Nano, C. and Box, P. (2022). Mapping the Future Project – Western Davenport. Biodiversity assessment of the Western Davenport area. Technical Report 30/2021. Department of Environment, Parks and Water Security. Darwin, Northern Territory; Biodiversity Report, pp. 8.
[67] Sacred Sites Act, ss. 33, 34 and 35.
[68] Sacred Sites Act, s. 34(2).
[69] Sacred Sites Act, s. 36.

5.2 – Overview

70. Part 5 relies on the letter included at **Attachment K** and the expert evidence included at **Attachments L and M**.

71. In its referral documents, Fortune says that after applying its mitigation strategies:

    a. the risk of "*potential impacts to sacred sites or Aboriginal cultural values from water drawdown*" is **MEDIUM**; and
    b. the risk of "*direct impacts to sacred sites of Aboriginal archaeological sites*" is **LOW**.

72. The risk to other cultural values is not assessed.

73. Those risk levels do not match what traditional Aboriginal owners and native title holders have told the CLC and the expert anthropologist engaged by it, Susan Dale Donaldson. Nor do they incorporate the high degree of uncertainty in the groundwater modelling identified by Dr Ryan Vogwill and described above. As set out in this section, the CLC considers that there is a **HIGH** risk of significant detrimental impact to Aboriginal cultural values if the Proposed Development proceeds as currently described. Further, the reliance of the Proposed Development on extracted groundwater renders illusory any distinction between "*indirect*" impacts due to drawdown and "*direct*" impacts from other activities.

74. According to the referral documents, Fortune relies on the following in order to protect Aboriginal cultural values:

    a. AAPA Certificate C2019/083;
    b. a new certificate it will apply to AAPA for covering the balance of the anticipated drawdown area; and
    c. conditions imposed on the Singleton Licence.[70]

75. Each of those documents is problematic for reasons including those set out in subsections 5.3 – 5.5.

76. Apart from protection via a current (and potentially a future) certificate from AAPA and the Singleton Licence conditions, traditional owner and native title holder involvement in mitigation strategies is limited to being consulted by Fortune to ensure the monitoring plan "*includes issues of importance to them*" and having Fortune's "*Engagement Plan … implemented which involves ongoing engagement with the TOs throughout the life of the project*".[71]

[70] Fortune's NT EPA Referral "*Main Document*", p. 127
[71] Fortune's NT EPA Referral "*Main Document*", p. 127

77. This is akin to traditional Aboriginal owners having things done to them. The better alternative is empowerment, as anthropologist Susan Donaldson encourages:

> *Good practice in the field of cultural heritage management includes working in cooperation with Traditional Owners to develop and apply an approach to cultural heritage management inclusive of a broad range of tangible and intangible cultural values. Traditional Owners' cultural values should not only be documented, Traditional Owners themselves should be empowered as active stakeholders and decision makers in matters that affect their land and waters.*[72]

78. In preparing the management plans required by the Singleton Licence conditions precedent, Fortune proposes to rely on the *Draft Environmental factor guidance: Culture and heritage* released for public comment by the NT EPA in 2022.[73] It should be made clear to Fortune that the draft guidance document currently has no force or effect. The CLC relies on its previous submissions to the NT EPA about changes required to that document.

5.3 – Current AAPA Certificate C2019/083

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[72] See Attachment L: Singleton Water Licence Aboriginal Cultural Values Assessment – Public Report prepared by Susan Dale Donaldson dated 01.09.2021, p.13

[73] Fortune's NT EPA Referral "*Main Document*", p. 127

81. In addition to concerns about the validity of AAPA Certificate C2019/083, an expert anthropologist engaged by the CLC has identified five sites that are missing from AAPA Certificate C2019/083:

> *Critically, the current assessment identified five sacred sites within the* [AAPA Certificate] *subject land not identified in the AC or overlapped by any of the RWAs. <u>These sites are all within the drawdown area and are all associated with GDE features; all are soakages</u>. An additional 32 sacred sites were identified outside the AC subject land and within the drawdown zone.*[76] (underline added)

82. Those five soakages receive no protection from AAPA Certificate C2019/083.

83. At no time has Fortune acknowledged these valid concerns about AAPA Certificate C2019/083 by agreeing not to rely upon it. The contrary is in fact the case. Fortune's referral documents make clear that it intends to keep relying on C2019/083, subject only to application for the second certificate described below.

84. Fortune could allay AAPA's, the CLC's, traditional Aboriginal owners' and native title holders' concerns by:

    a. consenting to the withdrawal of AAPA Certificate C2019/083; and

    b. working with the CLC, traditional Aboriginal owners and native title holders through the CLC's sacred site clearance procedures; and

    c. if it wishes to do so,[77] additionally applying for a single AAPA Certificate covering the entire anticipated drawdown area plus a reasonable buffer in case groundwater drawdown limits exceed what has been modelled.

85. Fortune has not done so. In the absence of Fortune taking those steps, there remains a real and significant risk that reliance by it upon AAPA Certificate C2019/083 will allow use of groundwater in a way that damages sacred sites, both inside and outside the subject area of that certificate.

[76] See Attachment L: Singleton Water Licence Aboriginal Cultural Values Assessment – Public Report prepared by Susan Dale Donaldson dated 01.09.2021, p. 70.
[77] We consider that a Sacred Site Clearance Certificate issued by the CLC would provide an equivalent level of statutory protection to Fortune as an AAPA Certificate: see Sacred Sites Act, s. 36

<u>5.4 – Potential future AAPA Certificate</u>

86. Fortune commits in its referral documents to "*engaging AAPA to consult and issue Authority Certificate(s) for any area <u>outside</u> the current Certificate that may in the future be subject to groundwater drawdown*".[78]

87. That proposed step does not mitigate the risks identified in the previous subsection.

    a. First, the new certificate would provide no protection for the five omitted sites identified by Donaldson.

    b. Secondly, it is arguable that unlimited drawdown is permitted under current AAPA Certificate C2019/083. Fortune has not proposed to apply for a new certificate covering both the existing subject area of C2019/083 and the entire drawdown area. Rather it proposes a new certificate that would only apply outside the existing certificate. It is not clear how the two certificates would interact, if one (arguably) permits unlimited drawdown and the other seeks to limit it in order to protect sites. There is potential for conflict between certificates and legal argument could ensue. That is an unsatisfactory position, not only for traditional Aboriginal owners and native title holders, but also for Fortune. The purpose of an AAPA Certificate is to provide certainty for all parties. Having two certificates that interact in unclear ways will not do that.

    c. Thirdly, the drawdown area remains uncertain and will keep expanding over time. By limiting the application for a new certificate to the currently predicted spatial extent of groundwater drawdown, sites outside of that limit will not be protected, even if the predictions are invalid. For the reasons set out in the section addressing the sensitivity analysis and predictive uncertainty of the groundwater model, it is inadequate to limit the extent of a sacred site clearance to the currently predicted drawdown extent. The clearance boundary must exceed the anticipated drawdown extent and allow sites in that outer region to be incorporated now into an appropriate monitoring regime.

88. The impact on sacred sites outside the subject area of AAPA Certificate C2019/083 could be better avoided if Fortune followed the steps set out in paragraph 84 above. Further, undertaking that work now (rather than at a later stage once the groundwater drawdown exceeds the boundaries of C2019/083), would allow those sites to be incorporated into an appropriate monitoring regime and increase the chance of avoiding any impact to them.

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[78] Fortune's NT EPA Referral "*Main Document*", p. 127

<u>5.5 – Groundwater Extraction Licence Conditions Precedent</u>

89. Condition precedent 10 (**CP10**) requires Fortune to develop a groundwater depended Aboriginal cultural values impact assessment. It was added to the Singleton Licence by Minister Worden on 15 November 2021 following submissions by the CLC and others about the Controller of Water Resources' failure to consider Aboriginal cultural values. The CLC and its clients had no input into the drafting of CP10. The lack of procedural fairness offered to Mpwerempwer about CP10 (and others) is a matter before the Supreme Court of the Northern Territory. Judgment in that matter is reserved.

90. There are a number of startling features of CP10.

    a. Although the cultural values are those of Aboriginal people, it is left to Fortune to do this work. CP10 imposes on Fortune no obligation to consult traditional Aboriginal owners, native title holders or the CLC. The only restriction is that the assessment must be prepared by a suitably qualified professional. To undertake such an assessment, the professional will need to have a relationship of trust and confidence with traditional owners and native title holders. That is likely to be strained if the person has been contracted by Fortune and is understood to be acting on Fortune's behalf. It would be preferable to direct Fortune to engage with the CLC and properly resource it to undertake some of the tasks identified in CP10.

    b. Furthermore, approval of the assessment is left entirely in Fortune's hands. CP10 requires that Fortune "*develop and submit to the Controller a groundwater dependent Aboriginal cultural values impact assessment*". By contrast, all other conditions precedent (except CP6 re salinity) require Fortune to "*develop and submit <u>for approval by</u> the Controller…*".

    c. The scope of CP10(b), (c) and (d) show the magnitude of the task that remains to be done. First, the Aboriginal cultural values must be identified, mapped and documented. Then reference points need to be identified to be used in modelling the impacts of groundwater extraction on those Aboriginal cultural values. Finally, monitoring parameters, trigger values and limits of change for adaptive management need to be determined.

    d. Any errors or omissions in the baseline studies, links to modelling or selection of monitoring parameters, trigger values and limits of change required by CP10 have real potential to cause significant impacts of the kind described in **Attachment M**.

91. The NT EPA has been asked to decide this referral before the large scope of work required by CP10 has been done. It would be appropriate for the NT EPA to direct Fortune to engage with the CLC about the substantive matters included in CP10, to take

the steps described in paragraph 84 and to mandate inclusion of that material in a full environmental impact statement for proper consideration by the NT EPA.

5.6 – Cultural Values Assessment and Impact Assessment

92. **Attachments L** and **M** are two reports commissioned by the CLC from an expert anthropologist, Susan Dale Donaldson. **Attachment L** is a report dated 1 September 2021 which identifies Aboriginal Cultural Values in the area of Singleton Station. It does not purport to be a definitive or exhaustive assessment: "*It is also possible that other sites exist within the drawdown area that were not identified during this assessment*."[79]

93. **Attachment M** is an addendum to Attachment L and assessed the impact of the Proposed Development upon the identified Aboriginal cultural values.

94. The Aboriginal cultural values identified by Donaldson extend beyond protection of sacred sites. The broad categories of values include:

    a. Following the *Altyerre* Law and cultural obligations;[80] and

    b. Maintaining spiritual connections and protecting sacred sites;[81] and

    c. Undertaking ritual associated with groundwater and GDEs;[82] and

    d. Upholding ecological knowledge associated with collecting natural resources; [83] and

    e. Continuing customary roles and responsibilities;[84] and

    f. Being able to live and travel on country.[85]

95. In its referral documents Fortune focuses solely on potential impacts to sacred sites and archaeological sites. Despite the CLC writing to Fortune and providing a copy of the Donaldson report (2021),[86] Fortune has not made any assessment of the potential impacts the Proposed Development will have on other Aboriginal cultural values. This is a significant omission that must be addressed as part of a full environmental impact assessment.

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[79] See Attachment L: Singleton Water Licence Aboriginal Cultural Values Assessment – Public Report prepared by Susan Dale Donaldson dated 01.09.2021, p. 10.
[80] As above, p. 25.
[81] As above, p. 29
[82] As above, p. 37
[83] As above, p. 42
[84] As above, p. 50
[85] As above, p. 53
[86] By letter dated 21.07.2022.

96. The two Donaldson reports, read together, are far more rigorous than that offered by Fortune in its referral documents. They provide a far more detailed understanding of the breadth of cultural values and their on-going exercise - and by way of extension, of the scope of possible impacts to them. Nevertheless, the author freely acknowledges that the assessment may not be complete.

97. While both reports need to be read in full, a summary of key conclusions in the Impact Assessment Addendum is as follows:

a. The Singleton Licence and associated drawdown has the potential to have significant impacts on each of the identified Aboriginal cultural values.[87]

b. The reduction in groundwater will cause negative consequences to cultural places and values held by Akwerlpe-Waake, Iliyarne, Anerre and Arlpwe people and their neighbouring tribal groups including factors associated with culture and heritage; human health; community and economy; aquatic ecosystems; hydrological processes; and terrestrial ecosystems.[88]

c. The potential impacts will likely or almost certainly result in highly significant cultural values to be lost, degraded and damaged, as well as notably altered, modified, obscured or diminished.[89]

d. Whilst an AAPA Certificate has been issued, the substantive risk of damage to, or interference with sacred sites on or in the vicinity of the AAPA subject land is highly likely, even if the sacred sites are covered by restricted work areas. Another highly likely consequence of harming sacred sites is the distress caused to the Traditional Owners. Both of these potential impacts are significant and not adequately addressed by approvals received under the Sacred Sites Act.[90]

<u>5.7 – Level of understanding and consultations</u>

98. According to Donaldson:

> *There has been extensive community engagement with Traditional Owners and other affected Aboriginal community members in relation to the proposal. The overwhelming community response is one of concern for future generations given the unknowns in relation to how the significant impacts will be managed in order to avoid catastrophic consequences (for people and country).*[91]

[87] See Attachment M: Addendum: Aboriginal Cultural Values Impact Assessment prepared by Susan Dale Donaldson dated 07.02.2023, pp. 27, 29, 33, 35, 38 and 41
[88] As above, pp. 2 and 46.
[89] As above, pp. 2 and 46.
[90] As above, p. 44.
[91] As above, p. 44.

99. That powerful conclusion is based on *her* consultations with traditional owners and native title holders.

100. By contrast, to the best of the CLC's knowledge, there has been very limited consultation of and engagement with Aboriginal people by or on behalf of Fortune.

101. The CLC facilitated one introductory meeting in 2019 to allow Fortune to introduce its representatives and the agricultural project. There was no discussion of the size of the water licence Fortune required to undertake the project. No free, prior or informed consent was given to anything at that meeting.

102. Between October 2020 and February 2021 the CLC consulted with native title holders about the project using information that was publicly available at the time. That information was not complete and was significantly less than has now been made available through the EIA process.

103. Fortune's representatives attended a meeting in Tennant Creek in February 2021. It was a CLC information meeting, not a substantive consultation by Fortune with native title holders.

104. At the February 2021 meeting the CLC was given instructions to scrutinise the Proposed Development and if necessary to take legal action to protect native title holders' rights and interests. Since shortly after that date, the CLC has been pursuing merit review and judicial review proceedings on behalf of Mpwerempwer. With the litigation on foot, it has not been appropriate for the CLC to facilitate consultations between Fortune and native title holders or traditional Aboriginal owners.

105. The CLC is aware of limited consultations by GHD on behalf of Fortune in Ali Curung during 2022. While acknowledging that CLC's information about those consultations is incomplete, some reports that reached us were concerning.

   a. The most clear recollection attendees had of the meeting was the "*teaspoon and bucket*" story. Some attendees did not understand the analogy and reported to us that Fortune must surely need more water than that. Other attendees understood GHD to have been saying that if the bucket represents the aquifer, then all Fortune needed was one teaspoon of it.

   b. If it is correct that such an analogy was used, that is concerning. The vivid image would stick in attendees minds while conflating the difference between aquifer storage and recharge, and ignoring the importance a "teaspoon" from the top of the "bucket" may make to key depth to groundwater measurements. Such an analogy is culturally inappropriate, misleading and oversimplifies complex groundwater matters.

   c. There were mixed reports of representatives door knocking in the community and perhaps being asked to leave. It is not clear to us whether that occurred.

Nevertheless it is important to understand that consultations of this nature should be done collectively in a public space, not individually in a private house.

d. While reports given soon after the meeting were relatively clear (especially about they teaspoon and bucket), recollections have faded in the months since. That demonstrates that underlying understanding of the Proposed Development based on consultations done by Fortune is inadequate for a project of such magnitude.

106. Donaldson concludes:

The capacity of affected community members to access and understand information about the proposal and the management of potential significant impacts is hindered by a lack of information required to enable informed decision making. As such, the level of community confidence in predicting and managing potential significant impacts to sacred sites and other important cultural values is low.[92]

107. While the CLC is prepared to facilitate consultations with traditional Aboriginal owners, native title holders and other affected Aboriginal people, it needs to do so in a way that empowers native title holders and does not exacerbate those issues identified by Donaldson. To consult properly, CLC must be armed with complete information about the Proposed Development well before consultations are scheduled. Full information must be provided freely by Fortune, but should also be tested by independent sources (such as by experts engaged by the CLC, but funded by Fortune) and the EPA through a full EIS. It must be done alongside the matters raised in the previous section about protection of cultural values and the empowerment of native title holders through that process. It must be done after the ongoing litigation has been resolved. It must be done with no pre-conceived outcome in mind if free, prior and informed consent is to be obtained.

PART 6: AQUATIC ECOSYSTEMS

108. The CLC notes that Fortune has only undertaken a desktop analysis to determine the possible presence of stygofauna in aquifers affected by drawdown. This analysis concluded that their presence was 'likely' [93] and that impacts could include 'localised extinctions and reduction in populations and communities' as a consequence of the 'predicted water level drawdown.' It went on to note that 'the species and community assemblages of stygofauna found within the aquifer will inevitably dictate the extent of the impact on the stygofauna community.'[94] Notwithstanding these conclusions, the referral documents ultimately concludes that the residual risks with respect to aquatic

[92] See Attachment M: Addendum: Aboriginal Cultural Values Impact Assessment prepared by Susan Dale Donaldson dated 07.02.2023, p 45.
[93] Referral Report, p. 82.
[94] Referral Report, p. 105.

ecosystems (including stygofauna) is 'low'.[95] The CLC submits that these two elements – the possibility of extinction and a 'low' risk profile – are difficult to reconcile.

109. The referral documents state that the assessment was confined to a desktop study due to the absence of suitably located registered bores from which to conduct appropriate monitoring and evaluation.[96] However, the CLC contends that the results of the desktop assessment, rather than being sufficient, actually indicate that further field work is required to properly determine the likely presence and potential impacts of the Singleton Licence. Existing bores (of which there are 110) in the local area could be used, or additional ones drilled if necessary. Indeed, this is precisely the sort of matter that ought to be properly investigated as part of a full EIS.

PART 7: GREENHOUSE GAS ASSESSMENT

110. The CLC notes that Fortune's greenhouse gas (**GHG**) assessment fails to include all Scope 1 and 2 GHG emissions for both the construction and operational phases. The GHG assessment omits at least:

a. burning of cleared vegetation during the construction phase (as detailed in Site Preparation and Establishment Plan);

b. emissions from landfill associated with the Community Hub;

c. fuel consumption for field operations to produce the crops (ploughing, planting, spraying, harvesting); and

d. the use of nitrogen (N) fertiliser for crop production (this should be included as a Scope 1 direct and indirect N2O emissions).

111. Unanswered questions include:

a. What would total GHG emissions estimates be if all Scope 1 and 2 GHG were covered (burning cleared vegetation, landfill from Community Hub, fuel use for field operations and the use of nitrogen fertilizer) through all phases of the project, using the Full Carbon Accounting Model (FullCAM) as consistent with the National Greenhouse Accounts (DISER 2021)?

b. What is the real value of land clearing emissions, when reported separately and not obscured by offsets which should be reported separately according to National Greenhouse and Energy Reporting standards?

[95] Referral Report, p. 118.
[96] Referral Report, p. 104.

c. What is the large amount of biomass composted in the Construction phase and why does this end during Operational phase?

d. What data assumptions have been used to verify transport and electricity emissions?

112. These matters are relevant to the Key Assessment Criteria for the decision currently before the NT EPA. They go to the level of confidence in the work undertaken by Fortune to assess the significance of impacts of the Proposed Development.

113. Fortune's referral documents mention a future PV solar plant which will reduce emissions. However construction and operation of a solar plant will necessarily require land clearing. No land clearing application made to date includes this component of the Proposed Development. The NT EPA ought to require all components of the project (particularly ones already foreshadowed, foreseeable and required to meet emissions targets) to be referred together, so that the cumulative impacts of the Proposed Development can be assessed.

PART 8: ECONOMIC ANALYSIS

114. Expert evidence included at **Attachments N, O** and **P** of this submission critically review the economic and social impact assessments supporting the business case for the Proposed Development.

115. **Attachment N** is an expert review of the Proposed Development's water entitlement provision costs benefits and employment impacts published in July 2022.[97] **Attachment O** is a peer review of Attachment N.[98]

116. In January 2023, the CLC asked the authors of Attachment N whether the Social and Economic Impact Assessments included in Fortune's referral documents caused them to change the views expressed in Attachment N. Their review of relevant referral documents is **Attachment P**,[99] which concludes:

a. the Economic Impact Assessment does not meet the NT and Commonwealth governments' standards, nor does it adhere to guidelines for Economic Impact Assessment of proposed projects;

[97] Attachment N, Review of the Singleton Horticulture Project's water entitlement provision costs, benefits and employment impacts, released by Connor J et al in July 2022.
[98] Attachment O, Peer review by Professor Quentin Grafton of UniSA's Economic Analysis report of the Singleton Horticulture Project, updated 7 July 2022
[99] Attachment P, Singleton Project Economic Impact Analysis: review in reference to the Connor et al (2022) critical review, by Connor, J et al.

b. optimistic assumptions were used to estimate public benefits, leading to overstated public benefit forecasts;

c. the Economic Impact Assessment omits social costs, including potential loss of groundwater-dependent cultural and spiritual benefits, thereby effectively assigning them a value of ‘zero’;

d. the Economic Impact Assessment did not account for the value of water entitlements that would be provided free of charge to Fortune;[100]

e. the Economic Impact Assessment uses unsubstantiated assumptions about potential flow-on benefits, which suggests exaggerated flow-on impact estimates;

f. the Economic Impact Assessment overstates employment benefits, which questionably assumes that there is, currently, a large pool of available skilled labour in the Barkly Region; and

g. the economic impact assessment contains vague statements about the Proposed Development’s public service and benefit provision without providing any financial commitment to support these claims.

117. These conclusions undermine the assumption that the purported economic benefits flowing from the Proposed Development justify or somehow ‘counterbalance’ its significant environmental and cultural impacts (and impacts on future generations). They also reinforce the need for far more rigorous EIA in the form of an EIS to ensure that economic analysis of the Proposed Development conforms with relevant guidelines – and that the methods applied and results obtained are made publicly available and are subject to further public comment.

PART 9: LEGAL ANALYSIS AND CONCLUDING REMARKS

118. In making these submissions, the CLC relies on the full text of each of the attached reports and other documents. The analysis presented in Parts 2 to 8 of this submission and in supporting expert evidence and literature demonstrates that:

a. the likely impacts on groundwater resources, GDEs, Aboriginal values and wellbeing, and biodiversity (including sandplain habitat) are likely to be significant and mostly irreversible;

[100] We note that this is inconsistent with one of the principles of ESD espoused in the EP Act, notably the principle of improved valuation, pricing and incentive mechanisms (s.24).

b. the underlying monitoring, modelling and surveying undertaken in relation to these matters is not based on best-practice and is not sufficiently rigorous, particularly given the unparalleled scale of water extractions associated with the Singleton Licence. As a consequence, impacts could far exceed those predicted. These matters require far more detailed and rigorous monitoring, data collection etc.;

c. there are fundamental flaws in the assessment undertaken in relation to salinity and the GHG assessment leaving key questions unanswered. Again, this could mean that impacts could exceed those predicted;

d. only a desktop analysis was undertaken to determine the presence of stygofauna and that based on this analysis, their presence is considered 'likely'. If they are present, the drawdown associated with the Proposed Development could result in localised extinctions. It is entirely feasible to undertake proper assessment via fieldwork (using existing or if necessary, new bores);

e. the adaptive management regime approved under the Singleton Licence is not a suitable mechanism for addressing the significant uncertainties associated with groundwater extractions of up to 40GL/year from 144 bores. In effect, it is being used as a substitute for rigorous, up-front EIA (which would simply not be acceptable in most other Australian jurisdictions);

f. the cultural values assessment work undertake by Fortune is substandard. Work commissioned by the CLC amply demonstrates that impacts on Aboriginal cultural values, sacred sites and wellbeing are more extensive and serious than acknowledged by Fortune in its referred documents. Further, the CLC's expert considered it highly unlikely that affected Traditional Owners had had the opportunity to properly grasp the scale of the development and its likely impacts on their country; and

g. the Economic Impact Assessment conducted by Fortune is based on a number of optimistic and/or erroneous assumptions and omits key facts and data. Overly optimistic assumptions about the likely socio-economic benefits flowing from the Proposed Development have been used to justify its significant environmental and cultural impacts, which is fundamentally flawed.

119. The evidence presented in this submission therefore demonstrates that:

a. impacts are likely to be significant – regulation 59(a);

b. there are unacceptable bands of uncertainty around the precise extent and nature of this significance due to insufficient and/or flawed monitoring, modelling and surveying – regulation 59(b);

c. mitigation measures are inadequate and/or ill-conceived, including in relation to groundwater, GDEs and cultural values – regulation 59(c);

d. community engagement by Fortune with affected Aboriginal people is limited – regulation 59(d);

e. affected Aboriginal communities do not have sufficient information at their disposal to fully grasp the scale and impact of the Proposed development – regulation 59(e).

120. It further demonstrates that there is a real risk of irreversible damage to groundwater, GDEs, sandplain habitat and cultural values and sacred sites, and that as a consequence, a precautionary approach must be taken (EP Act, s.19). These impacts also pose a threat to inter-generational and intra-generational equity (EP Act, s.21) and clearly undermine the conservation of biological diversity and ecological integrity (EP Act, s.23) and the sustainable and prudent use of natural resources (s.22). Notably, the best-available and most reliable evidence in the circumstances (the circumstances including the sheer scale of the Proposed Development and its likely impacts) has not been presented (EP Act, s. 20). The evidence also makes it clear that if EIA is to occur in a manner that promotes the objects of the EP Act (EP Act, s. 3) and the stated purpose of EIA (EP Act, s.42), far more rigorous assessment is required. Hence, and in light of the foregoing analysis, the CLC has formed the view that the NT EPA is legally obliged to undertake EIA in the form of a full EIS.

END

CLC CONTACTS

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ATTACHMENT A:

WESTERN DAVENPORT PLAN, ASSOCIATED DOCUMENTS AND GROUNDWATER MODEL REVIEW

Prepared by Dr Ryan Vogwill of Hydro Geo Enviro Pty Ltd

16 July 2021

WESTERN DAVENPORT PLAN, ASSOCIATED DOCUMENTS AND GROUNDWATER MODEL REVIEW

PREPARED FOR | Central Land Council - Northern Territory

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Contents

Definition of Terms

Depth of Groundwater (DGW): The depth from the ground surface to the water table. Synonymous with depth to groundwater (DTW).

Environmental (or ecological) water requirement (EWR): Descriptions of the water regimes needed to sustain the ecological values of water-dependent ecosystems at a low level of risk (Richardson et al., 2011).

Groundwater dependant ecosystem (GDE): Natural ecosystems that require access to groundwater to meet all or some of their water requirements on a permanent or intermittent basis so as to maintain their communities of plants and animals, ecological processes and ecosystem services (Richardson et al., 2011).

> **Aquatic GDE**: Ecosystems dependent on the surface expression of groundwater, also known as Type 2 GDEs (Richardson et al., 2011).
>
> **Terrestrial GDE**: Ecosystems dependent on subsurface presence of groundwater, also known as Type 1 GDEs (Richardson et al., 2011).

Hydrograph: Graphical representation of river or stream discharge or of groundwater-level fluctuations in a well (Richardson et al., 2011).

Regolith: The entire unconsolidated or secondarily recemented cover that overlies more coherent bedrock, that has been formed by weathering, erosion, transport and/or deposition of the older material. The regolith thus includes fractured and weathered basement rocks, saprolites, soils, organic accumulations, volcanic material, glacial deposits, colluvium, alluvium, evaporitic sediments, aeolian deposits and ground water (Craig et al., 2001).

Watertable: The top of the water surface in the saturated zone of an unconfined aquifer (Richardson et al., 2011).

Sources:

Richardson S., et al., 2011, Australian groundwater-dependent ecosystem toolbox part 1: assessment framework, Waterlines report, National Water Commission, Canberra

Craig M., Caritat P., Field J., Gibson D., Greene R. & Hill S., Jones M., Lintern M., Mcqueen K., Pain C., Pillans B. & Robertson I., 2001, The Regolith Glossary - Surficial Geology, Soils and Landscapes. Cooperative Research Centre for Landscape Environments and Mineral Exploration, Perth Editor: R. A. Eggleton ISBN: 0 7315 3343 7

Introduction

1. This report is a high-level review of the Water Allocation process in the Central Plains area as defined in the Western Davenport Water Allocation Plan 2018-2021 encompassing environmental water requirements (EWRs) for groundwater dependant ecosystems (GDEs), environmental impact potential, current impact assessment groundwater model and the Fortune Agribusiness application for a 40GL/yr allocation on Singleton station. It must be noted that the review of the modelling herein does not constitute a full model review as per the Australian Modelling guidelines (Barnett et al, 2012) which would be much more detailed with respect to the modelling. During a full model review the reviewer will typically have access to the model files if they request it.
2. My more than 20 years of technical expertise encompass groundwater modelling, water resource planning and recovery of hydrologically impacted ecosystems, with a focus on applying research to sustainable groundwater management and environmental impact/risk assessment. My curriculum vitae is in Appendix 3. This report contains my independent and expert views about the subject matter contained in the report. Within the limitations stated herein, I have made all the inquiries I believe are appropriate about the subject matter. No matters of significance which I regard as relevant have been withheld in the report.
3. As stated in the contract the purpose of the consultancy is:
    - To identify the assumptions underpinning the Fortune Agribusiness modelling for the Singleton water licence application
    - To assess the veracity of those assumptions and the reasonableness of extending the range of those assumptions beyond existing data.
4. A number of specific questions were also posed in my contract. These are set out in Appendix 4, and answered later in this report.
5. The next sections of the report are specific points identified during the review of various relevant documents followed by a summary. In the review sections for the various reports, the text in italics is that which has been extracted from the various documents which will be followed by my comments. Note that page numbers refer to the PDF file page numbers, not the page numbers in the footer of the document.

Summary

6. Fortune Agribusiness Pty Ltd (Fortune Agribusiness) have applied for and have been provisionally granted a licence of 40 GL/yr at Singleton Station which is to be released for use in 4 stages. The first stage is 12.788 GL/yr, second stage is an additional 10.057 GL/yr, third stage is an additional 8.934 GL/yr and the final stage an additional 8.221 GL/yr. These stages are proposed to be released every two years. The first stage of this licence is the largest of the proposal and is also the single largest allocation granted in the Central Plains area.
7. Water Allocation planning and model development for the Western Davenport Central Plains has been hampered (in terms of rigor) by a lack of spatially distributed data on aquifer geometry, lithology, hydraulic properties (particularly storage properties), water levels and water quality. Water level data with any useful time series (in the context of long-term predictive modelling) is lacking over much of the model domain, particularly in the regolith which is only an inferred (i.e. not based on any measured data) groundwater resource. Aquifer testing data is sparse and is typically restricted to short duration, single borehole tests which cannot determine storage properties. Storage properties are a key control on the relationship between abstraction and groundwater level change (drawdown) which is the key focus of the modelling and allocation planning.
8. The water resource and impact assessment presented is simplistic. From a water resource/hydrogeological and environmental impact perspective the biggest issues are:
   - Lack of drilling and aquifer testing in the Singleton Station area. Most of the previous groundwater investigations have been undertaken in the central and eastern parts of the Central Plains. Given the different aquifers in this area (which appear less prospective for groundwater i.e. Hooker Creek Formation etc) groundwater investigation results from the other parts of the Central Plains area are not transferrable to the project area.
   - Storage estimates are based on modelling alone (with no direct measurements of the aquifer's storage properties and ability to produce sufficient water at the site). If these estimates are too high then the basin's storage will be reduced substantially and drawdown impacts greater than predicted. Also, the storage properties are assumed uniform throughout all aquifers of the basin, which they will not be. The value of specific yield is likely too high for the fractured rock areas and too low for sediments near the surface including the alluvium. The bulk of water stored in the basin will be in the fractured bedrock. Confined aquifer conditions may also be present in the deeper aquifers so specific yield is not relevant as dewatering of confined aquifers does not occur, only changes in pressure storage.
   - Total storage is being quoted as a basis for an allocation limit but total storage (especially when so uncertain) is misleading as it's only the groundwater to 100-150m depth that is economically viable to abstract. Better to quote allocation in terms of accessible storage. This would reduce the relevant storage (accessible) to approximately 36,000 GL. If the total storage of the basin is 138,314.2 GL and the modelling indicates that no more than 3.9% of this can be depleted this equates to 5394.25 GL of depletion, which is 14.98% of the accessible storage across the entire Central Plains.
   - The regolith aquifer, which accounts for 30.7 GL/yr of the total of 112.7 GL/yr of sustainable yield, is based on no data as this has not been investigated directly. It is difficult to see how incorporating this in the available water resources for allocation is justified.
   - Lack of understanding of region-specific vegetation groundwater dependent ecosystems (**GDEs**) drawdown impact criteria and the use of criteria that are not consistent with those used in other jurisdictions. In the WDWAP and Guidance Document: *Limits of acceptable change to groundwater dependent vegetation in the Western Davenport Water Control*

District, all GDE areas with a depth to groundwater of 10m or less are lumped together with the same drawdown magnitude and rate impact criteria. Areas with considerably shallower depth to groundwater than 10m will be more highly groundwater dependant, hence impact criteria need to be more stringent. The Gnangara Mound GDE work from Western Australia done by Ray Froend and others, is seen as best practise and often applied in other areas. These management criteria have different drawdown rate and magnitude criteria for 10-6m, 6-3m and 3-0 m depth to groundwater areas with total drawdown and rate of drawdown criteria becoming more stringent as the depth to groundwater decreases. There is no justification presented for all GDEs with a depth to groundwater of 10m or less having the same drawdown impact criteria. There is also potential for groundwater dependence of vegetation at depth to groundwater of 20m or more.

- No assessment of risks to aquatic GDEs. A major gap in the allocation planning and impact assessment currently exists as aquatic GDEs have not been included and numerous sites with potential to contain aquatic GDEs exist. Aquatic GDEs are typically those with the greatest sensitivity to drawdown, particularly wetlands, springs, soaks etc which are often the sites of greatest biodiversity and highest cultural value. Impacts to Stygofauna also need consideration. According to the Bureau of Metrology GDE atlas (http://www.bom.gov.au/water/groundwater/gde/) there are numerous sites with potential to contain aquatic GDEs, a map of this is shown in Appendix 2.

9. Essentially it is unclear why the proponent needs to have a licence for nearly 13 GL/yr prior to having completed what would be considered the basic work required in other jurisdictions.
10. Allocation planning (as presented in the WAP and GDE-Guidance document for Western Davenport) presents estimated sustainable yield which involves aquifer depletion so by definition is not truly sustainable. Managed depletion is a more appropriate term for the overall philosophy of groundwater management, which is a more risky but commonly used philosophy in areas of low and/or episodic recharge. An assumption of 30% impact to GDEs from drawdown being acceptable seems like an arbitrary figure. No robust reasoning behind this is presented but may be in the references which are not publicly available. Until more detailed work is undertaken to determine which sites have the highest floristic/biodiversity values and if a 30% decrease in the distribution of these GDEs would have undesirable impact at a regional scale accepting impact to 30% seems a bit premature.
11. Environmental water requirements (EWRs) for terrestrial groundwater dependant ecosystems (GDEs) are presented based on work from other jurisdictions including the Ti Tree basin (more appropriate) and banksia woodlands (less appropriate) on sandy soils (Gnangara Mound). Vegetation community and soil type specific EWRs (namely rate and magnitude of drawdown criteria) need to be determined as the criteria being used are currently of only limited applicability. Application of some of the research that is being used for EWRs (for example the WA banksia work by Ray Froend and others as cited in Cook and Eamus (2018b)) is reasonable in the absence of better information but there will still be high levels of uncertainty about the applicability of these criteria and hence terrestrial vegetation GDE impacts. When approaching 100% allocation, robust site and species specific vegetation EWRs should be used.
12. The banksia woodland criteria from Gnangara Mound were developed based on 20 years of vegetation condition and groundwater level change information which gives an indication of the research effort required to determine these criteria with any degree of rigor.
13. To fill the environmental impact gaps identified herein will require (in my opinion) at a minimum:
    1. Ranking of relative importance of terrestrial vegetation GDEs that will likely require considerable additional survey/mapping work and subsequent analysis.
    2. Assessment of aquatic GDEs location, biodiversity and cultural value and EWRs.

3. This should be set in in combination with a regional groundwater investigation (including geophysics) and monitoring regime covering water levels and quality which will require additional drilling. It is important that monitoring of hydrology, hydrogeology and biology is done at the same sites and at a frequency/timing that ensures consistent overlap of these two datasets.
4. Determination of appropriate vegetation community specific and aquatic GDE EWRs
5. Development of an improved groundwater model to assess impact on new, robust EWRs.

14. I have worked on water allocation planning in areas of low data availability before and I empathise with the issues that the DENR are grappling with here. However, allocation of groundwater to anywhere close to the "sustainable yield" (approximately greater than 50% of the existing limit) will be high risk at this level of understanding. Especially considering that this level of allocation is predicted to result in depletion of water storage in the aquifer.
15. The allocation of groundwater is best done when the level of use is kept below the sustainable limit minus the level of uncertainty as shown in Appendix 1. The approval of the Fortune Agribusiness, Neutral Junction and other pending licences would exceed this safety margin considerably and the area would be near full allocation if the Strategic Aboriginal Water Reserve was taken up. Approval of all pending allocations would align with the allocation line A in Figure 1 of Appendix 1, not the desirable line B where allocation stays below the sustainable limit minus the level of uncertainty.
16. Adaptive management in the context of near full allocation limit immediately, with the current level of data and analysis, is fraught with risk that may result in undesirable impacts to the environment or big reductions in allocations that may have serious project feasibility or negative economic outcomes. The Murray-Darling is a good example of what happens and the cost of recovering water when areas are highly allocated prior to a rigorous understanding.
17. It may be useful for context to compare the Northern Territory process with the Western Australia Department of Water and Environmental Regulation (DWER) process. Western Australia is seen as a world leader in groundwater management due to that jurisdiction's high degree of dependence on groundwater. The first stage of acquiring a licence from WA DWER would be obtaining a 26D licence to install a bore and undertake aquifer testing. This work is required to be done before any licence decision. The level of assessment required from a proponent depends on a number of factors covered in Table 1 from Operational policy no. 5.12- Hydrogeological reporting associated with a groundwater well licence, Department of Water, Perth, November 2009.
18. My assessment of this project against those criteria for Stage 1 alone is as follows:
    - **Volume** for Stage 1 12.788 GL/yr any allocation larger than 2.5 GL/yr requires an H3 level of investigation. This equates to 20 points;
    - Current **level of allocation** (pre Fortune licence) is near 0 which is 0 points;
    - **Impacts to other bore** users likely is 5 points;
    - **Impacts to GDEs** likely is 5 points; and
    - **Salinity** is fresh (<500 mg/L) to marginal which is 4-3 points
19. This is a total 33-34 points and anything over 19 points requires an H3 level of investigation, which the current analysis competed by the proponent falls well short of.
20. H3 Tasks that are missing are the drilling, aquifer testing (hydraulic properties and water quality), GDE assessment (particularly aquatic GDEs) and more rigorous modelling than is currently presented. The WA DWER would also request that the model was peer reviewed as per Australian Groundwater Modelling Guidelines but this hasn't occurred in the Singleton case either.

21. It is only after all this work was provided to and approved by the regulator that a groundwater licence would be issued, even if that was for only 2.5 GL/yr, less than 20% of what has been licenced to Fortune Agribusiness in Stage 1 alone.
22. The modelling is not unreasonable but nor is it backed up by a rigorous dataset, in fact there are more gaps than there are areas with a high level of understanding. Many of the assumptions in the model (although not unreasonable) cannot be tested due to a lack of data. The model has not had a peer review, but it has been undertaken by an experienced modeller, however a formal peer review as per the Australian Groundwater Modelling Guidelines is appropriate given the allocation decisions being based on it.
23. Given the model has a very high level of uncertainty, as do the GDE impact criteria, it seems premature to do such a precise impact assessment of where impacts will occur and where they won't. Considerable conceptual uncertainty exists as many areas haven't been explored for groundwater (drilled and tested) so the numerical model's conceptual basis will likely need considerable refinement. Low amounts of time series data to calibrate against is also a serious concern for a long-term predictive model.
24. I would suggest use of the groundwater model and spatial predictive uncertainty analysis to get a feeling for maximum and minimum draw down predictions or even assess the range in drawdown predictions probabilistically. The modellers have produced uncertainty analysis for one hydrograph only – see figures at the end of this section. In that hydrograph the model predictions for 100 different hydraulic parameter sets are shown, this indicates the variability in drawdown predictions across a reasonable range in hydraulic parameters. PEST will automate this and produce a distribution of drawdowns and the probability of their occurrence across the entire model domain. This still has limitations due to the considerable conceptual model uncertainty but will give a better feel for best, worst and expected case drawdown predictions under the current conceptual model and a reasonable range of hydraulic parameters. The model files were requested so this could be undertaken but this has been refused by DEPWS. A simple definition of conceptual model uncertainty is that which arises from the model's design being inaccurate with respect to the actual aquifer geometry and processes that are relevant to the aquifer in question. A simple description of numerical model uncertainty is that which comes from the error in measurements and lack of data in time/space in the data used to build and calibrate the model. The reader is directed to Section 7.2 and 7.3 of the Australian Groundwater Modelling Guidelines (Barnett et al. 2012) for a more detailed description.
25. In the Western Davenports Water Allocation Plan it states on page 9: "Approvals for large groundwater entitlements greater than 2,000 ML/year are recommended to be subject to staged increases in groundwater entitlements."
26. I would agree this approach is prudent in a data poor area such as this, possibly the large allocations could be staged in 5 GL/yr entitlements with increases assessed every 5-10 years as better data becomes available. The Fortune Agribusiness licence is staged with increases occurring approximately every 2 years with nearly 13 GL/yr allocated in the first stage.
27. It is unclear if an Environmental Impact Statement (EIS) is to be prepared for the Northern Territory Environmental Protection Authority but I would strongly encourage this to be the case given the state of the current analysis and environmental and cultural values at risk. The EIS will need to be extensive and involve significant investigations to address current shortcomings.
28. Adaptive management is an over utilised framework to address project approval when insufficient understanding of impact risk exists. It is fraught with problems and there have been serious issues in this context in other jurisdictions. Adaptive management needs a really strong understanding of the water resource, biodiversity/cultural values and GDE impact potential to be successful, particularly in the long term. This project does not currently have this and it is unclear

if investigations proposed as part of Stage 1 will provide an appropriate level of understanding as the proposed investigations are not presented with any operational detail.

29. 5-10 years of data will be required to understand groundwater-environment-cultural linkages in sufficient detail to develop strong management criteria. Impacts may take considerable time to manifest (10+ years) but by then it will be difficult to restrict/reduce the project's water allocation as approval for the full licence will occur in a similar timeframe.
30. Given the infrequent and small amount of groundwater recharge in the area, if impacts occur that are deemed unsuitable, groundwater recovery may take decades if it occurs at all. Their own modelling predicts almost no recharge for nearly 60 years (2016 to 2076 Figure 10 of the WAP). Given the high degree of uncertainty independent peer review of the adaptive management framework (including all documents underpinning it) should be completed and distributed to stakeholders before it is accepted. It is difficult to see how any adaptive management framework will be able to deal with the current level of uncertainty prior to substantial additional investigations being completed. In my opinion such investigations will take 5-10 years to progress, if the required financial resources are available and the investigations were under way now.
31. Key stakeholders such as traditional owners need to be kept informed of and involved in this process in my opinion. Relying on proponents to complete regional assessments of cultural and biodiversity values is in my opinion a mistake, this work is best done by government to preserve confidentiality for both proponents **and** key stakeholders such as the CLC. Traditional owners and conservation groups are unlikely to want to work with a private company in the context of biodiversity and cultural values.
32. In short I have concerns over how this project will impact the area in the context of such a large allocation, for even Stage 1 of the project. I also have concerns over what seems a rushed approval process, with conditional license approval given prior to what would be considered the basics of investigation required in other jurisdictions.

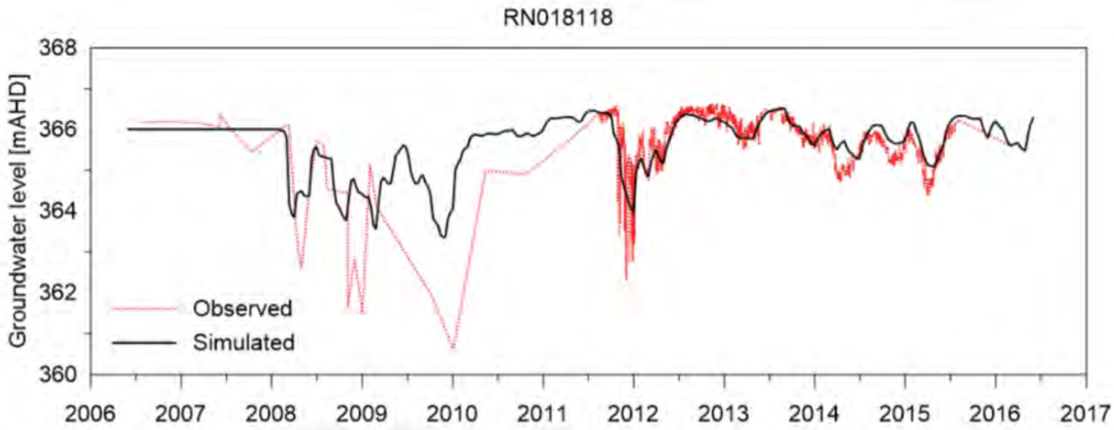


Figure 3-14 RN018118 groundwater level hydrograph showing response to groundwater abstraction with simulated groundwater response.

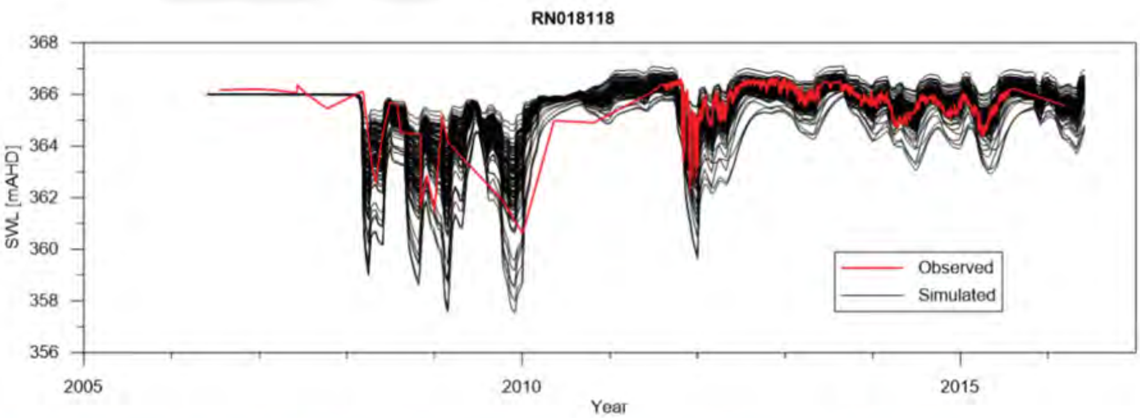


Figure 12-2 Results from 100 runs using null space projected random parameter sets.

Upper figure is the observed verses model simulated hydrograph for bore RN018118 (note the under prediction of drawdown) and the lower figure shows the observed data verses the range in model predictions under the PEST range of "plausible" hydraulic parameters.

Key Documents Review

Western Davenport Water Allocation Plan

Northern Territory Government (2018) Western Davenport Water Allocation Plan 2018-2021. Department of Environment and Natural Resources: Northern Territory, Australia.

> *Page 7 "It is recommended that accessing the consumptive pool for beneficial uses should not result in the depletion of aquifer storage by more than 3.9% over the next 100 years."*

33. 3.9% of storage depletion sounds small but what if this all happens in one small area? This will result in excessive water table declines which the WAP agrees can impact GDEs on page 27.

> *Page 8 "WDWAP recommends the following limits to change in groundwater conditions at GDEs caused by proposals to extract groundwater:*
>
> *• The maximum depth to groundwater does not exceed 15 metres.*
>
> *• The magnitude of change in the depth to groundwater is not more than 50%.*
>
> *• The rate of change of the groundwater table is not more than 0.2 metres per year."*

34. Depth to Water (DTW) maximum of 15m may not be appropriate at all GDEs and magnitude of change of DTW at 50% isn't widely used. This may be a surrogate for change in DTW and rate of change for the various antecedent depth to groundwater categories. Rate and absolute limit of drawdown (i.e. the other 2 criteria) are what other jurisdictions use but are presented as categories by which a risk can be prescribed to the drawdown (see table on the next page). It is important to note in this context that criteria should not be "all or nothing" in terms of impacts either side of a criterion. Greater magnitude and rate of DTW decline present greater risk of impact.
35. Section 5.2.1 Environmental water use identifies the research where the criteria are sourced from but these are not applicable for soaks, springs or wetlands (i.e. aquatic GDEs) which are a different type of GDE, typically more susceptible to drawdown, hence have more stringent drawdown criteria with often little to no drawdown acceptable at an aquatic GDE.

> *Page 9 "The onus will be upon proponents, through extraction volumes and design and management of proposed bore fields to demonstrate that groundwater extraction proposals can occur within the assessment criteria established in the WAP to protect GDEs and cultural values."*
>
> *"Approvals for large groundwater entitlements greater than 2,000 ML/year are recommended to be subject to staged increases in groundwater entitlements."*

36. The assessment criteria do not consider aquatic GDEs at all. A staged approach for large allocations is highly supported but the stages of 12.8GL/yr, then 22.8GL/yr, then 31.8 GL/yr, then 40GL/yr are very large. I would recommend smaller stages, preferably steps of 5GL or less.

> *Page 18 "The most significant groundwater resources are the Lake Surprise Sandstone, Arrinthunga Formation, Chabalowie Formation, and Dulcie Sandstone aquifers underlying the Central Plains Management Zone. Water stored in these aquifers is very old, having been in long-term storage for thousands of years."*

37. I don't agree, this is a bit simplistic, most groundwater maybe (particularly the deep groundwater) is old but there is clearly going to be some modern water around rivers wetlands

etc. where recharge is occurring and the water table is shallow. Section 4.3.1 Groundwater recharge talks about modern recharge occurring.

Table 2: Risk of impact level and magnitude of permissible change (m) for phreatophtyic vegetation.

Phreatophytic category	Low	Moderate	High	Severe
0-3m (wetland)	0-0.25	0.25-0.5	0.5-0.75	>0.75
0-3m (terrestrial)	0-0.75	0.75-1.25	1.25-1.75	>1.75
3-6m	0-1.0	1.0-1.5	1.5-2.25	>2.25
6-10m	0-1.25	1.25-2.0	2.0-2.75	>2.75

Table 3: Risk of impact level and rate of permissible change (m/year) for phreatophytic vegetation.

Phreatophytic category	Low	Moderate	High	Severe
0-3m (wetland)	0-0.1	0.1-0.2	0.2-0.3	>0.3
0-3m (terrestrial)	0-0.1	0.1-0.25	0.25-0.5	>0.5
3-6m	0-0.1	0.1-0.25	0.25-0.5	>0.5
6-10m	0-0.1	0.1-0.25	0.25-0.5	>0.5

Table of Gnangara Mound EWR criteria. Source Dr. R. Froend, R. Loomes, Dr. P. Horwitz, M. Bertuch, Dr. A. Storey and M. Bamford, 2004, Study of Ecological Water Requirements on the Gnangara and Jandakot Mounds under Section 46 of the Environmental Protection Act - Task 2: Determination of Ecological Water Requirements. Centre for Ecosystem Management, ECU, Joondalup.

Page 27 "The best available information (from banksias in Western Australia) suggested that woody plants can follow declining water tables at a rate of decline of 20 cm per year. Cook and Eamus (2018b) suggested that this is reasonable in the absence of better information."

38. This is risky as these are very different species (banksias primarily) and a very different soil type (deep sand typically). I've talked with Ray Froend about this numerous times (and was involved in doing groundwater modelling for his study on Gnangara mound) and he is very concerned how often his EWR and root elongation work gets used outside of its range of applicability (R. Froend, 2021, personnel communications, 15th of July). Ray also added he would have commented as follows about root elongation in the Central Plains area "This rate of root elongation is cited as one of the very few studies informed by direct measurement of root responses to declining water tables. More realistic rates for the study species/area would need to consider specific growth traits, water availability patterns and soil density. However, in the absence of site-specific data, the rates quoted should only be used as a tentative guide to what root response may be possible."

Page 33 Section 6.2

39. Estimated sustainable yield seems more like acceptable or managed drawdown as it clearly results in aquifer depletion and drawdown of nearly 20m. This could have significant impacts to GDEs and involves a storage loss so by definition is not "sustainable".

Page 35 Section 7.2

40. Agreed but should include an even greater focus around drainages/rivers, wetlands and other areas where groundwater seeps and springs will occur.

Page 36 "The inference that declining water levels would impact vegetation is based upon considerable evidence from other locations. There are no published experimental data available for Australian species that examine the impact of different rates of increase in depth-to-groundwater."

41. Should Australian in the paragraph from page 27 (underlined above) be changed to Northern Australian? The Froend work referred to on page 27 is difficult to apply in areas that are not the Swan Coastal Plain and banksia dominated woodlands on sandy soils but is work on Australian species. The species in the WAP area will have different environmental water requirements (EWRs) so I would recommend that the regulators move towards some local research to get more robust EWRs. This is identified in the text but is a plan in place? The Froend work required multi decadal data on groundwater levels and vegetation condition so it's a significant research effort over a long-time frame to achieve this.

Page 37-38 Section 7.4.5

42. This is a good list of additional work required to refine the modelling. I agree with it all but more investigations will be required to refine this modelling to the high level of understanding needed for the proposed level of allocation.

Page 38 Uncertainty in calculation of the ESY from regolith

43. The regolith is a critical issue as it is the connection between the surface and the groundwater (both ways) so is important for recharge estimates and understanding GDE vulnerabilities. There is no regolith targeted drilling, water level or water quality monitoring of groundwater to justify it as a basin wide aquifer with such a substantial proportion of the estimated sustainable yield. The regolith will exist but not everywhere and not with a uniform thickness.

Page 38 "Possible dependency relationships between GDEs and regolith resources could further limit the availability of this resource."

44. Totally agree.

Page 39 "In accordance with the NT Water Allocation Planning Framework, at least 95% of natural flow in Arid Zone waterways should be allocated to the beneficial uses of environment and non-consumptive cultural."

45. This is a surface water criterion. Note that 95% as a rule of thumb is ok but in the context of low flows being impacted consumption of 5% of natural flow (during a period of low flows) could still cause significant impacts. Important to recognise this as % of annual flow is a fairly coarse way to identify EWRs for surface water systems where intra-annual water distribution may be critically important.

Page 40 Section 8.1.3

46. The comment immediately above (para 45) applies to 8.1.3 also.

"For waterways it has been defined via modelling by Knapton (2017), as no more that 5% of total overland flow discharging from the respective management zone."

47. Table 12 should identify that the timing of water take may also be critically important for dependant ecosystem protection.

Page 43 "The Department of Environment and Natural Resources will monitor groundwater drawdown and the health and condition of a set of GDE reference sites to monitor the effectiveness of GDE protection approaches and refine the understanding of GDE groundwater interactions and dependence."

48. This is appropriate and could form the basis of more robust EWR criteria for vegetation communities that I've discussed above. Probably need 10+ years of data to give this scientific rigor. Is there a funded investigation plan in place?

Page 44 Section 8.2.3 monitoring triggers

49. Very terrestrial GDE focussed (vegetation); needs more consideration of aquatic GDEs such as rivers receiving baseflow, wetlands, soaks, springs, seeps etc.

Page 46 "Assessment of licence applications should be based upon modelling of the cumulative impact of groundwater extraction on aquifer levels."

50. Does this mean cumulative impact of only Singleton bores or all neighbouring bores (other groundwater licences) as well?

Page 46 "Rural dams with a bank height less than 3 metres and a catchment area of less than 5 km^2 are exempt from permit requirements. In accordance with the NT Water Allocation Planning Framework it is recommended that the interception volume of surface water on any property should be no more than 5% of the total estimated median annual run-off exiting that property."

51. Noting again that in some cases such as low flow years 5% of median annual runoff could have a significant impact on flows and dependant ecosystems. 5% of the median annual flow might be the entire surface water flow if it's only a 5% of median flow year.

Guideline: Limits of acceptable change to groundwater dependent vegetation in the Western Davenport Water Control District.

> *Page 6 "the probability of groundwater dependent vegetation (GDV) occurring has been modelled across an extensive area of Central Plains, based on time-series of relevant "greenness" and "wetness" indices derived from Landsat 8 satellite imagery."*

52. Is a report detailing the methodology available? Is this the "Singleton Horticulture Project Groundwater Dependent Ecosystem Mapping and Borefield Design" report by GHD? If so the methodology is only briefly discussed.

Page 6

53. It would be good to see the full detail of how the revised criteria were produced. Although the criteria acknowledge that different depth to groundwater classes would have different susceptibility to drawdown (i.e. differing degrees of dependency), why no criteria specifically for less than 5m?

Page 7

54. Has the depth to groundwater (DGW) data been generated by a model or contouring? It would be good to see the actual data points on these maps to give an impression of where this is constrained by data and where it isn't. Given the regional nature of the data set this DGW data is going to be inaccurate at a local scale. Also, the depth to groundwater areas <5m will likely be even more highly groundwater dependant than the 5-10m areas. The groundwater around the drainages running through the area likely have areas with a shallower depth to groundwater than 5m. There is also a strong likelihood of aquatic GDEs (wetlands, seeps, soaks etc) that no criteria have been presented for. The aquatic GDEs and depth to groundwater less than 5m will be the most sensitive areas for impacts from drawdown. The reasoning for this is well laid out in the Froend et al., (2004) report available here: https://www.water.wa.gov.au/__data/assets/pdf_file/0018/4644/82422.pdf.

Page 8

55. What is the basis for the 70% of GDEs must be protected threshold? Is this based on anything or a rule of thumb? Good to see some consideration to high value GDEs but agree it's going to be hard to assess what is high value until a considerable effort is made in terms of survey work.

Page 9

56. With respect to the 10-15m GDEs it is unclear why no maximum depth to water criteria (i.e. 15m) has been proposed as for the 10m category? There needs to be an absolute limit for water table depth at GDEs with a current depth to groundwater of 10-15m. If the depth to groundwater increases beyond the absolute limit (which is species/ecosystem specific) then vegetation will lose access to groundwater with typically severe impacts (vegetation condition decline and mortality). This is especially the case if groundwater decline occurs rapidly or during periods of reduced soil water availability. Also, these criteria do not make sense in the context of shallow DGW GDEs being more sensitive to drawdown, but the % decline criteria indicate otherwise.
57. For example, according to the GDE criteria on page 9 of this document for sites with DGW between 10 and 15m, a 36% decline relative to a baseline of no pumping for a 10.5m DGW site (impacted DGW 14.28m) is considered unacceptable. For GDEs occurring where the depth of groundwater is less than or equal to 10m, a 50% decline relative to a baseline of no pumping for a

9.5m DGW site (impacted DGW 14.25m) is considered acceptable. These are almost identical antecedent DGW but the shallower site experiences 4.75m of drawdown (acceptable) while the deeper site experiences 3.78m (unacceptable). Yes, the deeper site breaches one of the other criteria (10m DGW) but the % component of the criteria make no sense. There are other inconsistencies, for example a 9.9m DGW site would breach the criteria if it experienced a 0.2m drawdown. The shallower DGW sites are less tolerant of drawdown according to Froend et al., (2004) and would be at greater risk. If anything, these percentages should be reversed with 35% for the <10m DGW and 50% for the 10-15m DGW, but I would discourage the use of percentages at all.

58. Also given that the % criteria are relative to a natural baseline scenario with no pumping, this entails the use of groundwater modelling to separate the natural baseline from the pumping impacts. The current model cannot do this with any degree of rigor. EWR criteria are best focussed on measured data only as models are inaccurate, particularly when developed with little data. In terms of terrestrial vegetation GDE EWRs I would recommend the use of rate and magnitude of drawdown only, but for at least 3 classes of DGW (possibly 0-5m, 5-10m and 10-15m).

> *Page 10 "it is important that robust monitoring is implemented where changes may occur. Monitoring the health of GDEs may allow for the adaptive management of water extraction regimes, provided such adaptive management accounts for the potential time lags before significant negative impacts are detectable."*

59. Agreed, it's also important that good quality baseline data exists prior to any changes to ensure any impact areas are compared with the pre impact state. Is there an investigation/monitoring plan in place for this?

GHD, 2020, Singleton Horticulture Project Groundwater Dependent Ecosystem Mapping and Borefield Design.

> *Page 5 "The borefield configuration and pumping regime described in this report complies with DENR's criteria for acceptable impacts to GDEs."*

60. Unclear if this means in terms of adopting the criteria themselves or if the project meets those criteria (i.e. unacceptable impacts to GDES).

> *"This report provides an assessment of the percentage area of impact of groundwater drawdown on GDEs on Singleton Station and surrounding areas, across both sandplain and alluvial landforms based on the following inputs:"*

61. This should be terrestrial GDEs as they have not assessed aquatic. To assess aquatic GDEs requires an understanding of the seasonal proportion of the ecosystem's water inflow provided by groundwater, how the proposed abstraction would change that water availability and what the impact to the GDE will be of this altered water availability. The reader is directed to the National Water Commission's GDE Toolkit for more information on this complex subject area. http://www.bom.gov.au/water/groundwater/gde/GDEToolbox_PartOne_Assessment-Framework.pdf

"Currently understood depth to groundwater (DGW) contours provided by DENR"

62. Currently understood is a key point, worth noting that these are based on a coarse data set and at a local scale significant DGW discrepancies are certain.

Page 7-8

63. Why are there no absolute depth limit criteria for 10-15m DGW as there is for the 10m DGW GDEs? What about less than 5m DGW GDEs?

Page 9 "of relevant "greenness" and "wetness" indices derived from Landsat 8 satellite imagery" and Appendix A.

64. Unclear exactly how this methodology was applied, areas where relatively high normalized difference vegetation index (NDVI) and/or leaf area index (LAI) do not change significantly over time are often used as indicative of terrestrial GDE potential. This is particularly important to look at areas remaining with high NDVI/LAI after a prolonged drought.

"This had been set primarily at 70% and a secondary level at 50%."

65. 50% and 70% of what? Do you mean 0.7 and 0.5?
66. Also given the drawdown extends well outside of Singleton Station why has the landform mapping stopped at the station boundaries? Landforms should be mapped across the entire Central Plains to ensure that protected areas are representative at that scale, not the scale of the station.

Page 12 "The regional impacts of the proposed Singleton Station abstraction and the cumulative impact associated with existing neighbouring developments at Neutral Junction and Ali Curung"

67. Good that they have assessed cumulative impacts of these major allocations.

Page 19 Figure 4-1

68. What are the purple dashed lines on Figure 4-1?

Page 73 "It is clear from the analysis that the overall GDE impact of Scenario 28 does not exceed 20% in total, and the impact on the extensive sand plains landform remains comfortably below 20%. The alluvium however, whilst relatively small in area, is largely located in a small portion of the property near Wycliffe Creek and Thring Swamp, east of the Stuart Highway. It has been necessary to reposition the bore field further to the west than would be preferred, in order to reduce the impact on these alluvials to below the 30% threshold."

69. Yes, but the amount of uncertainty in the modelling (both conceptual and numeric) is considerable. This may be better done in the context of some groundwater model predictive uncertainty analysis so the probability of various levels of groundwater drawdown can be cross referenced with the terrestrial GDE maps and criteria.
70. A comment about impact figures and % generally. Given the model has a very high level of uncertainty, as does the GDE criteria, it seems premature to do such a precise impact assessment. Considerable conceptual uncertainty exists as many areas haven't been explored for groundwater (drilled and hydraulically tested) so the numerical model's conceptual basis will likely need considerable refinement (different parameter zones etc). Low amounts of adequate frequency time series data to calibrate against is also a concern.

CloudGMS, 2016, Development of a Groundwater Model for the Western Davenport Plains version 0.2

> *Page 3 "In the event that current and/ or projected consumptive use exceeds the threshold levels of 80% of the consumptive pool for aquifers, or groundwater discharges to groundwater dependent ecosystems are impacted, new groundwater licences will not be granted unless supported by directly related scientific research into groundwater dependent ecosystem/cultural requirements."*

71. No new licences would be one action but surely decreasing abstraction for existing licence would be required to reduce drawdown and allow for watertable recovery? At this point the system is nearing 100% allocated and we should have a much better understanding of regional hydrogeology and GDE interaction including dependant biodiversity and cultural values.

> *Page 3 "Based on the classification scheme outlined in the Australian Groundwater Modelling Guidelines (Barnett et al. 2012), the groundwater model presented herein is deemed to be Class 2. Based on the objectives of the modelling study this is considered appropriate."*

72. Is it Class 2 in the context of a lack of regional or time series data and a restricted understanding of GDEs their connectivity and EWRs? Aquatic GDEs have not been assessed. I think the model as Class 2 is debatable. After reviewing Table 1 I would suggest that some of the criteria could be debatable between Class 1 and Class 2. It also looks as though this model has not had a full peer review which I would recommend to ensure its construction meets industry best practise. Class 1 models have a simple level of complexity, Class 2 models are moderate complex and Class 3 are highly complex. Given the large volume of the allocation, the complex hydrogeology of the area and the abundant GDEs a Class 2 to Class 3 model is recommended. The reader is directed to the Australian Modelling Guidelines for a full description of model Class types and groundwater modelling generally: https://consultation.dplh.wa.gov.au/communications/14d86ef9/supporting_documents/Australiangroundwatermodellingguidelines.pdf

> *Page 3 "The extents of the modelled area have been determined from the surface water catchment that overlies the major aquifers in the central management zone of the Western Davenport Water Control District."*

73. Given the fractured nature of bedrock is this really a true no flow groundwater boundary?

> *Page 4 "The average root mean square error value of hydraulic head for the steady state model of the Western Davenport WCD groundwater system was 7.34 metres and the scaled RMS is 3.7%."*

74. RMS (RMSE) is ok but that is a high average error for a steady state model. Root Mean Square Error (RMSE) is the standard deviation of the model's prediction errors or residuals. Residuals are a measure of how far from the line of best fit data between observed and predicted data individual model predictions are. The high error of 7.34m in the steady state model shows that the current understanding is not accurately reflecting the water table elevation. Watertable elevation is of critical importance as it will control the distribution of areas identified as GDEs by their depth to groundwater.

> *Page 5 "The very large volume in storage is expected to provide a buffer to the impacts from groundwater abstraction provided development is not too close to areas sensitive to*

groundwater level decline. The robust nature of the aquifer system means an adaptive management approach can be applied where 5 – 10 year reviews of the water allocation plan would be appropriate."

75. Not near areas of intense abstraction where impacts can manifest much quicker than 5 years especially in areas where the model is later proved to be inaccurate due to a lack of data.

Page 43 "Whilst many bores have been drilled across the WDWCD they are not uniform in total depth, separation or reliability of the data, and, as such, do not provide an overall understanding of the extent, variability and characteristics of the main aquifers. There are clusters of bores in localised areas e.g. Alekarenge and Wycliffe Well, and only a relatively limited number of bores drilled into the deep Chabalowe and Arrinthrunga Formations aquifers."

76. This then limits the robustness of the model over a considerable area. Looks as though the regolith is not well covered as well.

Page 43-44 "Only a limited number of high yielding production bores have been drilled and test-pumped for short durations."

77. This very much restricts the accuracy of hydraulic property estimates at a regional scale.

Page 44 "The majority of bores have only been airlifted at completion of drilling. Such air-lift yields tend to underestimate the yield of the aquifer and are of little use in determining aquifer sustainable yields (and wellfield yields or capacity)."

78. Agreed, hence storage properties are very uncertain as these cannot be calculated from single borehole tests (i.e. are based purely on PEST calibration). Storage properties will be a critical control on abstraction verses drawdown, i.e. high storage reduced impacts; low storage greater impacts.

Page 81

79. No limits put on storage properties during PEST/calibration? Table 35 in the appendix indicates they were.

Page 114 - Transient Calibration

80. No graph of observed verses predicted head for transient calibration is presented and this would help understand if the RMSE of 1.98m is a good fit or not. This is a much better RMSE than for the steady state model. The way predictive data match the observed data and if the trend is following the line of best fit at individual bores are all important, but only predicted verses observed hydrographs are presented. This is likely due to the fact that the way the model's calibration has been focussed on key hydrographs (RN018118 for example which looks to be slightly underestimating drawdown impacts) due to a lack of spatial and temporally continuous data.
81. Looking through the calibration hydrographs in Appendix A there are concerns over some of the hydrographs where observed and predicted data do not match particularly well. This would be something that a full model review would look at in more detail.

Page 139 - Conclusions "Specific yield averaging 0.04 in the model domain have been determined through calibration."

82. One of the biggest concerns I have about the model is the storage properties as this is a critical control on the relationship between abstraction volumes and drawdown. If the specific yield is lower, then drawdown impacts will increase. Given the variation in lithology, specific yield will vary as well but there isn't enough data to get to this level of hydraulic parameterisation.

Page 139 "The calculated values for hydraulic conductivity and specific yield do not represent a unique modelled solution, but are considered the best estimates from the available data."

83. Agreed, what is the range in drawdown impacts under a reasonable range in ALL saturated hydraulic parameters (K, Kx/y, Sy Ss at a minimum).

Page 139 "There is no evidence that the groundwater flow system is constrained by aquitards or structural feature with the groundwater moving freely across the different formations. The basin aquifers can be regarded as a relatively contiguous system that responds isotropically to recharge and pumping stressors"

84. Given the lack of basin wide geophysics investigation and spatially distributed, appropriate quality aquifer testing (i.e. not single borehole air lift tests) this is still uncertain. Fractured rocks will definitely have at least some form of anisotropy (ie hydraulic conductivity (K) varies in different directions x,y,z). Some longer-term aquifer testing data could help identify recharge and barrier boundaries also.

Page 139 "Demand will be met primarily from storage.

Total groundwater storage in the area modelled is large, and is estimated to be around 145,000 GL at the end of the natural model scenario in 2015. The majority of groundwater is stored in the central zone and is estimated to be 141500 GL.

Assuming a maximum economic depth of groundwater abstraction of 150 metres below ground level, the accessible volume in storage in the saturated zone is about 36000 GL."

85. Yes, but storage properties are the least robust of all the model's hydraulic properties in the saturated model. Again, how does this storage vary under a reasonable range of storage properties?

Page 140 - 10.3 System sustainability.

86. Under this set of hydraulic parameters the report is drawing this conclusion, but given that PEST has been run can sustainability not also be assessed probabilistically as a range of drawdown predictions under a reasonable range of hydraulic parameters? This is a very non unique solution and the author clearly recognises this.
87. Final Point: Note that this review does not constitute a full model review as per the Australian Groundwater Modelling Guidelines.

Department of Environment, Parks and Water Security (2021) Groundwater extraction licence resource assessment - AG06221 - Singleton Station

Page 29 - The quality of the underlying groundwater available to Singleton Station, specifically in terms of salt content, may be considered to be significant. Sampling of bores on and near Singleton Station indicate groundwater salinity is approximately 700 to 900 mg/L (as total dissolved solids). For this application, the irrigation of 40,000 ML p.a. of groundwater would bring 28,000 to 36,000 tonnes of dissolved salts to the surface annually.

Nonetheless, it would be prudent to undertake a study of salt availability and its potential movement in the unsaturated zone. A recent study near Alice Springs (see Cook et al., 2017) indicated that the mobilisation of unsaturated zone salts could present an issue to the long term viability of the water supply if it is sourced from beneath the crops, as well as representing a threat to the integrity of the groundwater resource.

Recent deep drilling on Singleton (RN019452) and Murray Downs (RN019681) indicates that the salinity of the groundwater increases with depth. The density difference of the higher salinity water at depth creates a potential for vertical movement (upconing) under a groundwater pumping regime. The potential impact of this is not quantified due to limited data and knowledge of the system at depth.

88. Important estimate of salt load reinforcing the need for a detailed assessment for both soil salinity and groundwater salinity under irrigation. Salinity interface upconing will need purpose designed monitoring infrastructure. The regulator has requested this be done, but it is unclear what the scope is.

Page 30 - Data and knowledge gaps have been identified through the assessment, model development and output analysis processes. Some of the critical issues are identified below:

• There is inadequate spatial coverage of groundwater levels across the model domain.

• There are limited monitoring bores with data coverage that spans the planning timeframe. This data is critical to the eventual analysis of modelling output presented in this report.

• Metered groundwater- extraction data is limited.

• There are gaps in knowledge regarding the basement topography, and continuity and consistency of the aquifer across the region. This affects the aquifer's hydraulic characterisation and representation in the model.

89. These dot points all indicate an insufficient investigation, data and analysis.

Page 33- Due to limited stratigraphic drilling this groundwater system, aquifer thicknesses and hydraulic properties (storage and permeability) are poorly constrained. This uncertainty will ultimately result in modelling uncertainty that cannot be easily quantified.

90. This again indicates insufficient data. The conceptual uncertainty is difficult to quantify yes but the numerical uncertainty can be quantified across the model domain but hasn't. Figure 12-2 in Cloud GMS (2016) shows that some elements of uncertainty analysis have been completed but only one hydrograph is presented. To undertake an analysis of numerical uncertainty requires access to the model files and suitable software to undertake the analysis such as PEST. A useful description of model uncertainty is given in Middlemis and Peeters (2018) Explanatory Note,

Uncertainty Analysis in Groundwater Modelling. They identify four sources of scientific uncertainty affecting groundwater model simulations:

- Structural/Conceptual - geological structure and hydrogeological conceptualisation assumptions applied to derive a simplified view of a complex hydrogeological reality (any system aspect that cannot be changed in an automated way in a model);
- Parameterisation/Numerical - hydrogeological property values and assumptions applied to represent complex reality in space and time (any system aspect that can be changed in an automated way in a model via parameterisation);
- Measurement error/Numerical – combination of uncertainties associated with the measurement of complex system states (heads, discharges), parameters and variability (3D spatial and temporal) with those induced by upscaling or downscaling (site-specific data, climate data);
- Prediction/Scenario Uncertainties - guessing future stresses, dynamics and boundary condition changes (e.g. mining, climate variability, land and water use change).

91. The reader is directed to both Middlemis and Peeters (2018) and the Australian Groundwater Modelling Guidelines (link previously provided) for a full description of these concepts.

Cook and Eamus (2018a) The Potential for Groundwater Use by Vegetation in the Australian Arid Zone

Page 5 - In arid zones, use of groundwater by vegetation is likely to be much more widespread than in more humid climates, due to the scarcity of other water sources.

92. Agreed and an important point to consider in the context of greater GDE impact risk in arid zones.

Page 5 - Soil water potential data suggests that many trees have roots concentrated within the top 6 – 8 m of the soil profile, but also provides evidence of water extraction by roots to 15 m depth in areas where water tables are more than 20 m deep.

93. This statement is indicating evidence of groundwater use at 20m depth to groundwater. Therefore, is 15m really the most appropriate cut off depth for groundwater dependence? 20m is a more conservative approach. Areas with depth to groundwater of up to 20m should be included in the GDE impact assessment. See comment below on page 7 of this report.

Page 6 - The results show clear evidence of groundwater use throughout the basin in areas with water tables of 12 m or less, and evidence of soil water uptake from 15 m depth in areas where the water table is deeper. Although there is some evidence of soil water use from deeper than 15 m, the volume of groundwater extracted from these depths is likely to be small.

94. Volume of groundwater use is small at groundwater depths greater than 15m but again this suggests 20m might be a better cut off.

Page 6 - E. camaldulensis also access groundwater, and tend to occur in riparian areas and where perched shallow aquifers are present.

95. Alluvial aquifers are not necessarily perched. Perched implies there is a disconnected aquifer that the vegetation is dependent on. In the case of the Western Davenport area there is no site specific drilling or other evidence presented to indicated this is the case. I think perched aquifers in riparian areas would be the exception not the rule as they are in my experience rare. The perched aquifer referred to is in the Ti Tree Basin (Woodforde River) not Western Davenport. It is not justified to assume that all riparian areas are perched aquifers and this is possibly why they have excluded aquatic GDEs from their assessment.

Page 7 - The Ti Tree results are supported by studies at Rocky Hill, south of Alice Springs, where soil water potential profiles show extraction of soil water to at least 10 m in places, with some evidence of extraction to 20 m;

96. Again, this supports groundwater dependence potential to 20m depth to groundwater.

Page 9 - A conceptual framework for management of groundwater-dependent ecosystems (GDEs) has been devised for Australia (Clifton and Evans, 2001), and comprises four steps: (i) identify potential GDEs, (ii) establish the natural water regime of GDEs and their level of dependence on groundwater, (iii) assess the environmental water requirements of GDEs, and (iv) devise water provisions that will deliver these environmental water requirements. Subsequent work has further developed this framework, and also compiled and summarised the various tools that can be used for GDE assessments (Clifton et al., 2009; Richardson et al., 2011). However, despite these efforts, GDE assessments have generally stalled at the first *stage of the process, and have not progressed through the three subsequent steps of the conceptual framework.*

97. I'm very familiar with all of this literature and the Western Davenport is yet another case of a GDE assessment stalled at the first stage of the process. What are the plans from government or the proponent to complete the rest of the stages? The Cook and Eamus report gives an excellent overview of the techniques that should be applied.

Page 16 - For relatively fine textured soils, such as clay loams and silty clay loams, upward fluxes of more than 1 mm y^{-1} can occur even where the base of the root zone is more than 10 m above the water table.

98. These would be the common soils in many parts of the Western Davenport area away from the alluvium. This again reinforces that groundwater use might be occurring up to 20m depth to groundwater.

Page 19 - Dresel et al. (2010) were able to identify all pixels across a catchment that had a very high probability of being a GDE. Significant ground truthing was required to assess the validity of this method.

99. Likewise, with the methods applied in the Western Davenport area, what are the plans to validate and ground truth the remote sensing data/analysis?

Page 30 - Plant longevity was significantly and independently correlated with depth-to-groundwater. Thus, as depth-to-groundwater increased the proportion of perennial species increased and the proportion of annual species decreased.

100. If groundwater access is removed through drawdown then perennial vegetation may see condition decline and/or mortality but understorey species may not recruit at these sites and grasses/weeds would become dominant. If this happens important understorey vegetation species may become reduced in its distribution or locally extinct, impacting floristic biodiversity values directly. Grasses and weeds may not support fauna species dependant on individual GDEs causing further biodiversity impacts.

Page 59 - Consequently we do not know whether changing the natural groundwater depth regime at any site with depths less than 10 m will induce significant changes in ecophysiology or ecology. Only an experimentally induced change in depth that is maintained for many years will offer insight to the changes that may occur in response.

101. This highlights the long term (many years) and complicated nature of determining GDE impact from groundwater drawdown.

Page 59 -

For example, two recent reviews based on water balance approaches concluded that groundwater uptake ceased when depths exceeded 7.5 m (Benyon et al., 2006) or 8–10 m (O'Grady et al., 2010; Figure 32). Kath et al. (2014) identified thresholds of groundwater depth of between 12.1 and 26.6m across 118 sites in south-eastern Australia (within the Murray-Darling Basin) for two tree species. Thus, the existence of a threshold appears reasonable – but it appears to be site and species specific.

102. This reinforces the fact that thresholds are site and species specific. Groundwater use is entirely possible (until disproved at a particular site) to depth to groundwater of 20m or more based on this Cook and Eamus report.

Cook and Eamus (2018b) Treatment of GDEs in the Ti Tree and Western Davenport Water Allocation Plans.

Page 3 - This report reviews recent DENR attempts to map groundwater-dependent vegetation (type III GDEs, using the classification above) and assess likely impacts of pumping on vegetation in the Western Davenport region.

103. This confirms that the EWRs are focussed on groundwater dependant vegetation only with no consideration of type I or type II ecosystems which are also possible in the Central Plains area. The other two types of GDEs are:

(I) Aquifer and cave ecosystems where stygofauna reside. This class also includes the hyporheic zones of rivers and floodplains. The hyporheic zone is the region of porous sediment beneath and alongside a stream bed, where there is mixing of shallow groundwater and surface water.

(II) Ecosystems reliant on surface expression of groundwater. This includes base flow rivers, streams and wetlands, springs and estuarine seagrasses.

Page 4 - Indirect methods for mapping groundwater-dependent vegetation have three main limitations. The first is that areas of relatively high growth rate or good vegetation condition might exist for reasons other than access to groundwater. Possible alternative explanations include variations in soil type, or areas which receive surface water run-on from adjacent areas.

The second limitation is the spatial mismatch between the pixel size of widely available remote sensing imagery and the size of some GDEs. This can be problematic for mapping small wetlands associated with springs, and small waterholes that can be less than a few square metres in aerial extent.

It is also likely to be a problem for the open woodland systems that are characteristic of arid Australia, as it may only be individual species within the ecosystem that are groundwater dependent, and the canopy of an individual tree may be insufficient to influence the signal. In these landscapes, seasonal variability is often dominated by a dynamic herbaceous grass layer and this is strongly coupled to the timing and amount of rainfall, not groundwater availability. This strong seasonality of the grass layer can mask any GDE signals from the tree layer, thereby making the detection of GDEs problematic.

104. This highlights some of the limitations with the indirect techniques (remote sensing used by GHD) for identifying GDEs in the project area. They also talk about perched aquifers but we still have no proof that these exist in the project area. If an aquifer is perched then it won't be impacted by regional groundwater drawdown but to prove this requires evidence.

105. The type of GDEs identified in the second paragraph above are likely to have high degrees of biodiversity and cultural significance. The third paragraph suggests that not all species in a particular vegetation community or occurrence may be groundwater dependant so they may not show a high continuous vegetation density, hence will be missed by the currently applied methods.

Page 5 -Decile ranking values of 4-7 were chosen as diagnostic of GDEs, as these values would reflect areas that have a moderate reflectance in June-August 1994. The logic for this approach is unclear, as groundwater dependent vegetation would be expected to have lowest greenness during the period of lowest rainfall (relative to other years), albeit higher greenness than vegetation that are not using groundwater (see Figure 1). A better approach may have been to examine the variance of reflectance across the baseline period, and identify pixels with lowest variance over that period of time.

106. I agree with these points as the choice of June-August 1994 (the driest season on record) is not the most appropriate period for this method of GDE identification. The GHD (2020) study uses a data set from 2014-2019. Have Cook and Eamus reviewed the GHD (2020) study?

Page 6 - The Green Island mapping uses Landsat imagery, with a pixel size of 30 m x 30 m. Based on analysis of Google Earth imagery, the crown size of overstorey trees within open woodlands of the Ti Tree and Western Davenport regions is mostly 5 – 10 m diameter. This is likely to pose limitations on the analysis as outlined above.

Duguid observed that pixels identified as 'persistently green' by Green Island mapping were mostly areas where there was a cluster of potentially groundwater-dependent vegetation (e.g., C. opaca), but that apparently similar clusters of trees were not identified. This probably partly reflects the scale of the remote sensing method, which is too coarse to identify individual groundwater-dependent trees, and will only identify clusters of trees if they cover a large proportion of individual pixels (Figure 2).

However Duguid (2017b) also notes that some trees that are identified in the Green Island mapping are understory shrubs (including Acacia species) or ironwood, none of which are currently suspected of being phreatophytic. The Green Island mapping may therefore just be detecting pixels that have a high proportion of evergreen trees relative to bare soil or grass cover.

107. The techniques GHD have applied have the same spatial resolution shortcomings.

Page 7 - Persistently green vegetation overlying groundwater deeper than 15 m is assumed to be dependent on surface run-on rather than groundwater, and are hence classified as IDEs.

Use of water table depth is a pragmatic approach for discriminating between GDEs and IDEs, but requires accurate water table depth maps. In the Western Davenport Basin, bore data is scarce in some areas, and so the accuracy of the water table depth maps may be low, but is difficult to quantitatively assess.

108. IDEs are inflow (surface water) dependant ecosystems which I agree could be creating "green islands" picked up by the remote sensing. However the poor watertable elevation data coverage is likely to be introducing significant errors in the extrapolated watertable elevation data. So areas currently not identified as having a depth to groundwater <15m may meet this criterion and be groundwater dependant but are just not being identified. Other issues with the current depth to groundwater mapping are identified on page 7 of Cook and Eamus (2018b) and I agree with these issues.

Page 8 - Prioritising GDEs for Protection

Prioritisation of GDEs would appear to be particularly important in arid regions, where groundwater-dependent vegetation could be widespread across Water Allocation Plan areas. This approach is beginning to be adopted in NSW, where GDE mapping seeks to identify "high-value groundwater dependent ecosystems", and these are prioritised for management purposes (e.g., NSW DPI, 2017). Four criteria are used for assessing value: diversity, distinctiveness, naturalness and vital habitat (NSW DPI, 2016).

Criteria used for prioritisation of GDEs may vary across jurisdictions, and depending on GDE type, but should include:

- *Rarity of ecosystem and any fauna that it supports (e.g., presence of endangered or endemic species or subspecies)*
- *Pristine nature of ecosystem (current level of degradation)*
- *Cultural values of ecosystems*

Page 12 - There is some species-level knowledge of GDEs within the Ti Tree basin, although there has not been any mapping or prioritisation of ecosystems. The focus of the work to-date has been identifying species which are groundwater-dependent, rather than their distribution across the region.

109. Agreed and have raised this point previously. This has not been addressed and I see no evidence of it being addressed in the licence conditions.

Page 9 - Whilst theoretically it would be expected that roots should increase their rate of elongation in response to increases in water table depth, the Canham et al. (2015) study in Australia found little evidence that this was true.

Of course, it should be noted that timelags between declines in groundwater level and ecosystem impact can occur, as access to groundwater may only be important at certain stages of plant growth and/or during periods of very low rainfall. This means that the absence of observable declines in ecosystem condition in areas with declining water tables should not be taken as evidence that such declines in groundwater level will not eventually impact dependent ecosystems.

110. These are important points that I agree with. The rest of page 9 talks about the rate of root elongation that is a critical control for rate of drawdown criteria and how there are large gaps in this research for Australian species.

Page 10 - Thus, the method assumes that lowering the water table from 5 m to 13 m will not impact vegetation, but that lowering the water table from 14 m to 16 m will have a negative effect. The proposed approach thus poses a risk to GDEs in areas with shallow water tables (0 – 8 m), and probably over-estimates the risk to ecosystems in areas of intermediate water tables (10 – 15 m).

Page 11 -Although with current knowledge, the magnitude of the permitted decline is likely to be somewhat arbitrary, it should follow the principle that GDEs in shallow water table areas are likely to be more sensitive to water table decline than GDEs overlying deeper water tables.

111. Agreed and again I have raised this issue previously in that more depth to groundwater categories are required and the shallower the depth to groundwater the higher the degree of

dependency is, consequently drawdown (both rate and absolute change) need to be more stringent for shallow GDEs.

Page 11 - In the absence of detailed and species specific studies on acceptable rates of decline in the water table for central Australian species, the best way of setting rates of decline may be to examine bore data and determine historical rates of decline (for each season) that did not appear to induce negative impacts on vegetation structure and function (assessed through concurrent RS analyses).

112. This is a good approach but I don't think has been applied. It's likely that there is not enough data to undertake this however.

Page 12 - It is recommended that the WAP proceed on the basis that there is insufficient knowledge to determine the locations of GDEs, the timing and extent of dependency, the sensitivity of each GDE to changes in depth-to-groundwater or the risk to them, and specify that allocation and licence decisions will be conditional and subject to amendment as new hydro-ecological and GDE knowledge becomes available.

113. Agreed but also would add that there is not enough data on GDE condition or depth to groundwater to currently improve our understanding to a level I believe is appropriate for groundwater management. Substantial amounts (10 years +) of hydrogeological and biological data collection at existing and new sites will be required to improve this in my experience.

Cook and Eamus (2018c) GDEs in the NT Arid Zone Further Investigations, Monitoring and Research.

114. No specific points from this report are raised as it would make the review herein more repetitious as much of this comes from their other two document but this is an excellent summary of the work required to get to an appropriate level of understanding for groundwater management. Only recommendations 1 and 4 in Cook and Eamus (2018c) have been addressed to any degree in the GHD (2020) study but the rest haven't had any progress from what I can see. Recommendations 1 and 4 have only been progressed to some degree. Many of the Cook and Eamus (2018c) recommendations require data that doesn't currently exist and will take years (10+ in my opinion) to collect and analyse. Little detail on the investigations required is contained in the licence conditions so this leaves little certainty as to what is proposed to breach these considerable knowledge gaps.

Northey, Smith, Clark, Hostetler, Parige, McPherson, & Clarke, 2020, Exploring for the Future—geological and hydrogeological investigations in the Western Davenport region: Northern Territory.

> *Page 13 - Although the Wiso and Georgina basins are inferred to be continuous across the WD region (e.g. Kruse et al., 2013), there are multiple lines of evidence that suggest that this may not be true.*
>
> *This hampers any assessment of stratigraphic continuity between basins and has led to the boundary between them being arbitrarily defined as a straight line in the vicinity of the road and rail corridor.*
>
> *Finally, although some inter-basin lithostratigraphic correlations can be made, stratigraphy varies between the Lander and Dulcie troughs of the Wiso and Georgina basins, respectively.*
>
> *Thus, although it is likely that the Wiso and Georgina basins are continuous beneath Cenozoic cover in the WD study area, further data are required to confirm this.*

115. This highlights the lack of hydrostratigraphic units which bridge the two basins but the groundwater modelling has this as an assumption. If this is not the case and there is a flow boundary, or less productive aquifers in the Wiso Basin, drawdowns could be much higher than currently predicted around the proposed Singleton bore field. A hydrostratigraphic unit is a body of rock that forms a distinct hydrologic unit with respect to the flow of ground water and exhibit similar hydraulic properties.

> *Page 52 - There is evidence from the neighbouring Ti Tree Basin of significant groundwater use by vegetation in areas where the water table is 12 mbgl [metres below ground level] or less, with some evidence of groundwater use at depths of 15 mbgl to 20 mbgl (Cook & Eamus, 2017).*

116. Agreed which is further corroboration of vegetation's groundwater dependence potential at depths to groundwater of up to 20m.

Answers to Questions in Brief

The questions are repeated below for ease of reference and the answers are below each question (a).

1. Is there sufficient data to base a 40 GL allocation decision?
    a. This is a subjective question but in my opinion it's marginal for this allocation alone but when considered in combination with all other currently proposed allocations and the lack of understanding of environmental impact risk my answer is no. The lack of data, the current uniform storage assumed for all aquifers, lack of robust EWRs, lack of identification and inclusion of aquatic GDEs in the impact assessment and lack of predictive uncertainty analysis poses an unacceptable level of risk to the water resource, the environment and cultural values.
2. What are the ranges of plausible assumptions associated with the application? There is no drilling data to confirm aquifer characteristics are as assumed, particularly in Cambrian aquifers west of highway.
    a. I think I have covered this in the specific points raised in review of the various documents and the summary. With the current lack of data (see the summary) there is considerable uncertainty in all model predictions and aspects of the conceptual model.
3. What if the Wiso basin Cambrian is a much poorer aquifer than model assumes, for instance less storage, poorer hydraulic conductivity would be greater drawdown etc.
    a. Yes all of those scenarios would result in greater drawdown and change the area of impact.
4. What evidence exists for assumptions of direct recharge across aquifer? If in reality direct recharge is limited to creek lines in the Cainozoic then realistic recharge estimates would be much smaller.
    a. Hydrographs show distinct evidence of episodic recharge away from creek lines, recharge will be higher around creek lines (which receive incident rainfall as well as surface water flow both of which can produce recharge) but there is not data available to assess recharge near creek lines. The direct recharge away from the creek lines is evident from watertable rises post significant rainfall-runoff events. Northey et al., (2020) presents data which shows that recharge is highly variable between 0 and 12 mm/yr and is highly episodic. The CloudGMS modelling predicts nearly 60 years of no recharge.
5. Are there any other instances where so much water has been given away with so little supporting data?
    a. Yes, but that doesn't make it a good idea.
6. The Ti Tree model 100 km south had an average recharge of 1.1mmyr over whole model domain, what is the average recharge for the Western Davenport District? If the Western Davenport recharge is considered to be significantly higher than Ti Tree then what underpins that assumption? For example the Murray basin has recharge halved since 2000.
    a. There will be some distributed recharge but I think most of the recharge is coming from the focussed discrete high intensity rainfall-runoff recharge events at surface water features as modelled. I'd need to review the Ti Tree model but focussed verses distributed recharge modelling are different styles of modelling. But in reality, recharge from both sources (distributed and focussed) will be occurring, it's just a question of what is dominant where. The current level of groundwater monitoring (spatial and frequency) prohibits a robust understanding of recharge dynamics

across the model domain. Chloride mass balance only gives very long-term averages. You need monthly data to really start to get into this level of recharge assessment. Northern Australia's climate change impact and predictions are much less certain than for the Murray-Darling or south west Western Australia. I think recharge in the NT is more stable than in the Murray-Darling or south west Western Australia, bearing in mind that recharge is more episodic and sporadic as in most arid areas.

7. The allocation is apparently based on recharge estimate from model. So while supposedly calibrated, the sparsity of actual records of recharge i.e. water table rise in vast areas of the model and in all different aquifers, suggest that different equally plausible assumptions could be made. Is this an accurate assessment?
    a. Yes other plausible assumptions could be made. I think the difference here is the level of proposed allocation and the fact that the WAP is accepting loss of storage. Most allocation plans would not accept a decline in storage without a very high level of understanding.
8. Is it a better practice approach to run the model under various different assumptions and use the worst case scenario as the basis for a licence decision until more evidence becomes available?
    a. In my opinion yes, this could be done with the existing model and PEST predictive uncertainty analysis. It should be noted that this does not assess conceptual uncertainty, only parametric and numeric uncertainty.
9. It seems that there is a distinct lack of detailed information about the aquifer characteristics (a lack of drilling) so it appears to be based particularly on assumptions about characteristics. What is the minimum level of base information about a hydrogeological system that is required to inform a decision of this nature – has that minimum level been satisfied in this example?'
    a. Yes I agree with your statement and in my opinion no, the minimum level has not been satisfied. Appendix 1 will give you an idea of the required level of understanding for various levels of allocation. More information on this in my other text.
10. Likewise there appears to be some substantial questions about the calibration of the model and whether there have been sufficient recharge events to understand the characteristics of the aquifer in order to represent it reliably in a model – again there might be a good question in asking what the minimum requirements for model calibrations of this nature are, and have those requirements been met? What are the levels of uncertainties in the outputs – have these been documented/considered? Is the scale of the model fine enough to draw conclusions at the specific GDE locations etc.
    a. The calibration is "ok". I'd like to see some more transient calibration output but the (lack of) transient data that is being calibrated against is the issue. The minimum amount of data required is a bit subjective. I think to get anywhere near full allocation they would need an R4 level of understanding (according to Appendix 1). Currently level is R1 with some elements of R2. Obviously, this is a Western Australia Government document but I think it has merit in all jurisdictions.
11. What testing is needed to verify the underlying assumptions in relation to estimating aquifer recharge, storage and discharge, and confirming that the processes in the model are appropriate (e.g. rainfall, evapotranspiration, infiltration, through-flow and movement between aquifers).

    a. These processes are all covered at least somewhat. It's only the uncertainty in the conceptual hydrogeological model, numerical model parametrisation and predictions that are an issue.
12. The protection of biodiversity values and potential habitats found in groundwater dependent ecosystems is discussed and seems to underpin some of the justification. The Report states that the Department has looked at a GDE probability of occurrence of 70% and that Singleton has also looked at GDE probability of occurrence of 50%. Given there doesn't appear to have been field verification/mapping of GDEs, is the approach to modelling potential GDEs appropriate (i.e. what were the inputs into the model and do they make logical sense).
    a. I haven't seen the reasoning for 50%, their method is a rough first pass at locating GDEs and as described in this report field data is required.
13. The allowable impact to GDEs has been based on rates and quantum of groundwater drawdown as defined by the Government, and a definition that there can be impact of up to 30% of GDEs. What parameters were included in the model to determine the level of impact? Was the model based on a historic climate data series or a future scenario that considers likely climate change impacts on GDEs (both in terms of rainfall, heat and the resultant impacts to recharge). Without development and only looking at climate change impacts, are the GDEs that we would expect to see at full development (say 30 years in the future) be the same as what we see now, or should the impact on GDEs have been modelled from a different base? What requirement is there for government to consider climate change impacts in assessing water extraction licences – especially in the arid zone where there is meant to be an assessment covering at least 100 years into the future.
    a. Climate for the predictive model is the historical record repeated. Given the uncertainty over the climate change impact for Northern Australia this is a logical approach. To do better requires better climate predictive models i.e. out of the scope of what they could be expected to do.
14. I note that the NTG has a climate change response policy that states 'The Territory Government will use water monitoring data, real time weather observations and seasonal data, and projected climate change impacts to manage the sustainable use of water in the Territory.' Does the model adequately consider 'projected climate change impacts' for Central Australia, in accordance with NTG policy (northern-territory-climate-change-response-towards-2050.pdf).
    a. No but see answer above.
15. Does the GDE component of the modelling rely on the same information as was used to inform the recharge.
    a. No, the data used for these two purposes is different. GDE's were assessed using remote sensing data while recharge has been estimated via modelling and the small amount of time varying groundwater level data that is available. There is a lack of data to assess unsaturated zone hydrology and plant water use directly in the context of recharge/groundwater level fluctuations.

Appendix 1 – Allocation Planning Process in Western Australia.

Note that this text and figures are adapted from Department of Water (2011) Water allocation planning in Western Australia – A guide to our process. Water resource allocation planning series, Government of Western Australia. ISBN 978-1-921789-96-0.

The allocation planning process assesses risk to the environment and the water resource sustainability in order to determine allocation limits. However, different levels of scientific rigor are applied depending on the amount of use as a proportion of the allocation limit. The Category/Response Model is used to assess the required level of assessment (R1-R4) as function of level of use (C1-C4), as shown in Table 1. Table 2 further summarises the level of investigation required as a Management Response (Department of Water, 2011).

The level of uncertainty during the early parts (C1-R1) of this iterative allocation planning process is high, consequentially there is considerable uncertainty over the allocation limit, and no plan is produced, only an allocation limit. The level of uncertainty then becomes reduced as the level of scientific rigor is increased. For other areas (C2-C4 and R2-R4) the Department of Water produces three types of water allocation plans (Department of Water, 2011):

(1) Standard plans, which are developed for medium-demand areas (C2); these require a low level of planning investment. C2 plans are based on the use of existing information, applying simple, local management rules, and existing state-wide policies.
(2) Intensive plans are developed where demand is high (C3 and C4) during which new studies are commissioned to reduce uncertainty in the allocation limit; these will include water resource and ecohydrological modelling and broad stakeholder consultation. An important part of C3 level planning is to establish environmental water regimes or environmental water requirements (EWRs). Over half of the proclaimed water areas in the state are at, or approaching, full allocation (C3) (Department of Water, 2011).

Although this process is considered to be generally sound, the level of scientific investigation and subsequent rigor in the allocation limit can create issues in areas where there is rapid changes in water demand/licences. Figure 1 shows a problematic (A) and ideal (B) water use verses allocation limit trajectory. Under trajectory A the level of allocation rises rapidly during the initial period where the links between cause and effect are poorly understood. This has the potential to jeopardise the sustainability of the resource, risking loss of human value associated with impacts to dependent biota and water. Under this trajectory there may be a need for an urgent correction accompanied by environmental, social and economic consequences. Trajectory B is the desired course where the level of use stays within not only the allocation limit but the uncertainty of it at every level of management response. There will always be some level of uncertainty and risk but this process is about minimising this risk and making the process as transparent as possible.

Table 1 - Category/response water allocation planning model, taken from Department of Water (2011).

Category (C)				Response (R)							
Licensed % of allocation limit		Impact from further licences	Risk to in-situ values	Licences required		Plan type	Maximum availability from resource	New information developed for plan	Allocation limits protect in-situ values	Specific rules protect values	Specific regimes protect values
C1	Low 0 < 30	Low	Low	R1	✓	x	x	x	✓	x	x
C2	Medium 30 < 70	Med	Med	R2	✓	Standard	x	x	✓	x	x
C3	High 70 < 100	High	High	R3	✓	Intensive	✓	✓	✓	✓	✓
C4	Over >100	V high	V high	R4	✓	Intensive	✓	✓	✓	✓	✓

Table 2 - Work required in plan development, taken from Department of Water (2011).

		Resource assessment		Values			
Response	Aim	Surface water	Groundwater	Ecological	Economic	Social	Cultural
R1 Limits only no plan	Basic approach to avoid potential impact	Flow estimate from gauge data or regional model	Basic rainfall recharge, throughflow or discharge estimate	Existing info Regional mapping	Existing use info Licence analysis	Existing info	Existing info Important sites
R2 Standard plan	Standard approach to avoid impacts and prepare for C3	Flow estimate from gauge data or regional model	Detailed recharge, throughflow or discharge or regional model	Existing info Important sites Risk areas	Existing use info Licence analysis	Existing info	Existing info Important sites
R3 Intensive plan	Detailed approach to maintain C3 status and begin impact management	Flow estimate from gauge data or calibrated, localised model	Regional model and/or local models	Environmental water requirements Buffer zones Scenarios Risk maps	Use analysis Current and future use trends	Sites Flow/level requirements Risk maps	Sites Flow\level requirements Risk maps
R4 Intensive plan	Detailed approach to return resource to C3	Flow estimate from gauge data or calibrated, localised model	Regional model and/or local models	Environmental water requirements Buffer zones Scenarios Remediation measures	Impact/ cost analysis for recoup	Sites Flow/level requirements Remediation measures	Sites Flow/level requirements Remediation measures

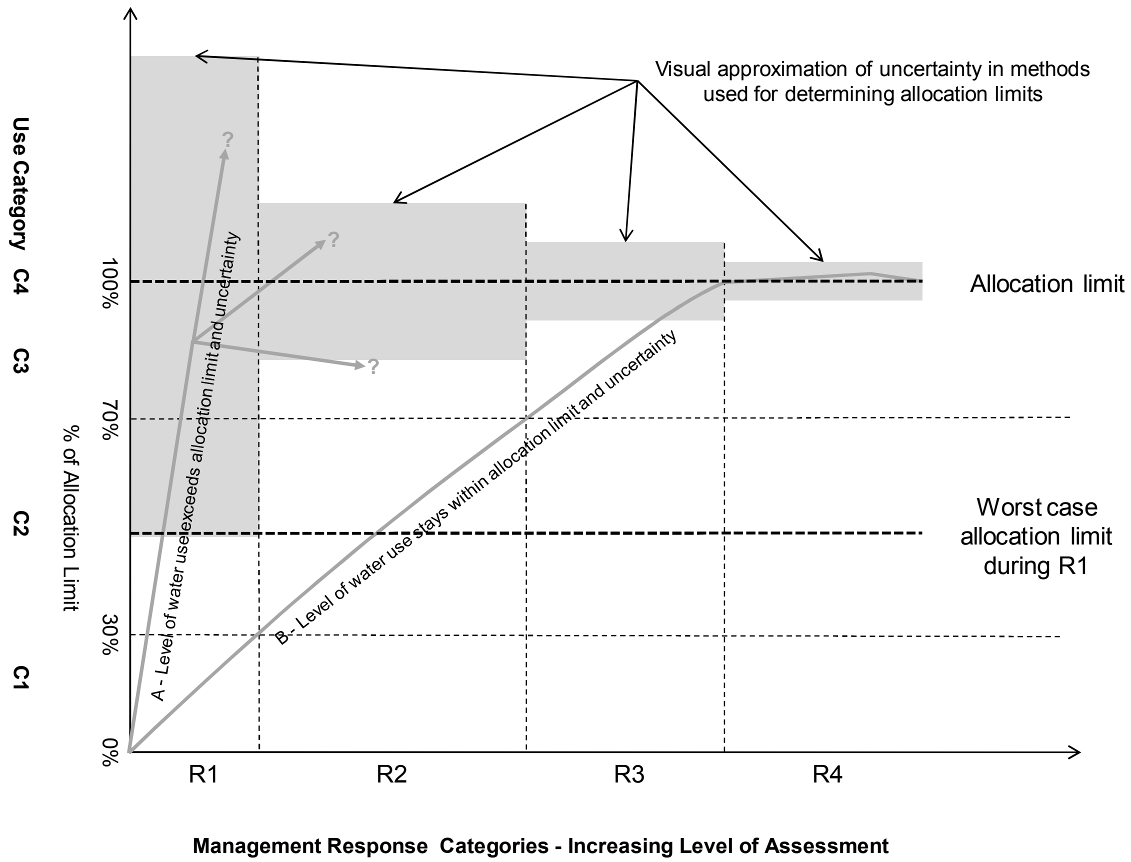
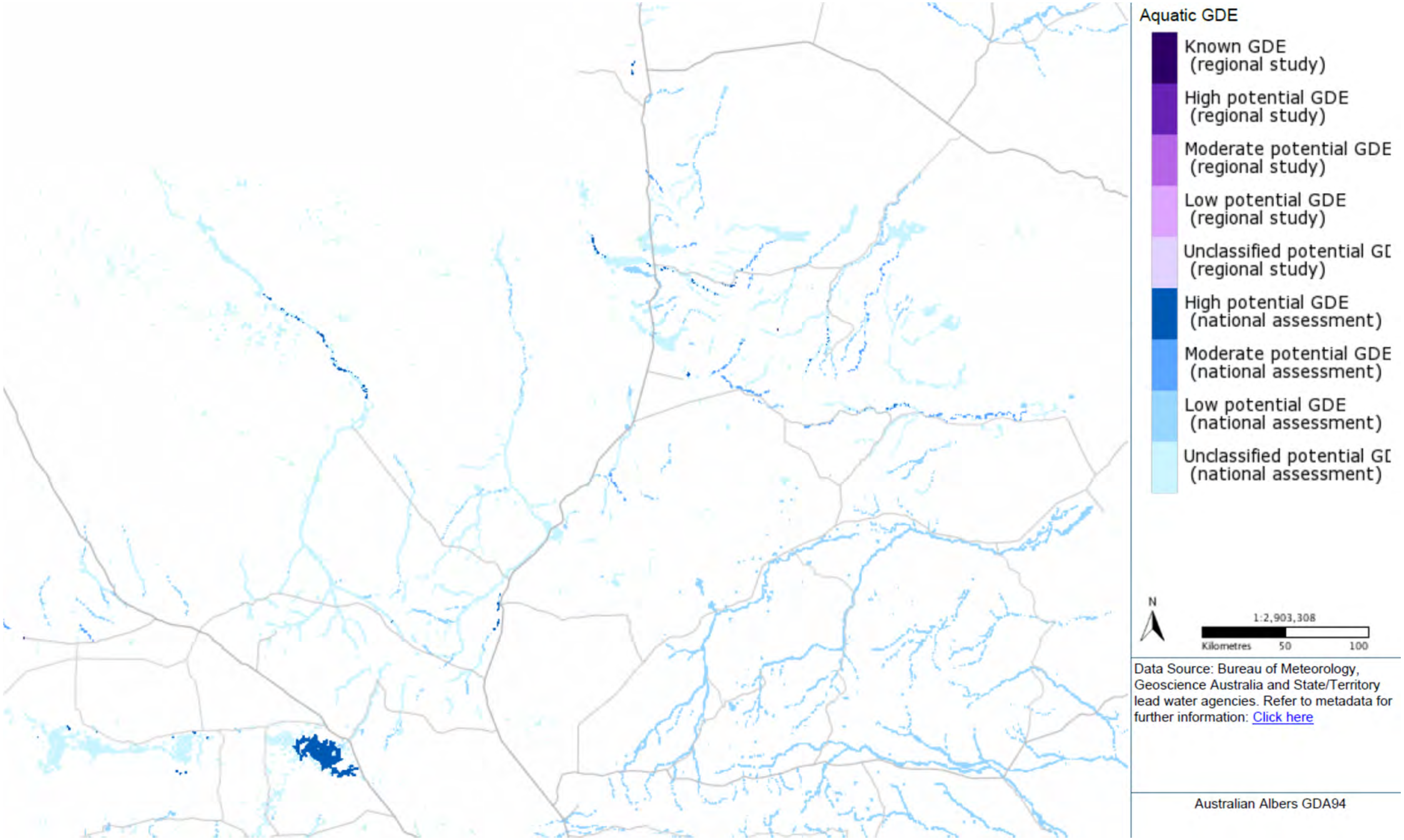


Figure 1 – Visual interpretation of the category/response water allocation planning model including approximate uncertainty at each stage of Management Response.

Undertaking the Resource Assessment in the allocation planning process requires application of a number of scientific techniques of increasing complexity (Tables 1 and 2). Basic desktop style evaluations at low levels of resource evaluation give way to detailed flow gauging, assessments of surface water/groundwater interaction, numerical modelling, ecohydrological assessment and precise determination of groundwater dependence of ecosystems, including EWR's. These are resource intensive and challenging projects that require long-term data sets.

Appendix 2 – BoM GDE Atlas Output.



Appendix 3 – Curriculum Vitae

CURRICULUM VITAE

Dr. RYAN I.J. VOGWILL

ABOUT

Ryan's more than 20 years of technical expertise encompass groundwater modelling, water resource planning and recovery of hydrologically impacted ecosystems, with a focus on applying research to sustainable groundwater management and environmental impact/risk assessment

QUALIFICATIONS

- BSc (Applied Geology) - Curtin University
- First Class Hons (Applied Geology) - Curtin University
- Doctor of Philosophy (Applied Geology) - Curtin University
- Member Australian Institute of Geoscientists

EXPERIENCE

Ryan has been an influential Hydrogeologist in Western Australia for more than 20 years. He has undertaken project work and provided advice regarding the management of groundwater resources and environmental impacts across most business areas and across all regions of WA, but also with national and international based projects. He played a significant role in establishing and the initial application of the Perth Regional Aquifer System Model, a platform for more responsible and informed management of groundwater resources in the Perth region. He also established, coordinated and was the primary lecturer for the Hydrogeology MSc course at UWA. He has worked in consultancy intermittently throughout his career, but this is now full time as of September 2016.

KEY SKIILS & EXPERTISE

- Technical and editorial review
- Regional and local scale water allocation planning including drought contingency planning
- Water quality and ecology (i.e. effluent discharge and algal blooms)
- Sedimentological and geochemical assessment
- Land use re-evaluation
- Environmental risk assessment
- Groundwater Dependent Ecosystems (GDEs) and Environmental Water Requirements (EWRs)
- Dryland salinity
- Groundwater training and education
- Groundwater modelling generally but with a focus on MODFLOW
- Surface water/groundwater interaction modelling including water and solute balances
- Project and staff supervision

AWARDS

Ocean Seas Ocean Hero Award.

Hydrology and Earth Systems Science - Jim Dooge Award 2020

KEY PROJECT EXPERIENCE

PRAMS development and application - a $5M groundwater model of the Perth (Moora to Mandurah) Region

South West Yarragadee groundwater and impact assessment modelling (SWAMS and local area models) review for the Department of Conservation and Land Management

Groundwater Modelling for the East Wanneroo Land and Water Use Re-evaluation

A member of the modelling technical reference groups for Ord Stage 2 - Weaber Plains and the southern river/Murray River MikeSHE modelling projects by CSIRO

Salt Lake Potash - Water supply and production impact assessment and licensing.

Millennium Minerals Limited - Multiple mine dewatering requirements and GDE impact risk assessment

Supervising Hydrologist for the Natural Diversity Recovery Catchment Program

KEY CAREER HISTORY

Director, Principal Hydrogeologist, Hydro Geo Enviro Pty Ltd, Feb 2018 to date

Principal Hydrogeologist (Sole Trader) September 2016 to Feb 2018

Associate Professor Hydrogeology, The University of Western Australia, December 2011 – September 2016

Supervising Hydrogeologist, Nature Conservation Division, Department of Environment, and Conservation, February 2006 – April 2011

Hydrogeologist, Department of Water, Groundwater Hydrology Section, February 2003 – February 2006

CONTACT

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PROFESSIONAL EXPERIENCE

DIRECTOR AND PRINCIPAL HYDROGEOLOGIST

HYDRO GEO ENVIRO AND SOLE TRADER SEPTEMBER 2016 – ONGOING

Key clients and project during this time include:

- Salt Lake Potash - water supply and production impact assessment/licensing.
- Millennium Minerals Limited - Multiple mine dewatering requirements, surface water management, GDE mapping and impact risk assessment
- City of Kalamunda - Acid sulphate soil management
- Adelaide Brighton Cement - Inorganic contamination conceptual modelling and remediation
- City of Rockingham - Lake Richmond microbialites, hydrology, chemical risk and weed management
- Rottnest Island Authority - Microbialite monitoring plan and impact criteria

ASSOCIATE PROFESSOR OF HYDROGEOLOGY

THE UNIVERSITY OF WESTERN AUSTRALIA, DECEMBER 2013 – SEPTEMBER 2016

JOINT ASSOCIATE PROFESSOR OF HYDROGEOLOGY

THE UNIVERSITY OF WESTERN AUSTRALIA/CURTIN UNIVERSITY, APRIL 2011 – DECEMBER 2013

SUPERVISING HYDROLOGIST, NATURE CONSERVATION DIVISION

DEPARTMENT OF ENVIRONMENT, AND CONSERVATION, FEBRUARY 2006 – APRIL 2011

Ryan was the key hydrogeologist employed by DEC, providing advice across all business areas. He continued working on GDEs of the Gnangara Mound, dryland salinity and all of the associated issues. Ryan has reviewed, critiqued and presented to the EPA on a number of subjects, including the sustainability of groundwater abstraction from the Gnangara Mound and Southwest Yarragadee project. He has also been heavily involved in many referrals from other government departments and sections of the DEC for many technical reviews of mining applications. Ryan continued to co-ordinate research and projects for the DEC, which involved the interaction of hydrology and biology in the Natural Diversity Recovery Catchments during the first 3 years of his time in academia until the Natural Diversity Recovery Catchment project was shut down.

HYDROGEOLOGIST

DEPARTMENT OF WATER, GROUNDWATER HYDROLOGY SECTION, FEBRUARY 2003 – FEBRUARY 2006

Preparation of modelling scenarios and the associated reporting; Section 46 modelling; Drought Contingency modelling; East Wanneroo Land Use Re-evaluation; graphic presentation of modelling data; database analysis and retrieval for various purposes; development of sampling programs; research proposals; and a large number of modelling/report critiques amongst other duties.

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Appendix 4 – Questions in Brief

As part of the contract the following questions were also posed:

1. Is there sufficient data to base a 40 GL allocation decision?
2. What are the ranges of plausible assumptions associated with the application? We understand there is limited drilling data to confirm aquifer characteristics are as assumed, particularly in Cambrian aquifers west of highway.
3. What if the Wiso basin Cambrian is a much poorer aquifer than model assumes, for instance less storage, poorer hydraulic conductivity would be greater drawdown etc.
4. What evidence exists for assumptions of direct recharge across aquifer? If in reality direct recharge is limited to creek lines in the Cainozoic then realistic recharge estimates would be much smaller.
5. Are there any other instances where so much water has been given away with so little supporting data?
6. The Ti Tree model 100 km south had an average recharge of 1.1mmyr over whole model domain, what is the average recharge for the Western Davenport District? If the Western Davenport recharge is considered to be significantly higher than Ti Tree then what underpins that assumption? For example the Murray basin has recharge halved since 2000.
7. The allocation is apparently based on recharge estimate from model. So while supposedly calibrated, the sparsity of actual records of recharge i.e. water table rise in vast areas of the model and in all different aquifers, suggest that different equally plausible assumptions could be made. Is this an accurate assessment?
8. Is it a better practice approach to run the model under various different assumptions and use the worst case scenario as the basis for a licence decision until more evidence becomes available?
9. It seems that there is a distinct lack of detailed information about the aquifer characteristics (a lack of drilling) so it appears to be based particularly on assumptions about characteristics. What is the minimum level of base information about a hydrogeological system that is required to inform a decision of this nature – has that minimum level been satisfied in this example?
10. There are substantial questions about the calibration of the model and whether there have been sufficient recharge events to understand the characteristics of the aquifer in order to represent it reliably in a model. What the minimum requirements for model calibrations of this nature, and have those requirements been met? What are the levels of uncertainties in the outputs – have these been documented/considered? Is the scale of the model fine enough to draw conclusions at the specific GDE locations.
11. What testing is needed to verify underlying assumptions in relation to estimating aquifer recharge, storage and discharge, and confirming that the processes in the model are appropriate (e.g. rainfall, evapotranspiration, infiltration, through-flow and movement between aquifers).
12. The protection of biodiversity values and potential habitats found in groundwater dependent ecosystems is discussed and seems to underpin some of the justification. The Report states that the Department has looked at a GDE probability of occurrence of 70% and that Singleton has also looked at GDE probability of occurrence of 50%. Given there doesn't appear to have been field verification/mapping of GDEs is the approach to modelling potential GDEs appropriate (i.e. what were the inputs into the model and do they make logical sense).
13. The allowable impact to GDEs has been based on rates and quantum of groundwater drawdown as defined by the Government, and a definition that there can be impact of up to 30% of GDEs . What parameters were included in the model to determine the level of impact? Was the model based on a historic climate data series or a future scenario that considers likely climate change impacts on GDEs (both in terms of rainfall, heat and the resultant impacts to recharge). Without development and only looking at climate change impacts, are the GDEs that we would expect to see at full development (say 30 years in the future) be the same as what we see now, or should the impact on GDEs have been modelled from a different base? What requirement is there for government to consider climate change impacts in assessing water extraction

licences – especially in the arid zone where there is meant to be an assessment covering at least 100 years into the future.

14. The NTG has a climate change response policy that states 'The Territory Government will use water monitoring data, real time weather observations and seasonal data, and projected climate change impacts to manage the sustainable use of water in the Territory.' Does the modelling adequately considers 'projected climate change impacts' for Central Australia, in accordance with NTG policy (northern-territory-climate-change-response-towards-2050.pdf).
15. Are the assumptions underpinning the GDE component of the modelling based on the same information as was used to inform the recharge.

<u>ATTACHMENT B:</u>

SUBMISSION SEEKING MINISTERIAL REVIEW OF WATER CONTROLLER'S DECISION TO GRANT THE NEW WATER EXTRACTION LICENCE WDPCC10000 TO FORTUNE AGRIBUSINESS

Made by the Central Land Council on 7 May 2021

Submission seeking ministerial review of Water Controller's decision to grant the new water extraction licence WDPCC10000 to Fortune Agribusiness

A. INTRODUCTION

1. On 8 April 2021, the Controller of Water Resources (**Water Controller**) made the decision to grant the following water extraction licence WDPCC10000 (**Singleton Water Licence**) under section 60 of the *Water Act 1992* (NT) (**Water Act**):

Applicant	**Volume of water (ML/year) and Beneficial Use**	**Land from which water may be taken and used**
Fortune Agribusiness Funds Management Pty Ltd (**Fortune Agribusiness)**	A maximum entitlement of 40 000 to service the Singleton Horticultural Project which includes: • 39 800 for agriculture • 100 for public water supply and • 100 for industry	Singleton Station NTP 653 (**Singleton Station**)

2. The Central Land Council (**CLC**) is a statutory authority established under section 21 of the *Aboriginal Land Rights (Northern Territory) Act 1976* (Cth) (**Land Rights Act**) and has functions and duties under Land Rights Act. These functions include:
   a) ascertaining and expressing the wishes and opinion of Aboriginals living in the area of the CLC as to the management of Aboriginal land in the area[1];
   b) protecting the interests of traditional Aboriginal owners of, and other Aboriginals interested in, Aboriginal land in the area of the CLC[2]; and
   c) assisting Aboriginals in the taking of measures likely to assist in the protection of sacred sites on land (whether or not on Aboriginal land) in the area of CLC[3].
3. Singleton Station is subject to a native title determination, *Rex on behalf of the Akwerlpe-Waake, Iliyarne, Lyentyawel Ileparranem and Arrawatyen People v Northern Territory of Australia* [2010] FCA 91 (**Singleton Determination**). Mpwerempwer Aboriginal Corporation (ICN: 7316) (**MAC**) is the prescribed body corporate for the purposes of section 57(2) of the *Native Title Act 1993* (Cth) (**Native Title Act**) and the registered native title body corporate for the purpose of performing the functions in section 57(3) of the Native Title Act in relation to the Singleton Determination.
4. The CLC is the recognised Aboriginal/Torres Strait Islander body for the southern region of the Northern Territory pursuant to section 203AD of the Native Title Act which includes Singleton Station.
5. The function of a native title representative body includes the performance of the assistance and facilitation functions set out in section 203BB of the Native Title Act. The carrying out of such functions is governed by a service agreement between CLC and MAC.
6. The CLC represents affected native title holders for Singleton Station, traditional Aboriginal owners of neighbouring Aboriginal land trusts including Warrabri Aboriginal Land Trust (**Warrabri ALT**) and Iliyarne Aboriginal Land Trust (**Iliyarne ALT**) and

[1] Section 23(1)(a) of the Land Rights Act
[2] Section 23(1)(b) of the Land Rights Act
[3] Section 23(1)(ba) of the Land Rights Act

residents of the affected Aboriginal community of Alekerange (together, the **affected Aboriginal constituents**).

7. The affected Aboriginal constituents are persons who are aggrieved by the decision of the Water Controller to grant the Singleton Water Licence for the purposes of section 30(1) of the Water Act:

a) **Native title holders have rights and interests over lands and waters in Singleton Station**

The Singleton Determination covers the *lands and waters* over Singleton Station. The native title holders' rights and interests include[4]:

(i) the right to hunt, gather, take and use the natural resources of the land and waters, including the right to access, take and use natural water resources on or in the land;

(ii) the right to access, maintain and protect places and areas of importance on or in the land and waters;

(iii) the right to engage in cultural activities and teach the physical and spiritual attributes of places and areas of importance; and

(iv) the right to share and exchange natural resources obtained on or from the land and waters, including traditional items made from the natural resources.

With the projected groundwater drawdown of up to 50 metres in the Singleton Station[5] and the potential impact on groundwater dependent ecosystems (**GDEs**)[6], the Singleton Water Licence affects the exercise of native title rights and interests by native title holders.

b) **Aboriginal persons have rights to enter, use or occupy Aboriginal land in accordance with Aboriginal tradition.**

Aboriginal land trusts hold Aboriginal land for the benefit of Aboriginals entitled by Aboriginal tradition to use or occupy the land concerned[7].

The Water Controller notes that a report prepared for Fortune Agribusiness by GHD titled "Singleton Horticulture Project Groundwater Dependent Ecosystem Mapping and Borefield Design" (**Fortune Report**) indicates that "*groundwater drawdown will extend beneath the Iliyarne ALT and may result impacts in GDEs on that land trust*[8]*".*

Given the groundwater drawdown and the potential negative impact on GDEs on Warrabri ALT and Iliyarne ALT, the rights of Aboriginals, including traditional Aboriginal owners, to use and occupy Aboriginal land will also be affected.

8. On behalf of affected Aboriginal constituents, MAC, Warrabri ALT and Iliyarne ALT, the CLC applies to the Minister to review the decision by the Water Controller to grant the Singleton Water Licence (**Water Controller Decision**).

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[4] Paragraph 4 of the Singleton Determination
[5] Paragraph 66 of the Statement of Decision by the Water Controller for the Singleton Water Licence dated 8 April 2021 (**Statement of Decision**)
[6] See paragraphs 101 and 102 of the Statement of Decision
[7] Section 4(1) of the Land Rights Act
[8] Paragraph 48 of the Statement of Decision

9. We seek a review of the Water Controller Decision on the following grounds:

   a) The estimated sustainable yield used by the Water Controller and derived from the *Western Davenport Water Allocation Plan* 2018 – 2021 (**WDWAP**) is not an *"estimated sustainable yield*" within the meaning of sections 22B(5)(a) and 71B(3)(d) of the Water Act because it results in depletion of the aquifer underlying the Central Plain Management Zone and unacceptable impacts on the environment.

   b) The Water Controller and the WDWAP fail to take into account the level and extent of uncertainty underlying the groundwater model for WDWAP (**Groundwater Model**) and the conditions imposed by the Water Controller in the Singleton Water Licence cannot address such deficiency (because the level of uncertainty has not been quantified and insufficient investigation has been undertaken).

   c) The Water Controller Decision fails to take into account the impact that the Singleton Water Licence will have on Aboriginal cultural values.

   d) The "*Guideline: Limits of acceptable change of groundwater dependent vegetation in the Western Davenport Water Control District"* (**Guideline**) is inconsistent with the WDWAP and the Water Controller should not have relied on the Guideline.

   e) The thresholds in the Guideline are arbitrary and the Water Controller fails to address the arbitrary nature of these thresholds in in the way that she made the Water Controller Decision.

   f) The authors of the WDWAP fail to assess the risks to aquatic GDEs in the Western Davenport District. The risks to the aquatic GDEs have not been considered in the Guideline, the Fortune Report and the Water Controller Decision.

   g) The WDWAP and Guideline demonstrate a lack of understanding of region-specific vegetation GDEs and the use of criteria are not consistent with those used in other jurisdictions in Australia.

   h) The Water Controller should not have granted the Singleton Water Licence for a term more than 10 years given the uncertainty underlying the Groundwater Model and the potential impacts arising from granting the Singleton Water Licence.

   i) The Water Controller fails to address concerns raised by CLC about biodiversity surveys undertaken by the Northern Territory Government which may impact on the assessment of lack of threatened species.

   j) Condition CP6 in the Singleton Water Licence does not sufficiently address the elevated soil salinity risks recognised in the Statement of Decision.

B. GROUND 1 – ESTIMATED SUSTAINABLE YIELD IN WDWAP NOT WITHIN THE MEANING OF "ESTIMATED SUSTAINABLE YIELD' IN THE WATER ACT

Ground 1: The estimated sustainable yield used by the Water Controller and derived from the WDWAP is not an "estimated sustainable yield" within the meaning of sections 22B(5)(a) and 71B(3)(d) of the Water Act because it results in depletion of the aquifer underlying the Central Plain Management Zone and unacceptable impacts on the environment.

10. In 2018, the Minister declared the WDWAP. Under the WDWAP, the estimated sustainable yield for the Central Plains Management Zone for the Western Davenport

Water Control District (**Western Davenport District**) was modelled at 112,720 ML/year (or 112 GL/year) with the consumptive pool being 87,720 ML/year (or 87 GL/year)[9].

11. Estimated sustainable yield was considered "*to be equal to the sum of modelled evapotranspiration, plus 100% allocation of modelled recharge using the longest available rainfall record, plus the staged depletion of water stored in the regolith above 15 metres below ground level over 100 years"*[10]. Under this scenario, modelling of aquifer storage in the Central Plains Management Zone predicts a reduction in the volume of aquifer storage of 3.9% in 100 years (i.e. an average aquifer drawdown of 18.9 m assuming available aquifer storativity of 0.04) based upon full abstraction of the consumptive pool[11].

12. Section 22B(5)(a) of the Water Act provides that "*a water allocation plan is to ensure in the water control district that (a) water is allocated within the estimated sustainable yield to beneficial uses*[12]*"*. In making her decision, the Water Controller relied on the estimated sustainable yield stated in the WDWAP to assess the availability of water in the Western Davenport District for use by Fortune Agribusiness for Singleton Station.

13. The term "*estimated sustainable yield*" is not defined in the Water Act. A definition of "*estimated sustainable yield"* is used in *Arnold v Minister Administering the Water Management Act 2000* [2014] NSWCA 386, the New South Wales Court of Appeal said (at [4]):

> "*in this context and relevant to the issues in the appeal, the estimated sustainable yield of a groundwater system is determined by reference to the long-term average annual recharge of the system. The latter is capable of determination by groundwater numerical modelling using known or assumed physical parameters.* ***The sustainable yield is then that proportion of the long-term annual recharge of the system which may be extracted without causing unacceptable impacts on the environment or other groundwater users****. Unlike the determination of the relevant recharge of the system, the assessment of the sustainable yield involves matters of policy. Depending on the environmental circumstances, the sustainable yield may be 100% of the recharge or a lesser percentage."*

14. "*Sustainable yield"* is defined in the *Oxford Dictionary of Environment and Conservation* (3rd edition) (emphasis added):

> *"The rate at which a renewable resource may be used in a sustainable way. Traditional ways of harvesting natural renewable resources, such as fish from the oceans, wood from the forests, and plants and products from natural ecosystems, have usually been sustainable,* ***so long as the quantities extracted were not greater than natural processes were able to replace****."*

15. A similar definition appears in *Merriam-Webster* dictionary:

> *"Production of a biological resource (such as timber or fish) under management procedures which ensure replacement of the part harvested by regrowth or reproduction before another harvest occurs."*

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[9] Table 2 in Section 1.1.2 of WDWAP, page 9.
[10] Section 6.2 of WDWAP, page 33.
[11] Section 6.2 of WDWAP, page 33.
[12] Beneficial uses are defined in section 4(3) of the Water Act.

16. The key concept is a sustainable yield which is equal to or less than the long-term annual recharge of the system and so cannot result in depletion of the resource.

17. However, the *"estimated sustainable yield"* in the Water Controller Decision and the WDWAP contemplates and results in aquifer depletion[13].

18. The grant of the Singleton Water Licence, using the estimated sustainable yield stated in the WDWAP, results in:

    a) groundwater drawdown up to 50 metres after 30 years[14]; and

    b) where the baseline depth to groundwater (**DGW**) is less than 15 metres:

        (i) 26% of alluvial GDEs and 13% of sandplain GDEs on the Singleton Station may be impacted; and

        (ii) 25% of alluvial GDEs and 15% of sandplain GDEs on the Central Plains Management Zone may be impacted after 40 years[15].

    CLC considers that such impacts on GDEs would result in unacceptable impacts on environment. This is particularly the case given that the relative importance (biodiversity and/or cultural values) of the GDEs is not known, i.e. those GDEs impacted may be the most important in terms of biodiversity and cultural values.

19. The CLC submits that allocation of water which result in:

    a) the depletion of aquifers; and

    b) unacceptable impacts on the environment,

    is not within the definition of "*estimated sustainable yield"* as contemplated in the Water Act.

C. <u>GROUND 2 – UNCERTAINTY IN GROUNDWATER MODEL</u>

Ground 2: The Water Controller and the WDWAP fail to take into account the level and extent of uncertainty underlying the Groundwater Model and the conditions imposed by the Water Controller in the Singleton Water Licence cannot address such deficiency (because the level of uncertainty has not been quantified and insufficient investigation have been undertaken).

20. The WDWAP recognises key issues underlying the Groundwater Model. These issues include:

    a) the volumes presented in Table 3 (Management Zones – hydrogeological attributes) being largely theoretical based upon modelled thickness of the aquifers;[16]

    b) groundwater recharge being highly episodic[17] and recharge periods are rare and difficult to predict;[18] and

    c) water storage in regolith not being defined with the same precision as the modelled aquifer recharge.[19] In fact, the water storage in the regolith is not referred to in the

[13] Section 6.2 of WDWAP, page 33.
[14] Paragraph 66 of the Statement of Decision
[15] Paragraph 101 of the Statement of Decision.
[16] Section 4.3 of WDWAP, page 21.
[17] Section 4.3.1 of WDWAP, page 21.
[18] Section 4.4.2 of WDWAP, page 23.
[19] Section 7.4.6 of WDWAP, page 38.

report prepared by Anthony Knapton for the Department of Environment and Natural Resources in 2017 (**Knapton Report**). Section 7.4.6 of the WDWAP recommended that additional work be done to better define the regolith resource. Further work could result in the exclusion of this resource from the allocation for consumptive beneficial uses[20].

21. The Groundwater Model presented in WDWAP is simplistic and based on inadequate investigations and very little site-specific data. This is recognised in the WDWAP itself which states that "*The model is based upon the available data and has been calibrated to reflect the observed aquifer response. However, there are limitations to the available data, notably, the small number of bores, regolith resource is not included in the model and the aquifer and GDE response to pumping is largely inferred*"[21]. The key issues for the Groundwater Model are:

    a) **Lack of drilling and aquifer testing in the Singleton Station:** Most of the previous groundwater investigations have been undertaken in the central and eastern parts of the Central Plain Management Zone. Drilling in the area shows that the north and middle blocks of the proposed development in the Singleton Station are underlain by more than 160 metres of the Hooker Creek Formation which is a likely low yielding aquifer (as it is silt and mudstone dominated)[22].

    The Hanson River beds and Hooker Creek formation in the Wiso Basin (composed of silts and mudstones and with poor aquifer potential) have been classified as Hydrostratigraphic Unit 3 (HSU3) in the Knapton Report. This erroneously equates them with the more prospective carbonate and sandstone aquifers identified in the Georgina Basin which is to the east of the Singleton Station. This could introduce significant errors in terms of yields and water in storage and result in an underestimation of drawdown and pumping impact predictions.

    This is a key example of why extrapolating groundwater investigation results from the other parts of the Central Plains Management Zone to the Singleton Station could be incorrectly interpreted which result in incorrect predictions. The assumption that Wiso basin sediments have the same aquifer characteristics as Georgina Basin sediments is simplistic and not consistent with known lithological differences between the two basins as described in the Fourth Annual and Final Surrender Report for EL 28211, EL 28213 and EL 28214.

    b) **Storage estimates based on modelling:** Storage estimates are based on modelling alone (with no direct measurements of the aquifer's properties and ability to produce water at the Singleton Station). If these estimates are too high then storage will be reduced substantially and impacts will be greater than predicted.

    c) **Regolith aquifer based on little or no data:** The regolith, which accounts for 30.7 GL/year of the total of 112.7 GL/year[23] of estimated sustainable yield, is based on little to no data as this has not been investigated directly. There is no justification for incorporating this in the available water resources for allocation.

22. Water allocation planning and the development of the Groundwater Model for the Western Davenport District has been hindered (in terms of rigour) by a lack of spatially

[20] Section 7.4.6 of the WDWAP, page 38.
[21] Section 9.1 of WDWAP, page 55.
[22] See the Fourth and Final Surrender Project for Davenport Project (EL 28211, EL 28213 and EL 28214 held by Areva Resources Australian Pty Ltd) dated 13 February 2015 and authored by Rachael Wilson
[23] Table 5 (Natural Water balance (ML/year), section 4.4.2 of WDWAP, page 24.

distributed data on aquifer geometry, lithology, hydraulic properties (particularly storage properties), water levels and water quality. Water level data with any useful time series (in the context of long-term predictive modelling) is lacking in the development of the Groundwater Model, particularly in the regolith.

23. Aquifer testing data is sparse and is typically restricted to short duration and single borehole tests which cannot determine storage properties. Storage properties are a key control on the relationship between abstraction and groundwater level drawdown change which is the key focus of the modelling and allocation planning.

24. The Water Controller and the authors of the WDWAP have not attempted to quantify the level of uncertainty and how it affects basic assumptions of the WDWAP such as storage. If the level of uncertainty concerning storage and estimated sustainable yield is high, say 50%, then a decision to allocate 40,000 ML/yr from an estimated sustainable yield of 112,720 ML/year for the Central Plains Management Zone (but where 50% uncertainty would take that level significantly lower) is unreasonable. Under the 2011 plan, the estimated sustainable yield for the Central Plains Management Zone (taken as 80% of estimated annualised recharge) was 27,224 ML/year[24]. There has been insufficient work undertaken to warrant the substantial increase in the estimated sustainable yield of 85,496 ML/year, from 27,224 ML/year to 112,720 ML/year

25. There is substantial work still required to be done under the WDWAP. The WDWAP sets out the work required to be done to address the uncertainties in the Groundwater Model (see section 7.4.5 of the WDWAP) and the regolith (see section 7.4.6 of the WDWAP). Additional work is set out in section 8.4.1 (Framework setting out WDAP implementation activities)[25] and section 9.1 (Table of risk management treatments)).[26]

26. CLC has previously submitted, in its submission in response to the Notice of Intention for the Singleton Water Licence, that the Water Controller should not consider any application for a groundwater licence in the Western Davenport District until such work has been completed. In the Statement of Decision, the Water Controller fails to address CLC's concerns and fails to identify the work in the WDWAP completed (if any) to refine and enhance the Groundwater Model.

27. The Water Controller claims that uncertainty in the Groundwater Model can be addressed by imposing the following conditions in the Singleton Water Licence:

    a) field validation and mapping of the type and extent of GDEs on the Singleton Station;

    b) development of a monitoring plan to detect potential impacts of groundwater extraction; and

    c) an adaptive management plan to respond to triggers of potential impact on groundwater levels, quality and GDEs.[27]

28. We submit that the conditions in the Singleton Water Licence are vague and deficient in addressing the uncertainty in the Groundwater Model. They key problem is that until the level and extent of uncertainty is known and the area better understood in a hydrogeological, biodiversity and cultural context, the effectiveness of these conditions is speculative. The conditions in the Singleton Water Licence require the preparation of

[24] Section 7 of the 2011 Western Davenport Water Allocation Plan, page 20.
[25] Section 8.4.1 of WDWAP, page 49.
[26] Section 9.1 of WDWAP, page 55.
[27] Paragraph 53 of the Statement of Decision.

a map and spatial data of groundwater dependent ecosystems[28] and development of a monitoring program[29]. However, such conditions do not specify what data is required to be collected, in which location and what frequency, to improve confidence in the Groundwater Model.

29. An adaptive management framework is an ineffective framework when there is insufficient understanding of the risks that a water licence poses and insufficient understanding of the uncertainty in the modelling. To be effective, an adaptive management framework needs a strong understanding of the water resource, biodiversity and cultural values of the GDEs and potential environmental impacts on GDEs. This understanding does not currently exist for the Singleton Water Licence and it is unclear if investigations proposed as part of the Conditions Precedent in the Singleton Water Licence will provide an appropriate level of understanding. Baseline monitoring of GDEs (GDE condition verses local water levels and quality) should be required for 5 to 10 years to understand the environmental and cultural linkages with GDEs in sufficient detail to develop strong management criteria and separate drawdown impacts from natural variability.

30. Given the acknowledged uncertainty underlying the Groundwater Model, the grant of a water licence which comprises nearly 50% of the estimated sustainable yield of the Central Plains Management Zone which was allocated for consumptive uses, renders this a high risk decision by the Water Controller.

31. The Water Controller has a duty under section 34 of the Water Act to ensure as far as possible that a continuous program for the assessment of water resources of the Territory is carried out, including the investigation, collection, collation and analysis of data concerning the occurrence, volume, flow, characteristics, quality, flood potential and use of water resources. The WDWAP identified further work to be done and much of it should have been done by now. If it has not been done, the Water Controller has failed to carry out her duty in section 34 of the Water Act. If it has been done, it should have been disclosed in advance of any decision being made and the failure to do so is a denial of procedural fairness.

D. <u>GROUND 3 – LACK OF PROTECTION OF CULTURAL VALUES IN WESTERN DAVENPORT DISTRICT</u>

Ground 3: The Water Controller Decision fails to take into account the impact that the Singleton Water Licence will have on Aboriginal cultural values.

32. One of the objectives of the WDWAP is to protect Aboriginal cultural values associated with water[30].

33. Water is fundamentally important to traditional Aboriginal owners and native title holders of the Western Davenport District and Aboriginal people who live in the Western Davenport District. Aboriginal people have a strong connection to country and a dynamic relationship with water which includes social, cultural and environmental components.

34. All water sources such as soakages, waterholes, rock holes, springs and rivers play a major role in the social, cultural, spiritual and customary values of traditional Aboriginal owners and native title holders of the Western Davenport District. The significance of water is not limited to surface water and GDEs as it is found throughout the country and

[28] Condition CP5 in Singleton Water Licence
[29] Condition CP8 in Singleton Water Licence
[30] Section 1 of WDWAP, page 6.

in all living things.[31] Water availability also affects many activities like hunting and harvesting for bush tucker, bush medicine, tool and craft making.[32]

35. Section 8.2.2 of the WDWAP states that:

> *"Groundwater modelling (based on the cumulative consideration of all approved extraction) should be undertaken to determine if proposed groundwater extraction will unacceptably impact on groundwater dependent Aboriginal cultural values. The proposed extraction should not result in a change to groundwater conditions that would result in the loss or decline of cultural values, as demonstrated through modelling."*

36. Section 8.4.1 specifies work required to be completed to ensure the protection of Aboriginal cultural values in the Western Davenport District. This includes mapping and documenting water dependent cultural values[33].

37. The Water Controller is required to consider whether Fortune Agribusiness has demonstrated a commitment to protect cultural values from the impacts of groundwater extraction applications[34].

38. In her statement of decision, the Water Controller did not address:

    a) how the Singleton Water Licence would not result in a change of groundwater conditions that would result in the loss or decline of cultural values in the Western Davenport District; and

    b) the commitments (if any) given by Fortune Agribusiness to protect cultural values in the Western Davenport District.

39. The Water Controller again claims that the conditions that she imposed[35] would suffice to address "*the full extent of cultural values and practices and their water requirements and responses to increased extraction*[36]*."*

40. Fortune Agribusiness is required to "*produce a map (and spatial data), verified through suitable on-ground surveys of groundwater dependent ecosystems in each landform on Singleton Station in the Aeolian sandplain and alluvial plain areas shown in Figure 7.2 provided in Attachment A."*[37] However, the Water Controller does not require Fortune Agribusiness to consider the cultural values of GDEs in preparing such a map and ensuring that measures are in place to protect such cultural values.

41. The drawdown area for the Singleton Water Station extends well beyond the Singleton Station[38] and the Fortune Report also recognises that the Singleton Water Licence may impact on GDES in the Central Plain Management Zone[39]. Yet, the Water Controller does not require Fortune Agribusiness to produce a map of the GDEs of the drawdown area and assess the cultural values of the GDEs in the drawdown area. This must be required of Fortune Agribusiness, *before* any licence is granted.

42. CLC has not been provided a copy of the authority certificate which Fortune Agribusiness obtained from Aboriginal Areas Protection Authority. However, as

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[31] Section 5.2.2 of WDWAP, page 28.
[32] Section 5.2.2 of WDWAP, page 28.
[33] Section 8.4.1 of WDWAP, page 50.
[34] Section 8.2.2 of WDWAP, page 43.
[35] See paragraph 53 of the Statement of Decision
[36] Paragraph 51 of the Statement of Decision
[37] CP5(a) of the Singleton Water Licence
[38] See pages 23 to 31 of the Summary Report
[39] Paragraph 101 of the Statement of Decision.

indicated in the Summary Report for the Singleton Horticulture Project prepared by Fortune Agribusiness dated August 2020 (**Summary Report**), the subject land in the authority certificate does not cover the drawdown area of the Singleton Water Licence[40]. It does not even cover the drawdown area of the Singleton Water Licence which is in Singleton Station. Given the limited subject land of the authority certificate, the authority certificate will be unable to protect cultural values as required under the WDWAP and there could be a substantial risk of damage to sacred sites in the drawdown area which is within the vicinity of the subject land.

E. GROUND 4 – GUIDELINE INCONSISTENT WITH THE WDWAP

Ground 4: The Guideline is inconsistent with the objectives of the WDWAP and the Water Controller should not have relied on the Guideline.

43. In making her decision, the Water Controller considered and relied on the Guideline[41]. The Guideline was not subject to public consultation including consultation with the Western Davenport Water Advisory Committee.

44. The Guideline specifies that 70% of the current extent of the GDEs in the Western Davenport District should be protected from negative impact[42] (**70% Threshold**). This means that 30% of the current extent of GDEs ***do not need to be protected from negative impact***.

45. One of the objectives of the WDWAP is to meet the environmental water requirements (**EWRs**) of water dependent ecosystems and detrimental impacts to water dependent ecosystems as a consequence of consumptive water use will be avoided as far as possible. [43]

46. Section 22B(4) of the Water Act provides that "*water resource management in a water control district is to be in accordance with the water allocation plan declared in respect of the district".*

47. The Guideline, which allows a potential 30% negative impact on GDEs, is inconsistent with the objective of the WDWAP to avoid detrimental impacts on water dependent ecosystems as far as possible. Given such inconsistency and the requirement under section 22B(4) of the Water Act that water resource management is in accordance with the declared water allocation plan, the Water Controller should not have relied on the Guideline in making the Water Controller Decision. Although the Water Controller claims that she is able to rely on the Guideline as it "*constitutes new scientific knowledge"*[44] (and this is disputed by CLC in Ground 5 below), the Water Controller fails to explain how her decision that foresees a potential 30% negative impact on GDEs meets the objective of the WDWAP to avoid detrimental impact to water dependent ecosystems *as far as possible*.

F. GROUND 5 - THRESHOLDS IN GUIDELINE ARBITRARY

Ground 5: The thresholds in the Guideline are arbitrary and the Water Controller fails to address the arbitrary nature of these thresholds in in the way that she made the Water Controller Decision.

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[40] See pages 23 to 26 and 28 to 31 of the Summary Report
[41] Paragraphs 46 and 95 of the Statement of Decision
[42] Page 8 of the Guideline
[43] Section 3 of the WDWAP, page 16
[44] Paragraphs 46 and 95 of the Statement of Decision

48. The Guideline recognises that there is limited scientific evidence to confidently set this threshold for Australian Arid zones specifically[45] and fails to specify the basis for the 70% Threshold. Without providing any basis, the authors of the Guideline, which was approved by the Chief Executive Officer of the Department of Environment and Natural Resources, who is also the Water Controller, has arbitrarily set this threshold without any reasonable grounds.

49. Furthermore, until more work is done to rank the biodiversity and cultural values of the various GDEs in the Western Davenport District, and particularly GDEs impacted by the Singleton Water Licence, there is a possibility that amongst the 30% of GDEs which are impacted, there are important cultural sites or sites of high biodiversity value. The Guideline also provides that "*additional consideration may need to be given to minimising the impact of groundwater extraction on sites or areas specifically identified as having important cultural values."*[46]

50. The Water Controller has failed to address the lack of scientific basis underlying the 70% Threshold and has mechanically applied the 70% Threshold. By mechanically applying the 70% Threshold without undertaking the necessary work to rank the biodiversity and cultural values of various GDEs, the Water Controller has failed properly to consider if the Singleton Water Licence will minimise the impact of that licence on sites with important cultural and biodiversity values.

G. GROUND 6 – NO CONSIDERATION OF AQUATIC GDES

Ground 6: The authors of the WDWAP fail to assess the risks to aquatic GDEs in the Western Davenport District. The risks to the aquatic GDEs have not been considered in the Guideline, the Fortune Report and the Water Controller Decision.

51. There is a major gap in the allocation planning and impact assessment in the WDWAP as aquatic GDEs have not been included.

52. According to the attached maps in Annexure A, which are extracted from the Bureau of Metrology GDE atlas, there are numerous sites with potential to contain aquatic GDEs. Given the proximity of these sites to Singleton Station, there is a possibility of the sites being impacted by the Singleton Water Licence.

53. Aquatic GDEs, particularly wetlands, springs and soakages, are typically those with the greatest sensitivity to drawdown. These are often the sites of greatest biodiversity and highest cultural value. The Fortune Report, which is a report considered by the Water Controller[47], fails to assess the impact of Singleton Water Licence on aquatic GDEs. The Guideline fails to contain any criteria for aquatic GDEs. The Water Controller also fails to consider the impact of the Singleton Water Licence on aquatic GDEs in the Western Davenport District in making the Water Controller Decision.

54. Aquatic GDEs are much more sensitive to drawdown than terrestrial vegetation GDEs, and the drawdown criteria proposed for the GDEs do not incorporate the more stringent drawdown criteria appropriate for aquatic GDEs. In some cases, any change in groundwater levels can "detach" the water table from these aquatic GDEs which will have serious impacts to aquatic fauna in particular. This could cause species to become locally or even regionally extinct. Rare and endangered species may be utilising these systems for resources and/or habitat but this has not been assessed.

[45] Page 8 of the Guideline
[46] Page 9 of the Guideline
[47] Paragraph 46 of the Statement of Decision.

H. GROUND 7 - LACK OF UNDERSTANDING OF REGION-SPECIFIC VEGETATION GDEs DRAWDOWN IMPACT CRITERIA

Ground 7: The WDWAP and Guideline demonstrate a lack of understanding of region-specific vegetation GDEs and the use of criteria are not consistent with those used in other jurisdictions in Australia.

55. The WDWAP and Guideline demonstrate a lack of understanding of region-specific vegetation GDEs and the use of criteria are not consistent with those used in other jurisdictions in Australia.

56. In the WDWAP and Guideline, all GDE areas with a DGW of 10 metres or less are considered together with the same drawdown magnitude and rate impact criteria. Areas with considerably shallower DGW than 10 metres, especially those areas with DGW of less than 5 metres, will be more highly groundwater dependant and will require more stringent rate impact criteria.

57. The WDWAP and the Guideline refer to a report by P.G Cook and D. Eamus titled "*The Potential for Groundwater use by Vegetation in the Australian arid zone"* (2018a). Cook and Eamus referred to a study done on banksias in Western Australia for a period over 20 years (**Banksia WA study)**. EWRs for terrestrial GDEs are presented based on the Banksia WA Study.

58. It is concerning that the Banksia WA study is referred to given that the Banksia WA study focussed on banksia woodlands on sandy soils (Gnangara Mound). The vegetation communities in the Western Davenport District do not contain these species and there are no similar soil types in Western Davenport District (with possibly the exception of the alluvial landform areas).

59. Given the limited application of the Banksia WA Study in determining the EWRs for the Western Davenport District, there are high levels of uncertainty about the criteria (namely rate and magnitude of drawdown criteria) and the impacts on the terrestrial vegetation GDEs in the WDWAP and the Guideline. EWRs specific to the vegetation community and soil type for the Western Davenport District need to be determined.

60. The banksia woodland criteria in the Banksia WA Study were developed based on 20 years of vegetation condition and groundwater level change information. This gives an indication of the research effort required to determine these criteria with any degree of rigor.

61. The Banksia WA study is seen as best practice with different drawdown rate and magnitude criteria for the following levels of DGW areas: 10 to 6 metres, 6 to 3 metres and less than 3 metres. The drawdown and rate of drawdown criteria become more stringent as the DGW decreases. There is no justification presented in the WDWAP and the Guideline for all GDEs with a depth to groundwater of 10 metres or less having the same drawdown impact criteria.

I. GROUND 8- SINGLETON WATER LICENCE SHOULD NOT BE LONGER THAN 10 YEARS.

Ground 8: The Water Controller should not have granted the Singleton Water Licence for a term more than 10 years given the uncertainty underlying the Groundwater Model and the potential impacts of granting the Singleton Water Licence.

62. Section 60(3) of the Water Act 1992 provides that a licence to take groundwater shall be granted for a period not exceeding 10 years. Section 60(4) provides:

> *"The Controller may, where in the opinion of the Minister there are special circumstances that justify so granting the licence, grant a licence for such period exceeding 10 years as is specified in the licence document."*

63. In her reasons, the Controller referred to the Minster of Environment having affirmed that in the Minister's opinion there are special circumstances for granting a licence in excess of 10 years[48].

64. The Guideline: Special circumstances for water extraction licence terms up to 30 years (**30 Years Guideline**) notes a case for special circumstances may exist where *"there is sound scientific knowledge of the water resource from which the licence takes water"*[49] and *"the impacts of extraction have been or can be assessed with a high degree of certainty."*[50] For the reasons given above under Grounds 2 to 7, particularly with the uncertainty underlying the Groundwater Model and the impact on cultural values in the Western Davenport District, these do not exist for the water extracted from the Western Davenport District.

J. GROUND 9- BIODIVERSITY SURVEYS UNDERTAKEN BY THE NORTHERN TERRITORY GOVERNMENT AND THREATENED SPECIES

Ground 9: The Water Controller fails to address the concerns raised by the CLC about the biodiversity surveys conducted by the Northern Territory Government which could have impacted on the assessment about the threatened species in the Western Davenport region.

65. In CLC's previous submission in response to the Notice of Intention for the Singleton Water Licence, the CLC requested that the Northern Territory Government undertake further biodiversity surveys as the Northern Territory Government conducted baseline flora and fauna survey work during a prolonged very dry period which meant that the results from such surveys were likely to be incomplete and unrepresentative. CLC also requested that the Northern Territory Government conduct surveys that included Warrabri, Mungkarta and Karlantijpa South Aboriginal Land Trusts in the Western Davenport District to establish a more thorough baseline with greater coverage.

66. Such concerns were not addressed by the Water Controller in her Statement of Decision and the Water Controller also did not set out the basis of the advice that she received that "*there are no known threatened species in the Western Davenport region that are dependent on GDEs.*[51]*"* The Water Controller's assertion of there being no threatened species should not rest on surveys conducted in the context described in paragraph 65.

67. This is significant as CLC considers that all GDEs known to support significant populations of threatened species (including both flora and fauna species) should be protected from negative impact.

K. GROUND 10 – CONDITION CP6 DOES NOT PROTECT FROM SALINITY IMPACTS.

[48] Paragraph 120 of the Statement of Decision
[49] Paragraph 5.2.1 of the 30 Years Guideline, page 6.
[50] Paragraph 5.2.1 of the 30 Years Guideline, page 6.
[51] Paragraph 105 of the Statement of Decision

Ground 10 - Condition CP6 in the Singleton Water Licence does not sufficiently address the elevated soil salinity risks recognised in the Statement of Decision.

68. The Water Controller notes that she has been advised that there is an elevated soil salinity risk associated with the Singleton Water Licence [52] and given that the salts are likely to flush beyond the root zone, there is uncertainty as to how this could impact the underlying groundwater resource[53].

69. CLC submits that the condition CP6 in the Singleton Water Licence does not adequately address such risks. The assessment and report to be provided to the Water Controller must include "*a discussion about the likelihood and extent of salinity impacts on the Land and Water Resource".* This is unnecessarily vague. A "discussion" does not suffice and that the Water Controller should require Fortune Agribusiness to conduct a detailed impact assessment if the study shows potential for elevated salt leaching from soils under irrigation. The assessment needs to consider irrigation return to the aquifer and potential for groundwater salinity increases and flushing during intense recharge events.

70. CLC also submits that such an assessment should be subject to independent peer review

L. <u>DECISION SOUGHT FROM THE MINISTER</u>

71. Based on the grounds set out above, the Water Controller should not have made the decision to grant the Singleton Water Licence.

72. CLC submits that the decision which should have been made by the Water Controller, in the first instance, is to ensure that the work set out in the WDWAP, including work to refine the Groundwater Model and to address the uncertainty in the Western Davenport District generally (see, for example, sections 7.4.5, 7.4.6 and 8.4.1) is completed before considering any application for a groundwater licence in the Western Davenport District, especially an application for a licence of such a significant volume comprising a substantial portion of the estimated sustainable yield. It is only once the work set out in the WDWAP and the additional work identified in paragraph 73 below are completed, that there will be certainty of sufficient understanding to manage the groundwater resource and environment in the Western Davenport District.

73. In addition to the work set out in the WDWAP, the following work should also be undertaken before any licence is granted to ensure that the objectives underlying the WDWAP are met:

    a) Ranking of relative importance of terrestrial vegetation GDEs based on biodiversity and cultural values. These studies need to cover:

        (i) flora and fauna surveys; and

        (ii) a relative biodiversity value ranking assessment.

    The assessment and the surveys need to be linked to cultural value studies. Groundwater monitoring is also required at these sites, particularly sites with the highest biodiversity value and/or cultural value.

    b) Assessment of the location, biodiversity and cultural value and EWRs of aquatic GDEs. As submitted in Ground 6 above, the risks to aquatic GDEs have not been

[52] Paragraph 81 of the Statement of Decision
[53] Paragraph 83 of the Statement of Decision

considered in the WDWAP, the Guideline, Fortune Report and the Water Controller Decision.

The sites identified in the maps in Annexure A should be selected at a minimum for biological, hydrological and hydrogeological investigation and other aquatic sites, particularly culturally significant aquatic sites, should also be included. Aquatic GDEs need to be surveyed for:

(i) aquatic flora and fauna; and

(ii) terrestrial flora and fauna;

These surveys need to be linked to cultural value studies. Once completed, a relative biodiversity and cultural value ranking assessment can be carried out and hydro-ecological linkages and degree of groundwater dependence determined. This will provide the requisite understanding of the ecological thresholds and EWRs required to manage these important sites.

c) Hydrogeological investigations of GDEs at a local scale need to be integrated with the regional groundwater and geophysics investigation and the monitoring regime covering water levels and quality. This will require additional drilling. Monitoring and investigation of hydrology, hydrogeology and biology must be done at the same sites, at the same frequency and timing to ensure consistent overlap of these datasets. To determine the degree of groundwater dependence and impact risk to aquatic GDEs will also require individual aquatic GDE water and solute balances to be derived from monitoring data.

d) The completion of work under paragraphs 73(a) and (c) will allow determination of appropriate vegetation community specific EWRs while work completed under paragraphs 73(b) and (c) will allow determination of appropriate aquatic GDE EWRs the latter of which will likely vary on site specific basis.

e) Development of an improved groundwater model to assess impact on new and robust EWRs. Only once this is completed can development of a long-term integrated monitoring plan, with periodic review of GDE condition and EWRs, be appropriately robust and precautionary.

74. As indicated in Ground 9 above, the CLC also requires the Northern Territory Government to undertake further biodiversity surveys as the Northern Territory Government conducted baseline flora and fauna survey work during a prolonged very dry period which meant that the results from such surveys were likely to be incomplete and unrepresentative.

75. Accordingly, the CLC submits that the Minister should substitute the Water Controller Decision with the decision set out in paragraphs 72, 73 and 74 above.

76. If the Minister appoints a review panel to advise her under section 30(3)(b) of the Water Act, it is important that someone with hydrogeological expertise is appointed on the review panel given the grounds raised in the submissions above are required to be considered by someone with such expertise.

77. CLC also submits that while the ministerial review process is underway under the Water Act, all other remaining approval process relating to the Singleton Horticultural Project (and as set out in the Singleton Horticulture Project approvals map which is available online) be halted to ensure that this ministerial review process is not undermined in an way. No works should be undertaken, including vegetation clearing, until the ministerial review process is completed.

ANNEXURE A - MAPS

Groundwater Dependent Ecosystems Atlas

Local WCD_rivers

Aquatic GDE

- Known GDE (regional study)
- High potential GDE (regional study)
- Moderate potential GDE (regional study)
- Low potential GDE (regional study)
- Unclassified potential GI (regional study)
- High potential GDE (national assessment)
- Moderate potential GDE (national assessment)
- Low potential GDE (national assessment)
- Unclassified potential GI (national assessment)

N

1:1,413,455

Kilometres 20 40 60

Data Source: Bureau of Meteorology, Geoscience Australia and State/Territory lead water agencies. Refer to metadata for further information: Click here

Australian Albers GDA94

Date: 24 February, 2021

Australian Government
Bureau of Meteorology

Groundwater Dependent Ecosystems Atlas

Local WCD_norivers

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Kilometres 20 40 60

Data Source: Bureau of Meteorology, Geoscience Australia and State/Territory lead water agencies. Refer to metadata for further information: Click here

Australian Albers GDA94

Date: 24 February, 2021

ATTACHMENT C:

WESTERN DAVENPORT GROUNDWATER MODEL – SENSITIVITY ANALYSIS AND INDICATIONS OF PREDICTIVE UNCERTAINTY

Prepared by Dr Ryan Vogwill of Hydro Geo Enviro Pty Ltd and Dr Eduard De Sousa of Intera Geosciences

10 February 2023

WESTERN DAVENPORT GROUNDWATER MODEL - SENSITIVITY ANALYSIS AND INDICATIONS OF PREDICTIVE UNCERTAINTY

PREPARED FOR | Central Land Council - Northern Territory

PREPARED BY | Intera Geosciences and Hydro Geo Enviro Pty Ltd

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Proprietary Information Statement

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Document Information

Prepared by: Dr Ryan Vogwill		**Date:** 10/02/2023
Prepared: Dr Eduardo DeSousa		**Date:** 10/02/2023
Approved by:		**Date:**
Client distribution:		**Date:**

Contents

Executive Summary

As part of assessing the likely variability in the CloudGMS model predictions in the Western Davenport area CLC has requested INTERA Geosciences Pty Ltd to conduct a predictive spatial sensitivity analysis of the CloudGMS groundwater model. The methodology consisted of generating model (sensitivity) runs using a range of hydraulic parameters in order to demonstrate that the model could still be calibrated (i.e. recreate the available groundwater level data) under said range and the implications of this range of hydraulic parameters in terms of model predictions. Particularly in terms of those parameter combinations which result in greater drawdown. A total of 14 scenarios were constructed to test different parameter configurations. These scenarios are divided into groups aimed at demonstrating different predictive outcomes while maintaining a similar level of calibration.

Visual inspection of the simulated predictive hydrographs shows that the groundwater level differences between scenarios and base model is considerably larger than those obtained for the calibration period. This indicates that 1 – the ability of the calibration dataset to constrain model predictions is limited and 2 – as the calibration period experienced modest groundwater use compared to the predictive period, historical groundwater levels provide little information regarding aquifer response to the large increase in groundwater abstraction proposed at Singleton Station.

The targeted sensitivity analysis presented in this study demonstrate that the non-uniqueness of model parameters, with respect to calibration, will have large implications to predictive uncertainty. Non-uniqueness is the concept that many different possible sets of model inputs (hydraulic parameters for example) can produce nearly identical computed aquifer head distributions (hence near identical model calibration) for any given model (Middlemis, 2019). The fact that differences between groundwater levels produced by the predictive results in the sensitivity scenarios are significantly larger than differences in calibration results clearly show this. While this analysis demonstrates some of the uncertainty regarding drawdown predictions, it has by no means explored the entire uncertainty range as relatively subtle changes in hydraulic parameters were used in most scenarios as compared to a full sensitivity range. Uncertainty quantification techniques such as the ones mentioned in Section 1.1 are widely used in the modelling community, but require large computational efforts to do so and are difficult to undertake in this case due to the choice of modelling platform. The results of the sensitivity scenarios we have provided give some indication of uncertainty in the model's predictions but to actually give a range for each prediction would require a predictive uncertainty analysis that wasn't possible with the resources provided, due to the proponent's choice of model platform (MikeSHE). Predictive uncertainty analysis would have entailed probabilistically defining a plausible range of hydraulic parameters and running 100's to 1000's of model scenarios across this range to produce the uncertainty in drawdown predictions according to the model.

In the context of how our scenarios meet or breach GDE impact criteria, given that the landform class data was not made available to CLC across the model domain we were not able to explicitly assess the various model scenarios against these criteria. However, it is clear that the area breaching these criteria increases significantly under a number of the sensitivity scenarios. The calibration and predictive modelled drawdowns are typically near the most optimistic (least drawdown) range of predictions shown in this modelling exercise.

It must also be noted firstly that conceptual uncertainty, another source of uncertainty associated with incorrect assumptions about the various aquifers' distribution and hydraulic connectivity, is not addressed in this assessment. There is considerable conceptual uncertainty due to the lack of drilling and aquifer testing available at the point in time that the model was constructed and calibrated. Secondly although this is not an exhaustive set or range of scenarios, the results clearly indicate how uncertain the model is. Modelling commensurate with our outputs should have, at a minimum, been provided to decision makers based on the

Australian Groundwater Modelling Guidelines, though a full predictive uncertainty analysis is recommended. For a full description of types of uncertainty in groundwater modelling the reader is directed to Middlemis (2019).

Given the uncertainty around the model in terms of conceptual and numerical uncertainty it is recommended that the areas which breach GDE criteria under any of these scenarios are reassessed by the proponent or DEPWS and are included as having impact potential until the modelling is refined substantially and has undergone a full uncertainty quantification. This would include the need for baseline data to be obtained on groundwater levels and biodiversity at the GDEs prior to any drawdown impacts manifesting. Our work reinforces that the use of model produced baselines and depth to groundwater relationships (a critical control on which areas are currently assessed as having impact potential) at GDEs is not justified with such an uncertain model. Relying on their single model's outputs to define baselines and depth to groundwater relationships will make it much more difficult to ascertain the causes of impacts when they manifest in the future, especially if they are areas outside the base model's currently estimated area of impact. Essentially if asked was it reasonable for decision-makers to rely on a single model's outputs to define baselines and depth to groundwater relationships? We would say, in our opinions, this is fraught with risk and not reasonable based on our scientific opinion, experience and the Australian Groundwater Modelling Guidelines (Barnett et al., 2012).

Models are limited by the data which has been used to construct them and in areas of no data we don't have any distinct measurements to compare the model's predictions to. Therefore, if some time in the future impacts at a particular site manifest (vegetation deaths etc) and we don't have baseline measured data at the site, it can often be difficult to determine the cause of an observed impact (i.e. is it pumping related drawdown, climate, landuse or a combination thereof).

As a final point we would suggest that this model in its current form is not the best-suited platform by which to make a licence decision nor is it suitable in terms of defining which biodiversity and cultural assets can be impacted. The single scenario used by the proponent and DEPWS may not identify a number of cultural and biodiversity sites which could may be impacted, hence need investigation and baseline data obtained to facilitate adaptive management. In terms of modelling platform, given the current lack of data many of the key strengths of MikeSHE (coupled unsaturated zone flow, saturated flow and overland flow) are not being utilised. MikeSHE is a difficult modelling platform to undertake predictive uncertainty analysis in, unlike MODFLOW 6 in which we can do this analysis routinely.

1.0 INTRODUCTION AND MODELLING CONTEXT

Hydrogeoenviro Pty Ltd. (HGE) was commissioned by the Central Land Council (CLC) of the Northern Territory to undertake the review of a MIKE-SHE (CloudGMS) Western Davenport Water Allocation Plan groundwater model. This model was presented as part of a water extraction licence application by Fortune Agribusiness Funds Management Pty Ltd (Fortune) for the purposes of the Singleton Horticultural Project. Part of that review (HydroGeoEnviro, 2021) suggested (at paragraphs 24, 86 and 90) exploring alternative model outputs resulting from model non-uniqueness and subsequent variability in model predictions. CLC has requested INTERA Geosciences Pty Ltd to conduct a predictive and spatial sensitivity analysis in relation to the uncertainty in predictions from the CloudGMS groundwater model.

We prepared this report without any written instructions from CLC and have carried out predictive spatial sensitivity analysis in the way we consider most appropriate and feasible, given the time and resources we had available, as described in this report.

Ryan Vogwill is a Principal Hydrogeologist and Director for HydroGeoEnviro PTY LTD. Ryan has more than 20 years of technical expertise encompass groundwater modelling, water resource planning and recovery of hydrologically impacted ecosystems, with a focus on applying research to sustainable groundwater management and environmental impact/risk assessment. He has undergraduate, first class honours and doctorate degrees in Applied Geology from Curtin University. He graduated from his PhD in 2003. Ryan is also a Member of the Australian Institute of Geoscientists (specialisation hydrogeology). His CV is presented in Appendix 5.

Eduardo de Sousa is a Principal Groundwater Modeller and Managing Director at INTERA Australia. He has nearly two decades of experience working in South America, Africa and Australasia delivering modelling solutions in hydrogeological systems of high complexity, including modelling of geothermal systems, reactive transport modelling, design of dewatering and depressurization systems, environmental impact assessments, ecohydrology and groundwater remediation. Dr. De Sousa's work has included the development of DHI's tool for MODFLOW6 to FEFLOW conversions, dewatering optimization workflows for consulting projects and software product, tools to emulate steam pressures in the unsaturated zones in geothermal sites, software infra structure to allow the use of PEST with FEFLOW models, and high-complexity three-dimensional (3D) models in mining environments for operations (dewatering and depressurisation), environmental purposes and dynamic coupling of pit-lake and groundwater models in mine closure projects. Eduardo graduated from his PhD at the University of Western Australia in 2021. His CV is also presented in Appendix 5.

The MikeSHE groundwater modelling files were obtained via secure FTP from DEPWS in November 2021. These files consist of the Western Davenport's model's specific files that comprise a functioning groundwater model that can be altered and/or run within the MikeSHE modelling software platform.

1.1 Objectives of the Sensitivity Analysis

Given that one of the concerns that led to the review of the model was related to uncertainty underlying its predictive estimates, the original scope of work investigated the possibility of implementing a full predictive uncertainty analysis approach using the groundwater model. This is calibration-constrained uncertainty analysis utilising methods such as the Null Space Monte Carlo (Doherty, 2015) or the Iterative Ensemble Smoother (White, 2018). These approaches would enable the uncertainty quantification of the predictions of interest. Simplistically, uncertainty quantification in a prediction allows us to understand if a model's predicted drawdown of 5m at a particular feature, is +/- 10 cm, 0.5 m, 10m etc.

Further exploration has identified that the use of these techniques for the model in question was not feasible within the project timeframe due to:

- Inability of MIKE-SHE to run in a parallelised environment, which is a pre-condition given the large number of model runs required during the uncertainty analysis; and
- Potentially long model run times typical of fully-integrated surface-water models.

The scope of work presented herein intends to therefore demonstrate the non-uniqueness of model parameters and the approximate consequence in terms of predictions, rather than full uncertainty quantification, utilising sensitivity analysis and "what-if" parameter scenarios.

2.0 METHODOLOGY AND SENSITIVITY SCENARIOS

The model developed for the Singleton Station (Fortune Agribusiness) water extraction licence consists of an integrated surface-groundwater model using the MIKE-SHE platform. This model is described in detail in CloudGMS (2018) and has been reviewed in HydroGeoEnviro (2021).

The methodology consisted of generating target sensitivity runs in order to demonstrate the parameter non-uniqueness and the implications in terms of predictive estimates. Small parameter changes were introduced in the original model setup (named base model in this report), aiming at obtaining different predictive estimates while preserving model calibration (i.e., the match between historical groundwater level records and corresponding model outputs). Parameters included in the sensitivity runs include:

- Horizontal hydraulic conductivity (Kh),
- Vertical hydraulic conductivity (Kv),
- Specific storage (Ss), and
- Specific yield (Sy).

Since recharge rates in the model were simulated rather than prescribed, direct sensitivity runs on recharge could not be undertaken. As an alternative the soil saturated conductivity (Ksat) parameter of the soil infiltration model was utilised as a proxy for recharge sensitivity.

Small changes in the parameters were introduced using multipliers on the original values in the base model. Most of these changes in parameters were less than 25% increases or decreases (Table 3) with the exception of scenarios 3, 4, 7 and 8 where changes of up to 75% have been made. With the exception of specific yield (Sy) being decreased by 75% (from 0.04 to 0.01 in Scenario 8) these hydraulic parameters are more or less equally plausible as compared to the base model at a regional scale.

We would note that in a full sensitivity analysis or predictive uncertainty analysis, hydraulic parameters would have typically been varied through a greater range than we have used. Generally, in a sensitivity analysis we would vary (from the calibrated values) hydraulic conductivity by up to an order of magnitude (10X increase and 10X decreases). As for storage parameters, these would be varied by +/-50% in the case of specific yield and by an order of magnitude for specific storage. We did not run scenarios across this full range as the range we used was sufficient to demonstrate the considerable variability in groundwater level and drawdown predictions.

There is not enough hydrogeological work done in the Western Davenport area such that ranges in these parameters can be defined precisely based on rock types/aquifers. Regardless, rock type does not precisely determine hydraulic parameters because there are other factors at play such as degree of fracturing, weathering, diagenesis among others. The lack of aquifer testing, drilling and other data means the conceptual uncertainty is too high for anyone to define a precise range of hydraulic parameters based on field data.

These hydraulic parameter multipliers were applied simultaneously over all the model parameter zones (for aquifer properties) and soil types (for the infiltration model). The base parameters for aquifer and recharge soil properties are summarised in Tables 1 and 2.

Table 1 – Base parameters for aquifer properties.

Zone ID	Description	Kh (m/s)	Kv (m/s)	Sy (-)	Ss (1/m)
1	Cenozoic	2.11E-05	5.44E-06	0.04	0.0001
2	Soil	1.00E-06	1.00E-06	0.04	0.0001
3	Dulcie	9.52E-06	9.52E-07	0.04	1.00E-05
4	Arrinthrunga	8.65E-06	8.65E-07	0.04	1.00E-05
5	Chabalowe	2.15E-05	2.15E-06	0.04	5.00E-06
6	Fractured rock	1.00E-06	1.00E-06	0.01	1.00E-06
7	Basement	5.00E-07	5.00E-07	0.01	1.00E-06

Table 2 – Base parameters for recharge soil properties.

Zone ID	Description	Ksat (m/s)
1	Loam	7.20E-07
2	Loam Sand	7.00E-07
3	Outcrop	1.00E-07
4	Alluvium	1.00E-07
5	Colluvium	1.50E-07
6	Hard Pan	1.00E-08
7	Calcrete	8.00E-07
8	Silt	1.00E-07
9	Floodout	6.00E-07

A total of 14 scenarios were constructed to test different parameter configurations. These scenarios are divided in four groups aiming at demonstrating different predictive outcomes while maintaining calibration, namely:

- Possibility of larger drawdown magnitudes by lowering hydraulic conductivity;
- Possibility of larger drawdown magnitude and extent by lowering hydraulic conductivity and storage;
- Possibility of larger drawdown footprint by increasing hydraulic conductivity; and
- Possibility of larger drawdown footprint by increasing aquifer diffusivity (ratio between hydraulic conductivities and storage parameters)

All the scenarios were simulated for the calibrated (1970-2020) and predictive (2020 to 2080) periods, with exception of Scenario 1 (which was only simulated for the calibrated period as the results were very similar to the base model in prediction due only a 10% decrease in the hydraulic conductivity values). Parameter multipliers, scenario descriptions and objectives are summarised in Table 3.

Table 3 – Summary of sensitivity runs.

Scenario	Description	Objective	Parameter multipliers				
			Kh	Kv	Sy	Ss	Ksat
1	Apply lower hydraulic conductivity and maintain K / Recharge ratio	Demonstrate possibility of larger drawdown magnitude	0.9	0.9	1	1	0.9
2			0.75	0.75	1	1	0.75
3			0.5	0.5	1	1	0.5
4			0.25	0.25	1	1	0.25
5	Apply lower hydraulic conductivity and maintain K, Recharge and Storage ratios	Demonstrate possibility of larger magnitude and faster drawdowns	0.9	0.9	0.9	0.9	0.9
6			0.75	0.75	0.75	0.75	0.75
7			0.5	0.5	0.5	0.5	0.5
8			0.25	0.25	0.25	0.25	0.25
9	Apply higher hydraulic conductivity and maintain K / Recharge ratio	Demonstrate possibility of larger drawdown footprint	1.1	1.1	1	1	1.1
10			1.25	1.25	1	1	1.25
11			1.1	1.1	1.1	1.1	1.1
12			1.25	1.25	1.25	1.25	1.25
13	Apply higher hydraulic conductivity, maintain K / Recharge ratio, and decrease storage	Demonstrate possibility of larger drawdown footprint by using larger diffusivity (K/S)	1.1	1.1	0.9	0.9	1.1
14			1.25	1.25	0.75	0.75	1.25

3.0 SENSITIVITY ANALYSIS RESULTS

3.1 Effects on Calibration

Since the original calibration dataset used in the base model was not available for this scope, calibration performance was undertaken through the comparison of results from the scenario runs and the base model in 43 locations (equating to the monitoring bores used in the calibration of the base model). Hydrographs of all sensitivity runs and the base model over the calibration period are presented in Appendix 1.

The analysis of these hydrographs suggests that:

- The difference and groundwater levels (or heads) between sensitivity runs and base model is small (usually less than 1 m) in most hydrographs, with exception of Scenario 4 which applied the lowest multiplier to the Kh, Kv and Ksat parameters;
- While the sensitivity runs show larger differences in head in some locations (e.g., Scenarios 4 and 8 in the borehole RN015585), they also show very small differences in others (e.g., borehole RN006440), likely related to heterogeneity within the different hydrogeological units;
- In hydrographs that show large head variations/fluctuations (like RN006440) from the sensitivity runs during the calibration period tend to be similar to those from the base model, possibly associated to proximity of boundary conditions and the subsequent lower parameter sensitivity (in terms of calibrated water levels) in these areas; and
- The fact that different parameter multipliers and settings from the sensitivity runs yield similar results to the base case demonstrate the non-uniqueness of the model.

3.2 Effects on Modelling Predictions

Modelling results are presented in three forms:

- Predictive hydrographs at the calibration locations for the period 2020 to 2080 (Appendix 2);
- Simulated drawdowns across the model domain for each of the scenarios, in terms of groundwater level difference between 2020 and 2080 (Appendix 3) and;

- Groundwater level differences between the scenarios and base model for year 2080 (Appendix 4).

Visual inspection of the simulated hydrographs shows that the groundwater level differences between scenarios and base model is considerably larger than those obtained for the calibration period. Some brief interpretation of the results (as compared to the results of the base case model) are given below for each scenario. The reader should compare these descriptions to the figures in Appendix 4:

- Scenario 1 (decreased hydraulic conductivity by 10%) produces drawdowns at the end of the model's predictive results (at year 2080) that are very similar to the base case so these results have not been presented;
- Scenario 2 (decreased hydraulic conductivity by 25%) shows drawdown increases of up to 4m near Singleton Station. Some groundwater level increases occur away from Singleton Station;
- Scenario 3 (decreased hydraulic conductivity by 50%) shows a drawdown increase of up to 11m near Singleton Station and a larger area of drawdown. Some groundwater level increases occur away from Singleton Station;
- Scenario 4 (decreased hydraulic conductivity by 75%) shows a drawdown increase of up to 30m near Singleton Station and a larger area of drawdown). Some groundwater level increases occur away from Singleton Station;
- Scenario 5 (all parameters decreased by 10%) shows a drawdown increase of 1m near Singleton Station and small changes elsewhere;
- Scenario 6 (all parameters decreased by 25%) shows a drawdown increase of up to 4m near Singleton Station. Some groundwater level increases occur away from Singleton Station;
- Scenario 7 (all parameters decreased by 50%) shows a drawdown increase of up to 14m near Singleton Station. Some groundwater level increases occur away from Singleton Station;
- Scenario 8 (all parameters decreased by 75%) shows a drawdown increase of up to 16m near Singleton Station. Very little difference elsewhere apart from on the model's western and southern boundaries where additional drawdown is predicted);
- Scenario 9 (all parameters increased by 10% except for storage) shows only minor change except at the model's north eastern and south western boundaries;
- Scenario 10 (all parameters increased by 25% except for storage) shows a drawdown reduction of 1m at Singleton Station but increased drawdown south of the Station of up to 4m. Groundwater level rises are predicted at the model's north eastern and south western boundaries;
- Scenario 11 (all parameters increased by 10%) shows little changes throughout;
- Scenario 12 (all parameters increased by 25%) shows a drawdown reduction of up to 2m at Singleton Station but increased drawdown of up to 4m is predicted south of the Station. Groundwater level rises are predicted at the model's north eastern and south western boundaries;
- Scenario 13 (hydraulic conductivity increased by 10% storage decreased by 10%) shows very little change at Singleton Station and surrounds. Most changes in drawdown are predicted near the model boundaries; and
- Scenario 14 (hydraulic conductivity increased by 25% and storage decreased by 25%) shows an increase in drawdown near Singleton Station of up to 2m but a greater drawdown of up to 4m occurs to the south of the station. Groundwater level rises are predicted at the model's north eastern and south western boundaries.

The predictive hydrographs in Appendix 2 should also be viewed noting that the black dashed line (the prediction of drawdown at the particular calibration bore for the base case model) are typically near the smallest predictions of drawdown from the multiple sensitivity model runs at that site. The additional drawdown predicted at some sites can be considerable (often 10+m of additional drawdown as compared to the base case). Some reduced drawdowns also occur under some of the scenarios but more often additional drawdown is predicted as would be expected based on our choice of scenarios. 8 sensitivity scenarios (1-8) are focussed on reduced (or constant) hydraulic parameters, 4 (9-12) on increased (or constant) parameters and 2 (13-14) on a mixture of increased and decreased hydraulic parameters.

Our interpretation of these results indicates:

1. the ability of the calibration dataset to constrain uncertainty in predictions is limited based on our experience with other models. This is demonstrated herein by large variations in drawdown predictions (while simultaneously having an only minor effects on model calibration) under the range of scenarios we have tested; and
2. as the calibration period experienced much smaller pumping regimes compared to the predictive period, historical groundwater and pumping levels used in the calibration provide little information regarding aquifer response to the large pumping regimes proposed at Singleton Station. Essentially until the drawdown response of the aquifer to a greater pumping regime is tested, measured and included in the modelling, through long term aquifer testing, the response of the aquifer to a large-scale increase in pumping is highly uncertain.

Sensitivity runs with larger hydraulic conductivity and diffusivity (i.e. Kh/Sy ratio) showed in general smaller drawdowns when compared to the base case. Although it was expected that the drawdown footprint would be larger, smaller drawdowns can be partly related to the fact that these scenarios show the largest drawdown over the calibration period, resulting in lower baseline levels in 2020 from which the predictive drawdowns are calculated. Furthermore, it is likely that the increased hydraulic conductivity added a "buffering capacity" for the aquifers due to their greater groundwater flowthrough facilitating the equilibration of groundwater levels as new hydraulic stresses (i.e., pumping) were introduced.

4.0 DISCUSSION AND RECOMMENDATIONS

The targeted sensitivity analysis presented in this study demonstrates that the non-uniqueness of parameters with respect to calibration have large implications to predictions, hence the model has a large amount of predictive uncertainty. The fact that differences between predictive results in the sensitivity scenarios are significantly larger than calibration results clearly show that.

While our analysis demonstrates the uncertainty regarding drawdown predictions, it has by no means explored the entire uncertainty range as relatively subtle changes in hydraulic parameters were used in most cases as compared to a full sensitivity range. Uncertainty quantification techniques, such as the ones mentioned in Section 1.1, are widely used in the modelling community, but require large computational efforts to do so. These approaches work best with a simpler and more efficient modelling approach.

The licensing constraints from the MIKE-SHE platform and the longer running times makes adoption of uncertainty quantification techniques very difficult. To that end, the use of simpler and more efficient approaches using open-source (without licence constraints) software would facilitate application of these techniques. For instance, MODFLOW 6 (Hughes et al., 2017) is a free, open-source and highly-efficient modelling platform, that would be better suited to assess the environmental, cultural and other groundwater user impacts associated with the drawdown. The trade-off with MIKE-SHE would be that recharge rates would have to be prescribed and calibrated as opposed to simulated. This is a small price given that soil parameters from MIKE-SHE soil infiltration model are also obtained through calibration, so differences between calibrating recharge directly would probably be small. There is also currently very little field data by which to parameterise and calibrate the MIKE-SHE soil infiltration model. Also given the surface water modelling capacity of MIKE-SHE wasn't particularly utilised MODFLOW is a better platform to have used in our opinion. Lastly, MODFLOW6 could be used in conjunction with other open-source software for recharge estimation, such as LUMPREM (Doherty, 2021) and SWB.

Therefore, should predictive uncertainty need to be quantified to further investigate the impacts from the groundwater abstraction, it is recommended that the current model be converted to MODFLOW 6, with or without use of additional software for recharge estimation.

The considerable amount of uncertainty in the CloudGMS model has flow on effects through the subsequent GDE impact analysis. The choice of point in time which is used for drawdown and depth to groundwater calculations (to apply to GDE criteria) is also a concern given the significant groundwater level fluctuations and uncertainty apparent in the model. The areas of significant groundwater level fluctuation (2-5m in most years in for example the hydrographs for RN006443 in appendices A and B) typically occur in areas with shallow groundwater (depth to groundwater 10m or less) and more frequent recharge due to leakage from surface water systems. These areas are more likely to contain GDEs but if the groundwater level fluctuates by as much as 5m in most years what is the appropriate baseline for calculating impact potential based on drawdown criteria? In this context the choice of the end of the calibration period is arbitrary and given the uncertainty around the model predicted groundwater levels explored herein, further consideration of this is required. For example, should the depth to groundwater be based on wet season groundwater levels, dry season groundwater levels, the highest groundwater level, the lowest groundwater level or some type of weighted average?

It is recommended that actual measured groundwater level data is used at all relevant GDEs (including cultural assets). Our work reinforces that the use of model produced groundwater level baselines at GDEs are highly uncertain which will make it much more difficult to ascertain the causes of impacts if they manifest.

The area of predicted impact which exceeds the groundwater dependent ecosystem (GDE) impact criteria as defined by DENR (2020) will vary considerably under this range of predictive sensitivity scenarios. These 3 groups of criteria are repeated here for reference:

Page 8 DENR (2020).

"In order that the principle of incorporating environmental variability is adequately applied, and in the absence of more comprehensive spatial data, the 70% threshold [i.e. 70% of GDEs must be protected] applies:

- within each of the two major landform classes (aeolian sandplain and alluvial plain)
- within each property occurring in the Water Control District."

Page 9 DENR (2020).

"For GDEs occurring where the depth of groundwater is less than or equal to 10 m, potential for negative impact occurs if modelled extraction shows that one or more of the following may occur:

- the maximum depth to water table exceeds 10 m below ground level
- the maximum depth to water table declines by more than 50% below the levels that would be expected under a natural baseline (no pumping) scenario
- modelled extraction results in a rate of groundwater drawdown that exceeds 0.2 m/year."

Page 9 DENR (2020).

"For GDEs occurring where the depth of groundwater is between 10 and 15 m, potential for negative impact occurs if modelled extraction shows that one or more of the following may occur:

- the maximum depth to water table declines by more than 35% below the levels that would be expected under a natural baseline (no pumping) scenario
- modelled extraction results in a rate of groundwater drawdown that exceeds 0.2 m/year."

Given that the landform class data was not made available to CLC we were not able to explicitly assess the various model scenarios against these criteria.

However, what is clear is that the area breaching these criteria increases under a number of the sensitivity scenarios. It does decrease in some scenarios but the calibration and predictive modelled drawdowns are typically near the most optimistic (least drawdown) range of predictions produced by our modelling exercise. As a comparison of the relative effect on drawdown of increasing the model's hydraulic parameters and decreasing parameters by an identical amount, we can compare the output of Scenario 2 (hydraulic conductivity decreased by 25% storage kept constant) and Scenario 10 (hydraulic conductivity increased by 25% storage kept constant). In Appendix 4 (the scenario drawdown difference maps relative to the base case) Scenario 2 predictions near Singleton Station indicate increases of up to 4 m over a large area while in Scenario 10 decreases of 1m occur over a smaller area than the area of increase in Scenario 2.

Given the uncertainty around the model in terms of both conceptual and numerical uncertainty it is recommended that the areas which breach GDE criteria under any of these scenarios (with the possible exception of Scenario 8) are included as having impact potential until the modelling is refined substantially at a minimum. Scenario 8 is considered unlikely as a specific yield of 0.01 (a 75% decrease from the base case's value of 0.04) is low. This would include the need for baseline measured (not modelled) data to be obtained on groundwater levels and biodiversity prior to impacts manifesting.

For reference of what should have been delivered as part of the licence application a number of the guiding principles from the Australian Groundwater Modelling Guidelines (Barnett et al., 2012) are repeated in this context.

- Guiding Principle 5.5: Sensitivity analysis should be performed to compare model outputs with different sets of reasonable parameter estimates, both during the period of calibration (the past) and during predictions (in the future).
- Guiding Principle 6.1: All model predictions are uncertain. The modelling process should acknowledge and address uncertainty through an appropriate uncertainty analysis (refer to Chapter 7).
- Guiding Principle 7.1: Because a single 'true' model cannot be constructed, modelling results presented to decision-makers should include estimates of uncertainty.
- Guiding Principle 7.6: Uncertainty should be presented to decision-makers with visual depictions that closely conform to the decision of interest.

The only uncertainty analysis presented in any reports provided to the CLC for drawdown predictions is on a pumping well which is not considered to relate to a "decision of interest". In this context the "decision of interest" is drawdown at GDEs, cultural sites and other groundwater users.

As a final point we would suggest that this model in its current form (MikeSHE) is not the best suited platform by which to make a licence decision nor is it suitable in terms of defining which biodiversity and cultural assets will be impacted and hence monitored. The use of a MODFLOW model would have made the application of predictive uncertainty analysis much easier as discussed in the executive summary and at the start of Section 4.

5.0 REFERENCES

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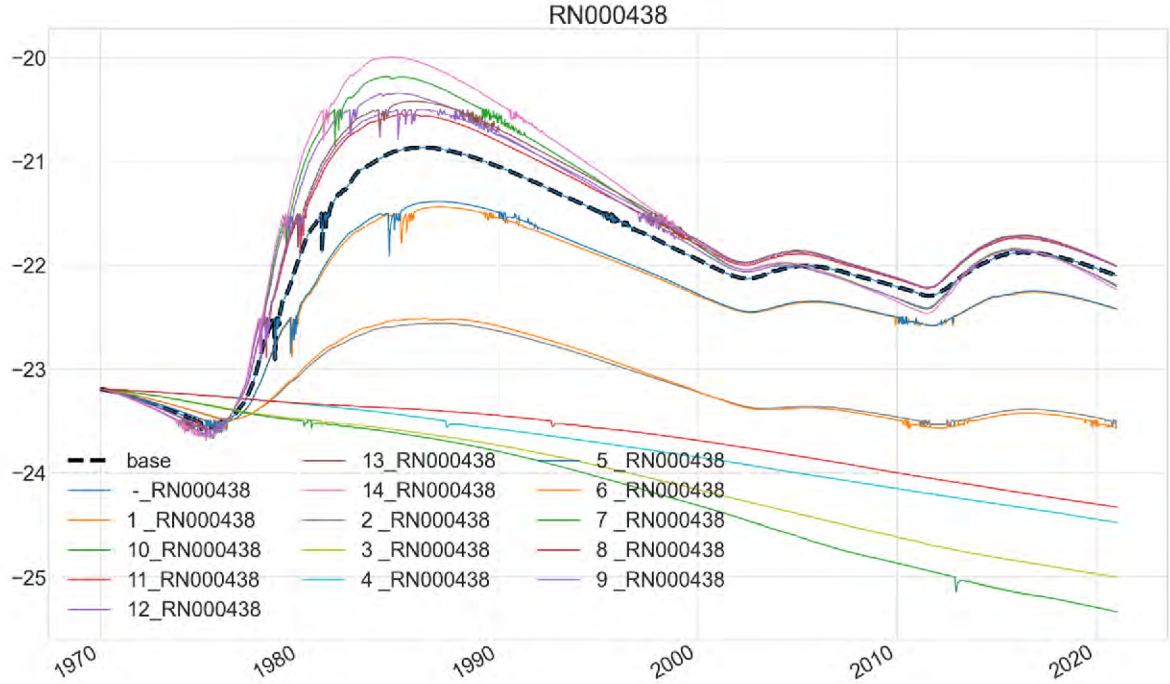
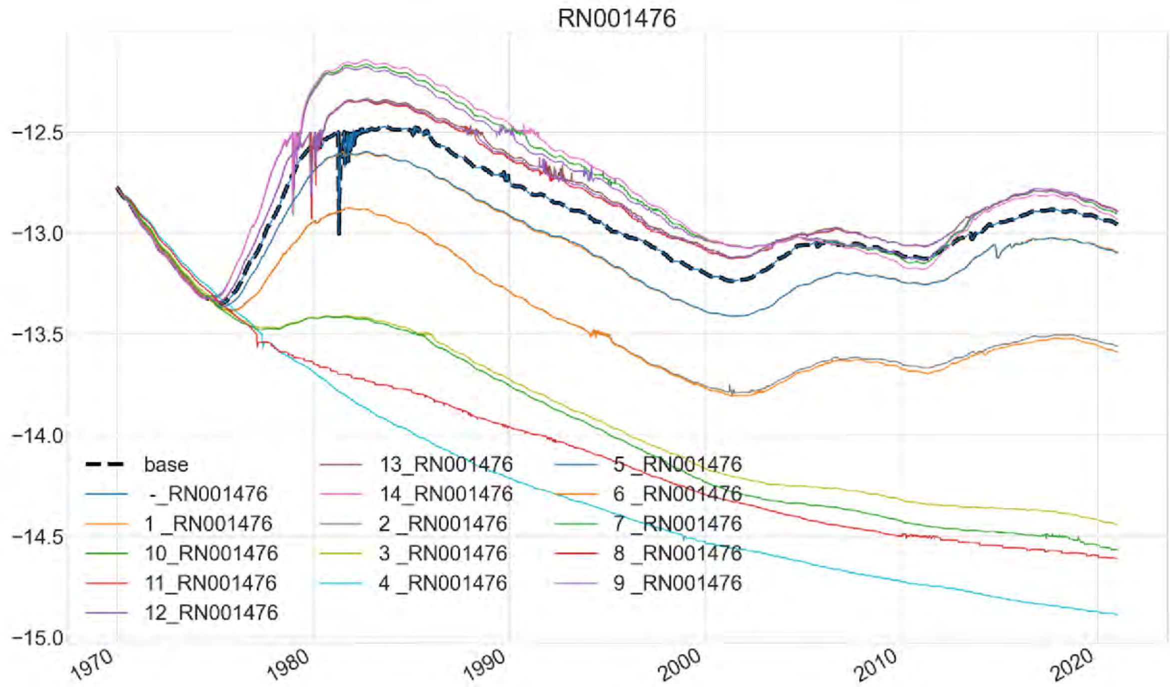
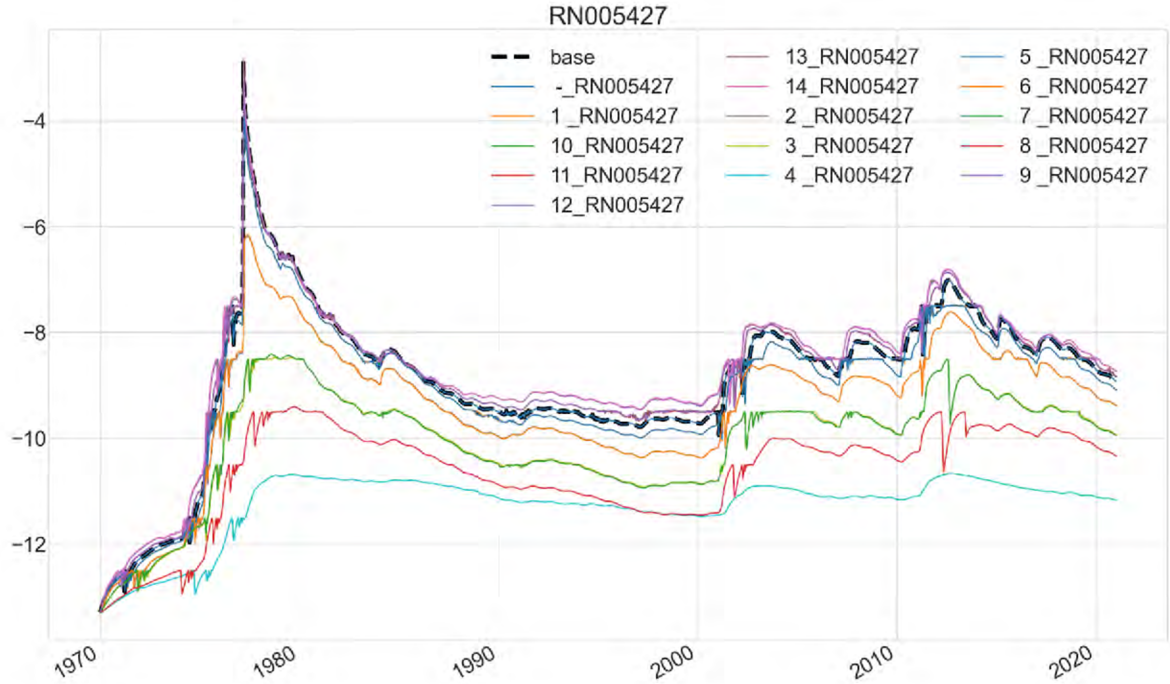
Appendix 1 - CALIBRATION HYDROGRAPHS



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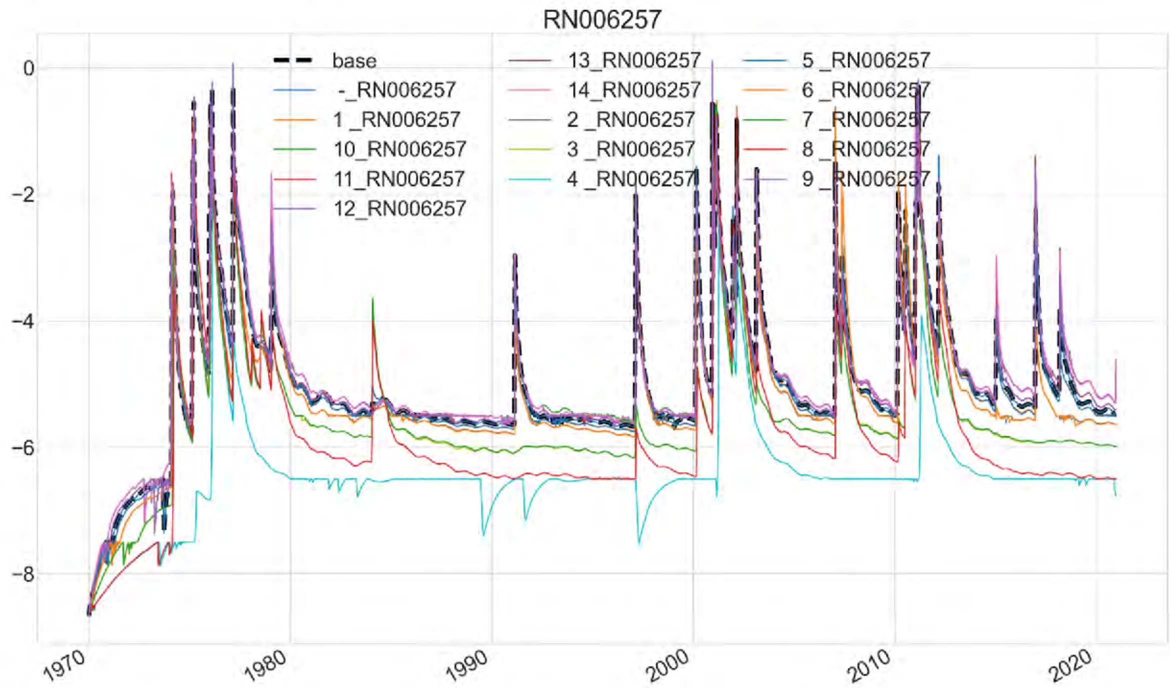
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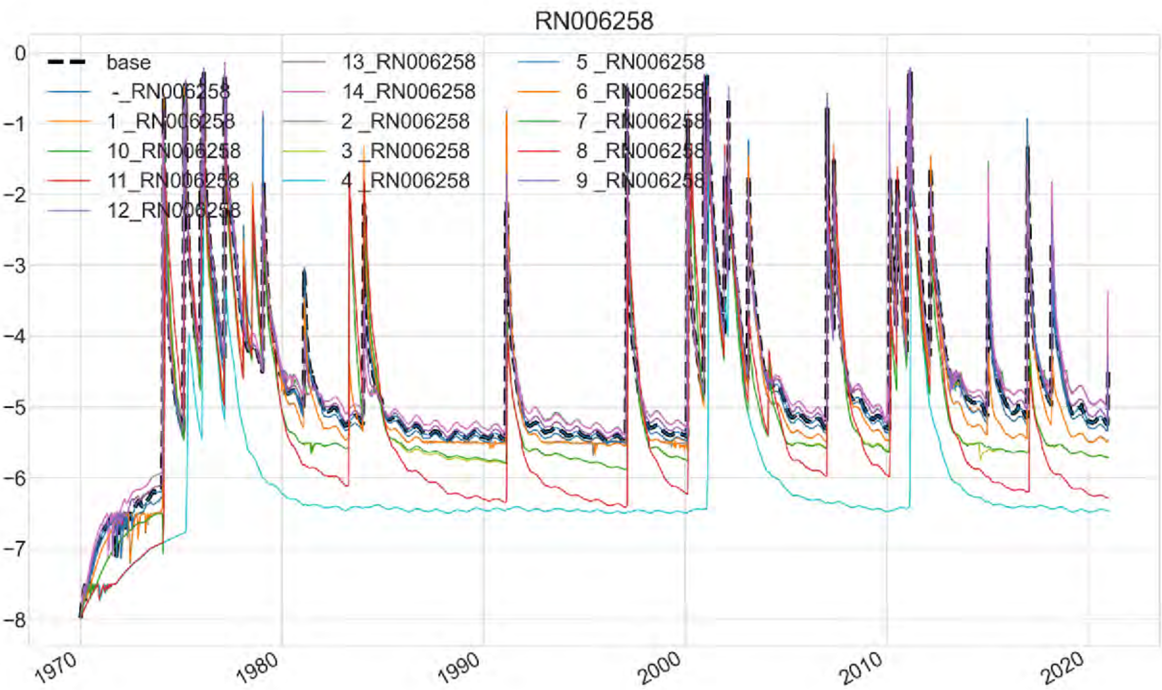

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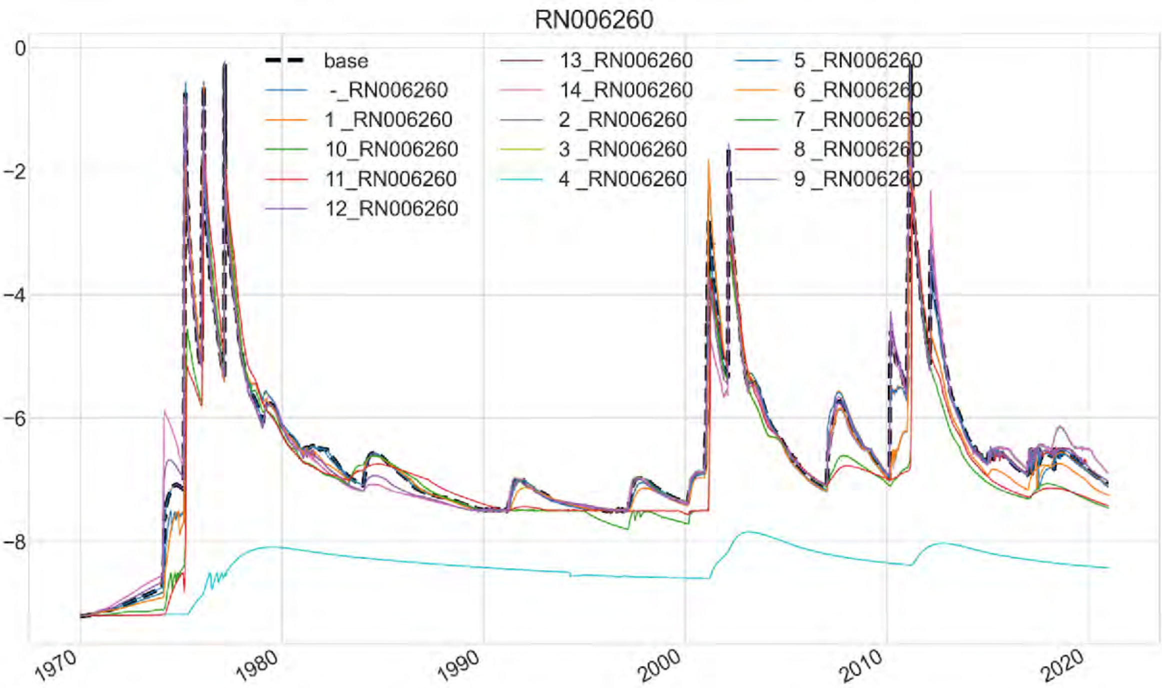

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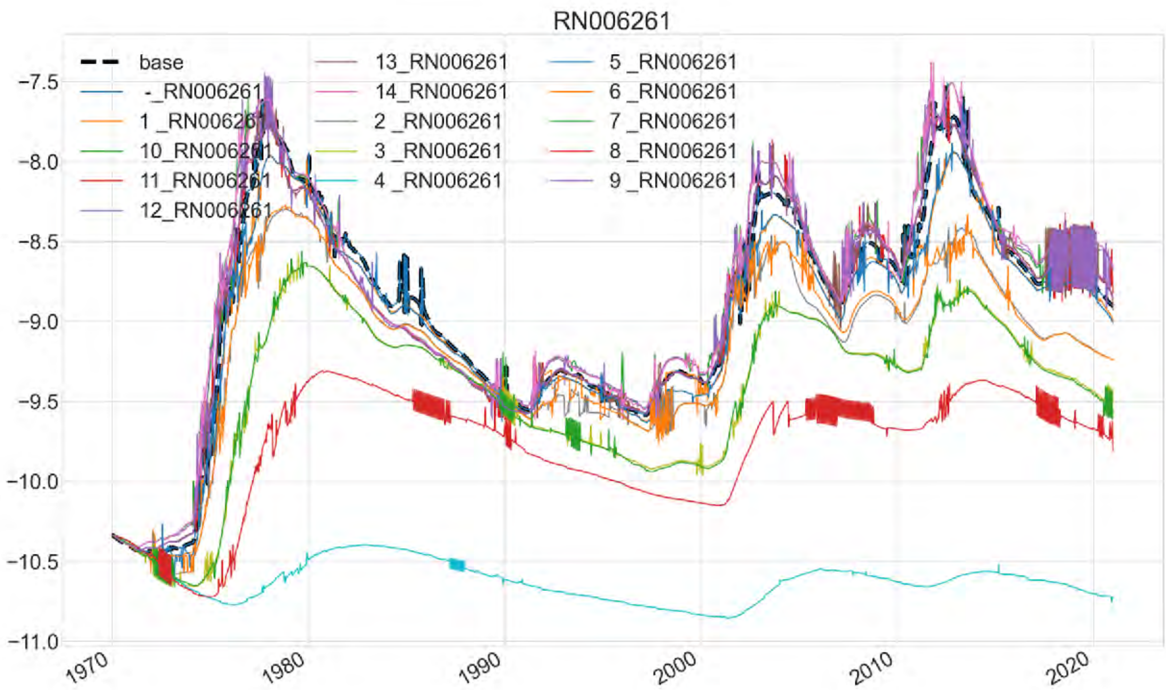
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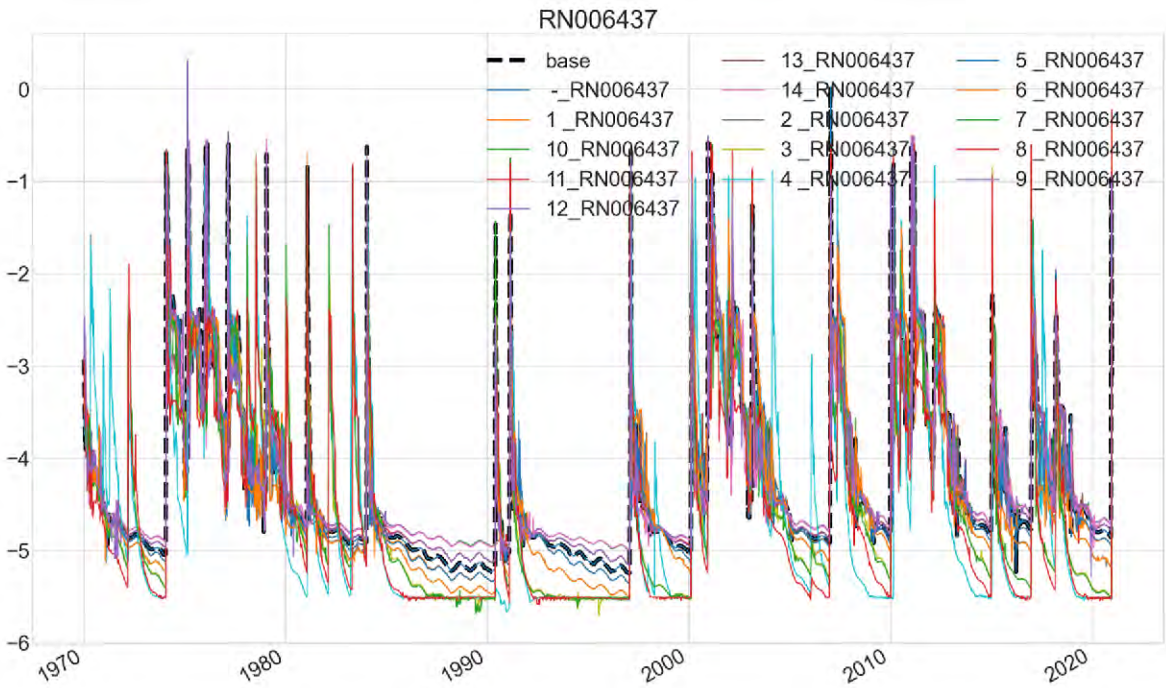
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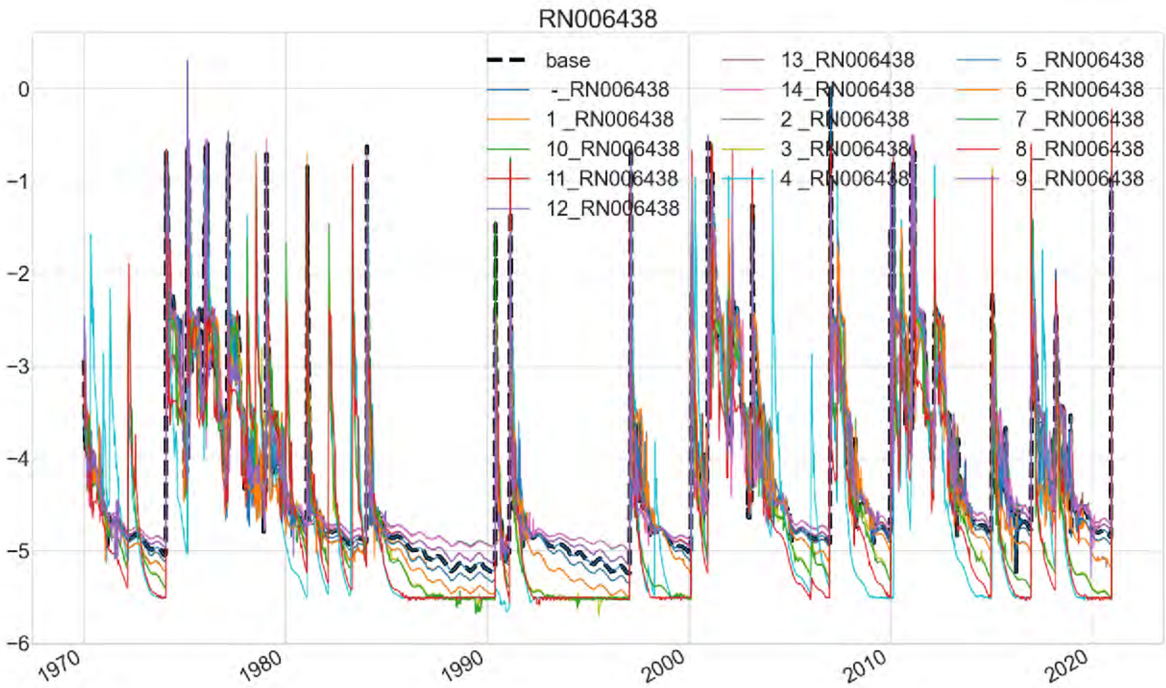
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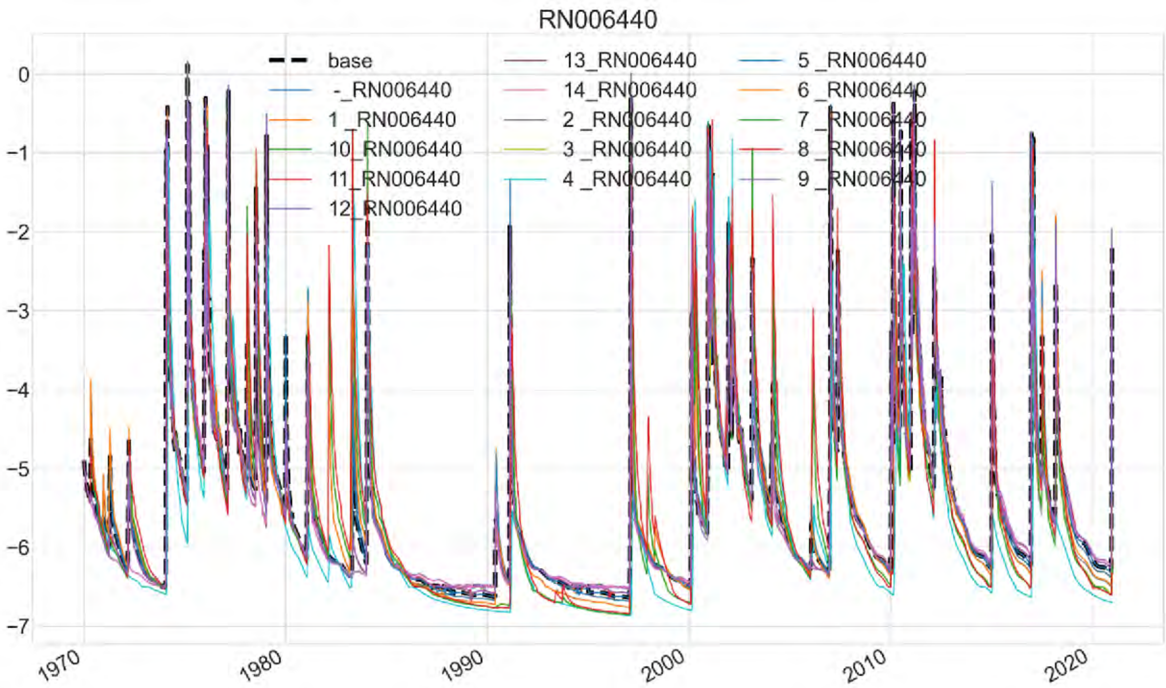
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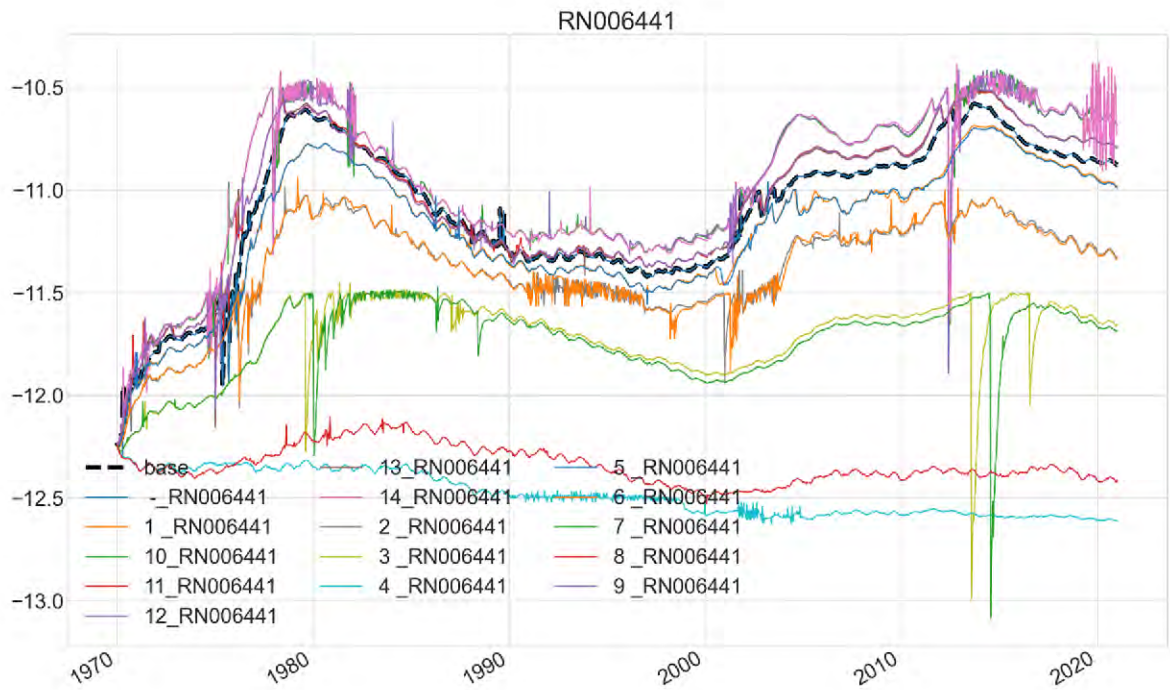
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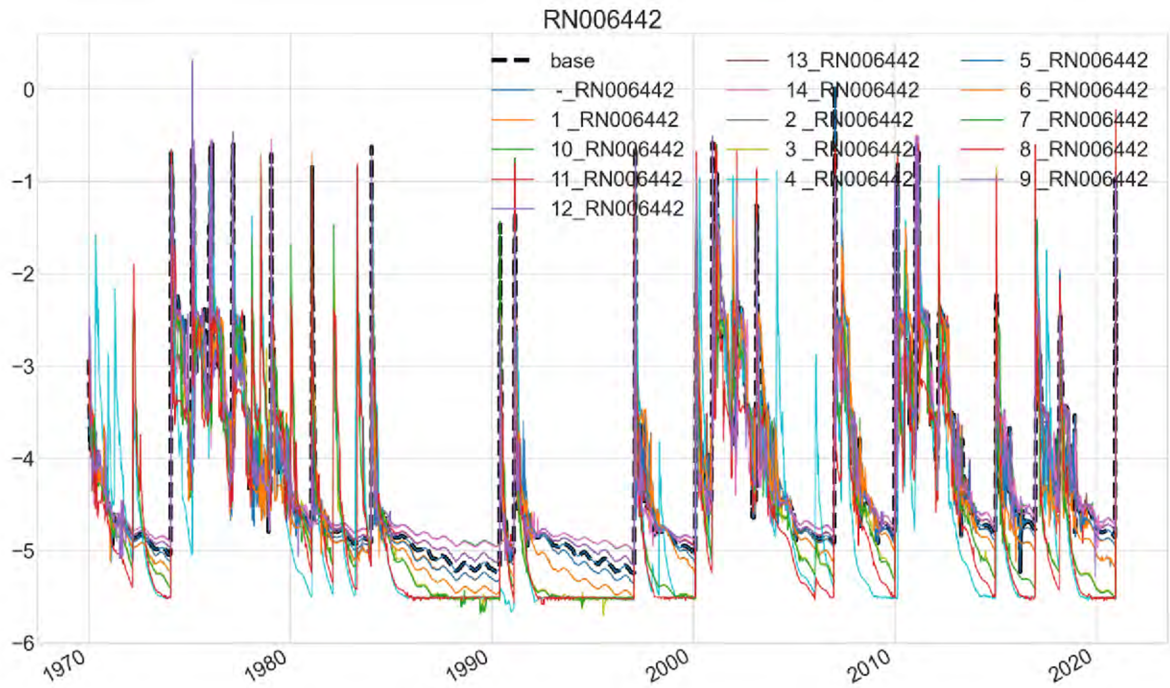
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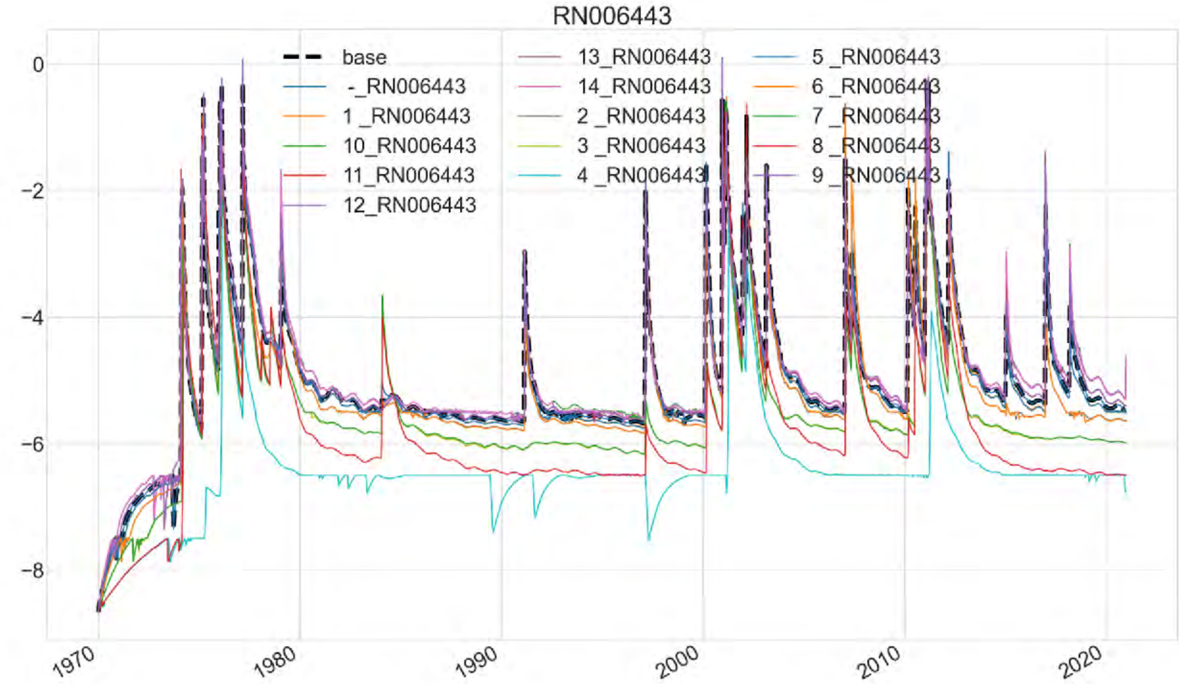
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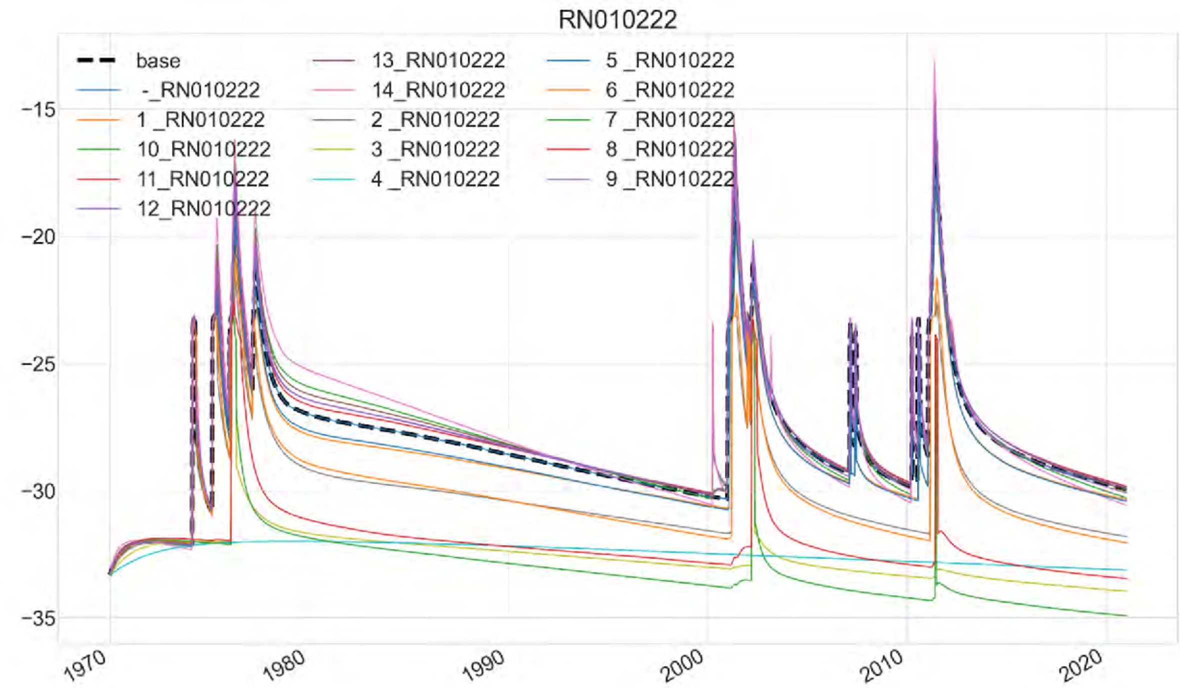
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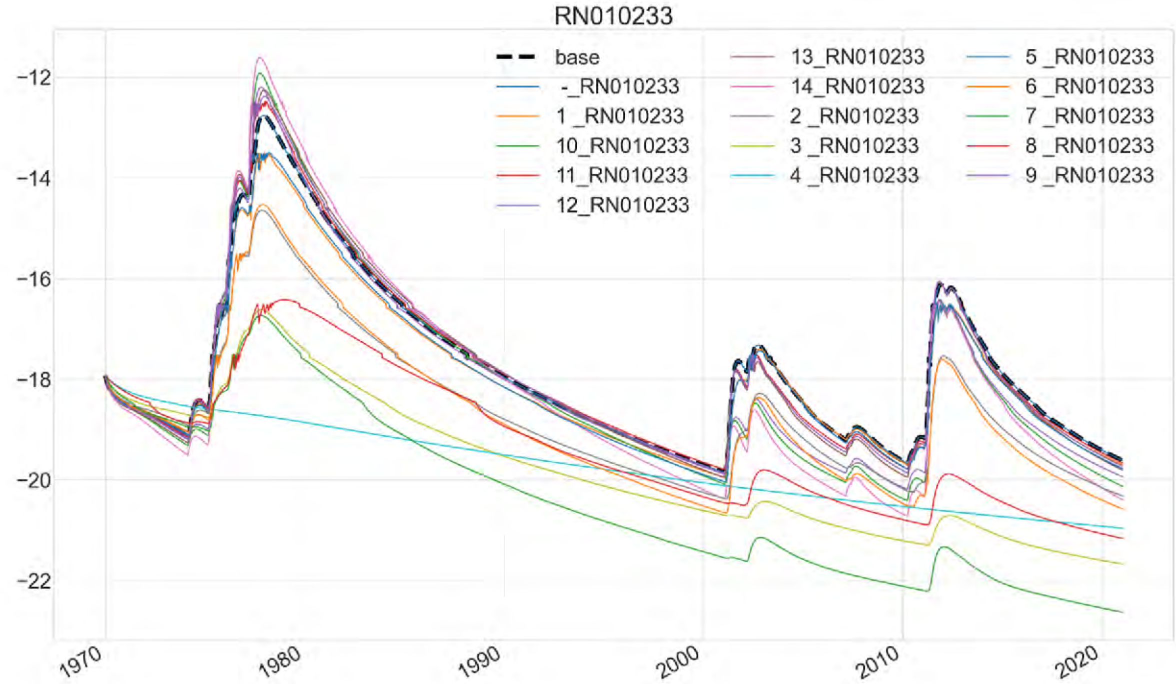
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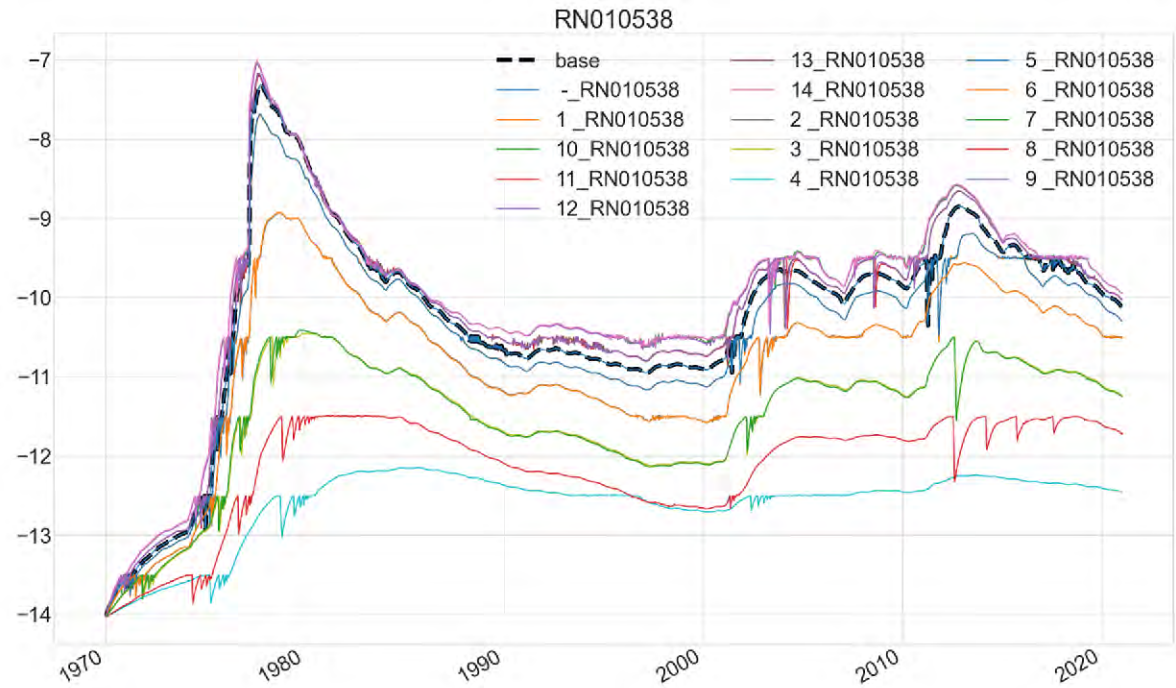
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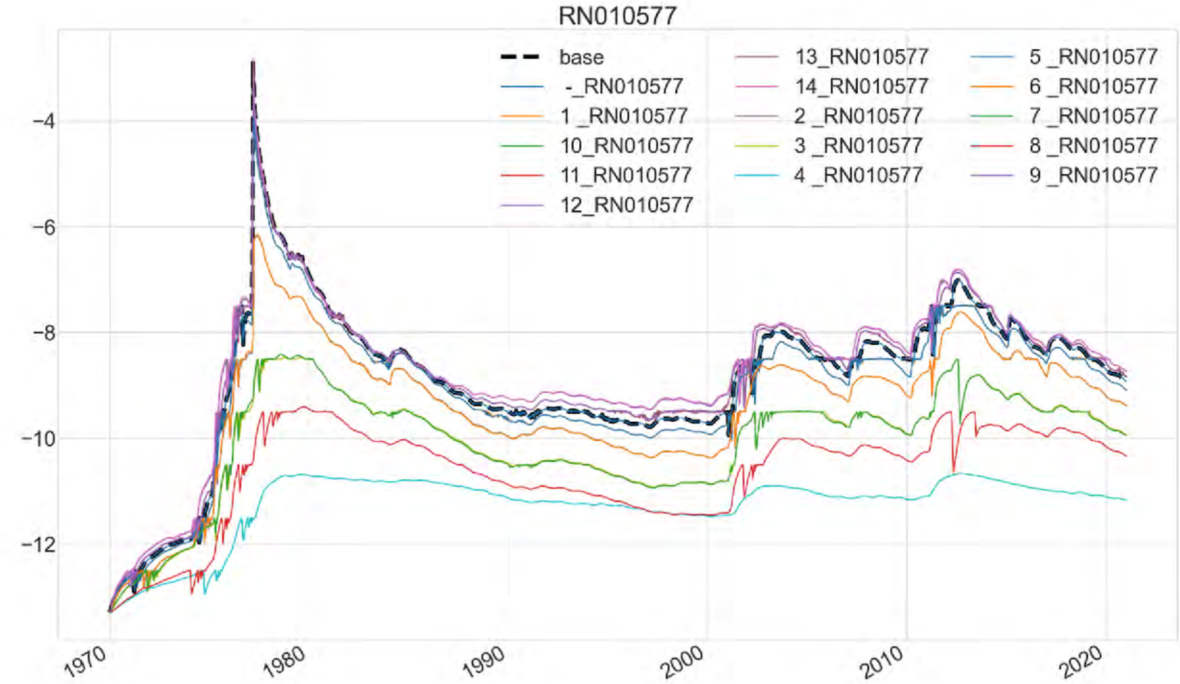
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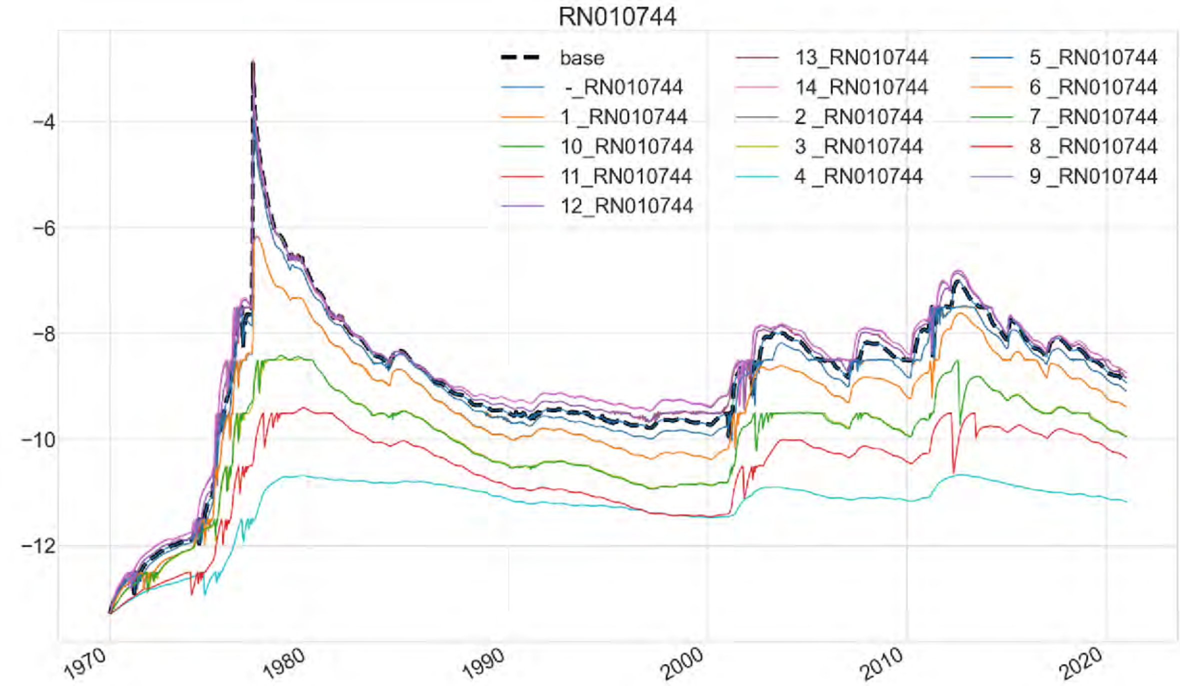
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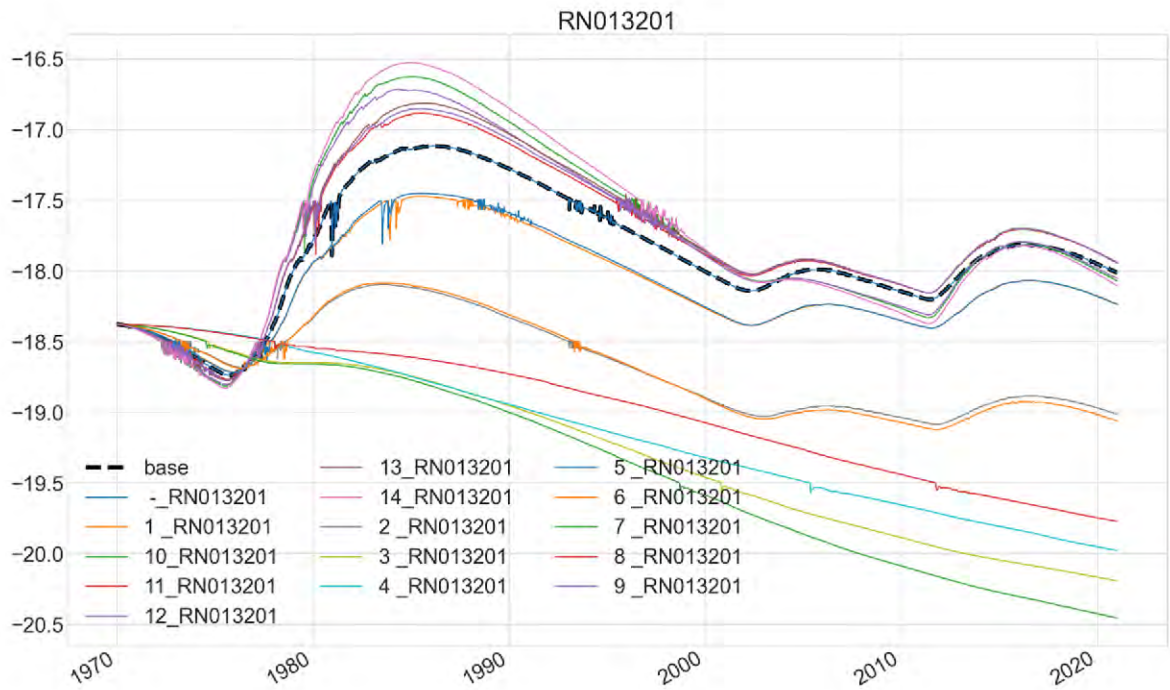
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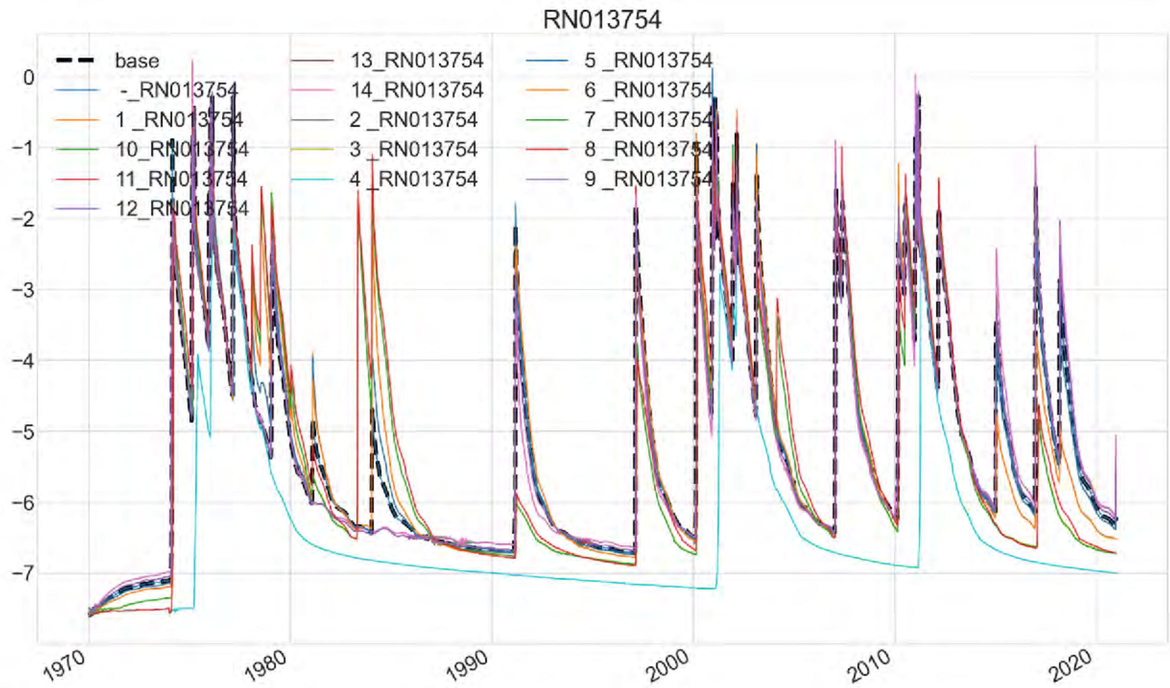
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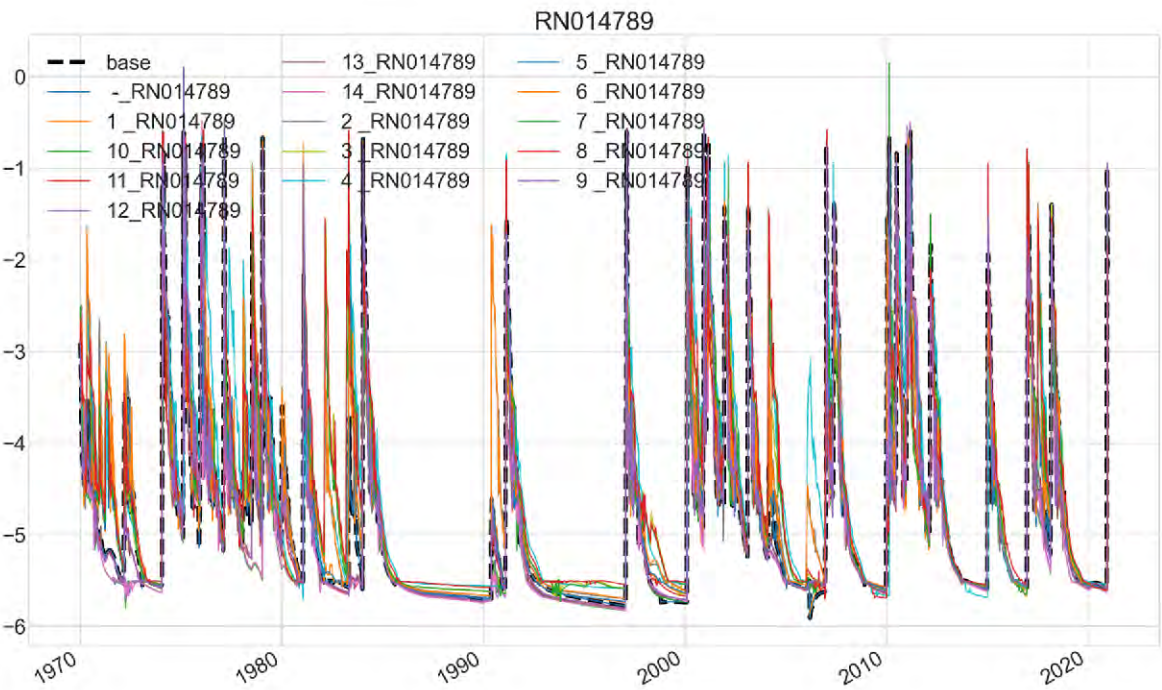

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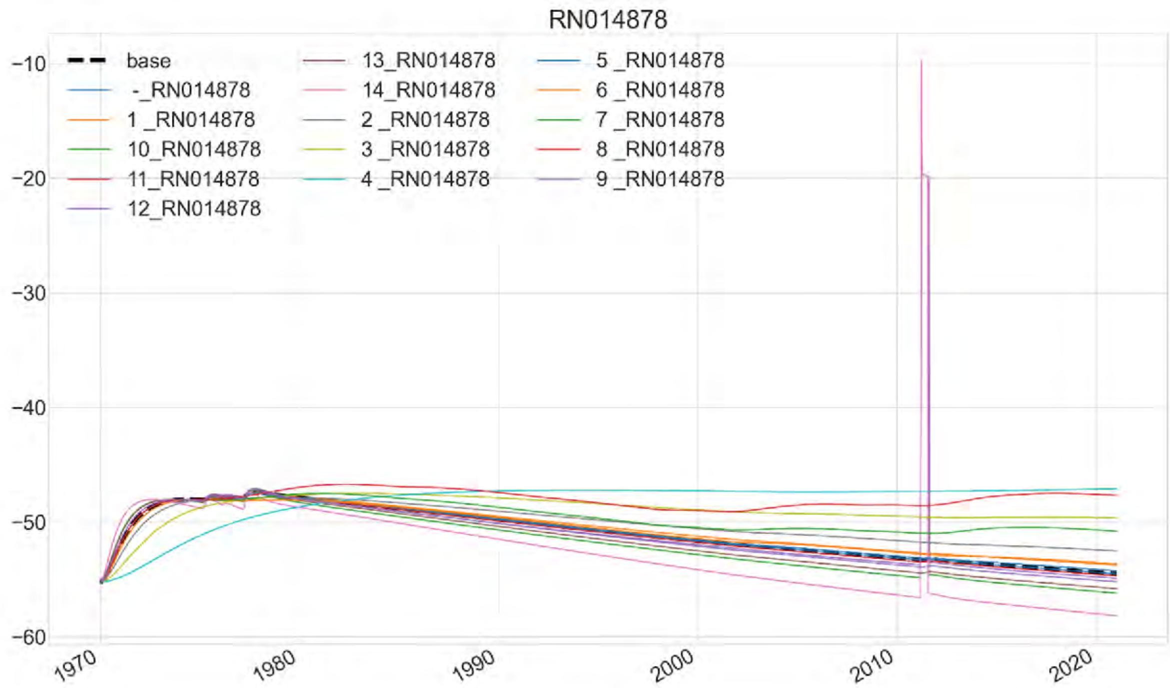

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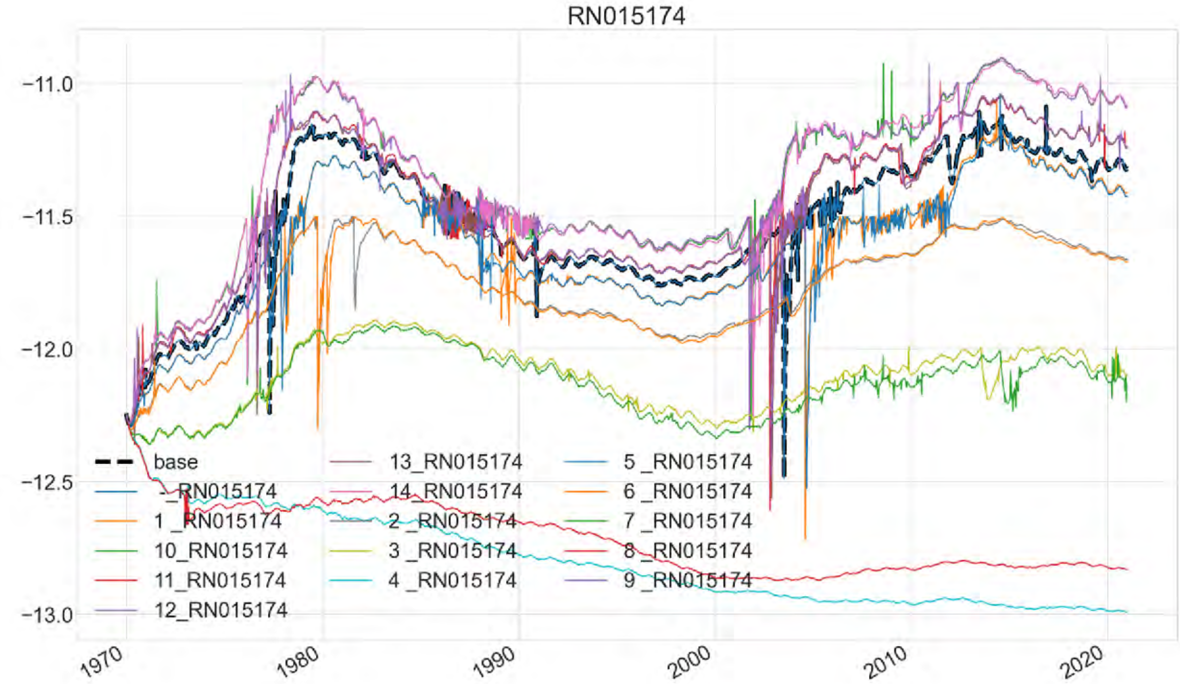
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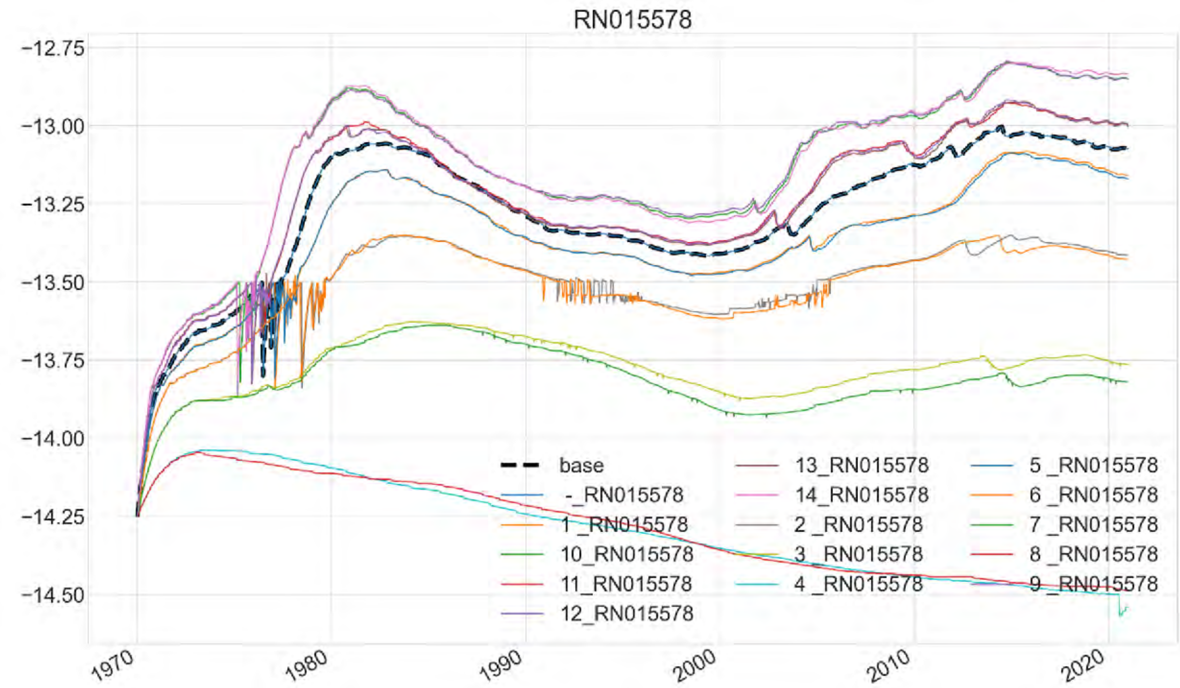
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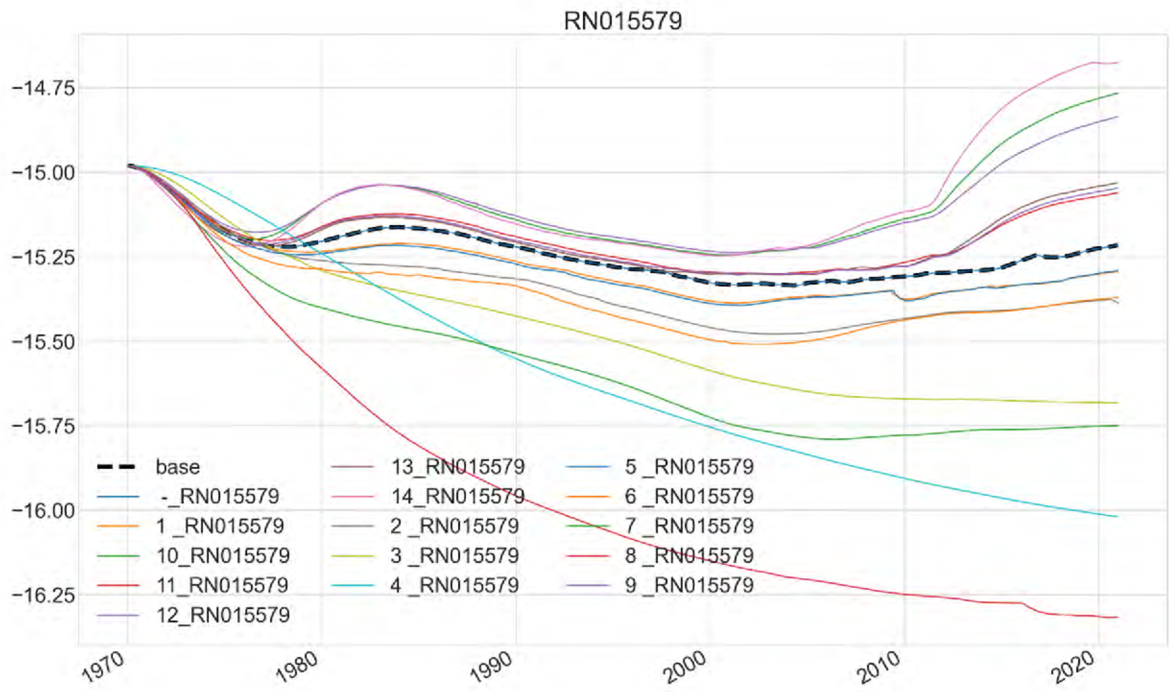
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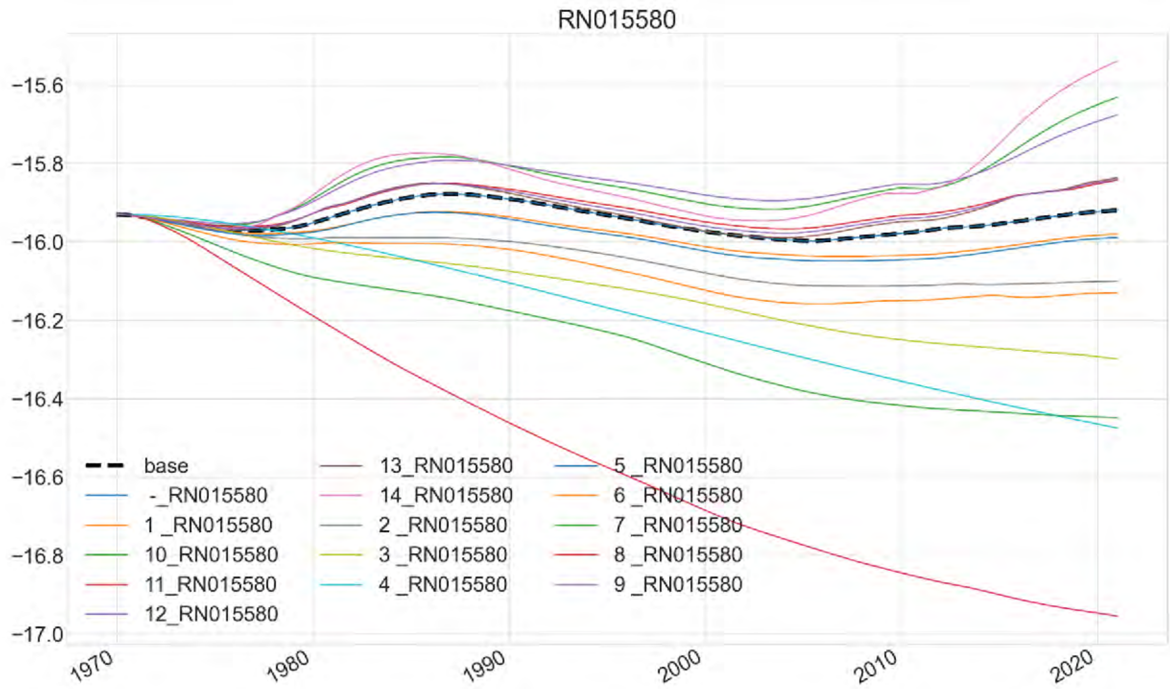
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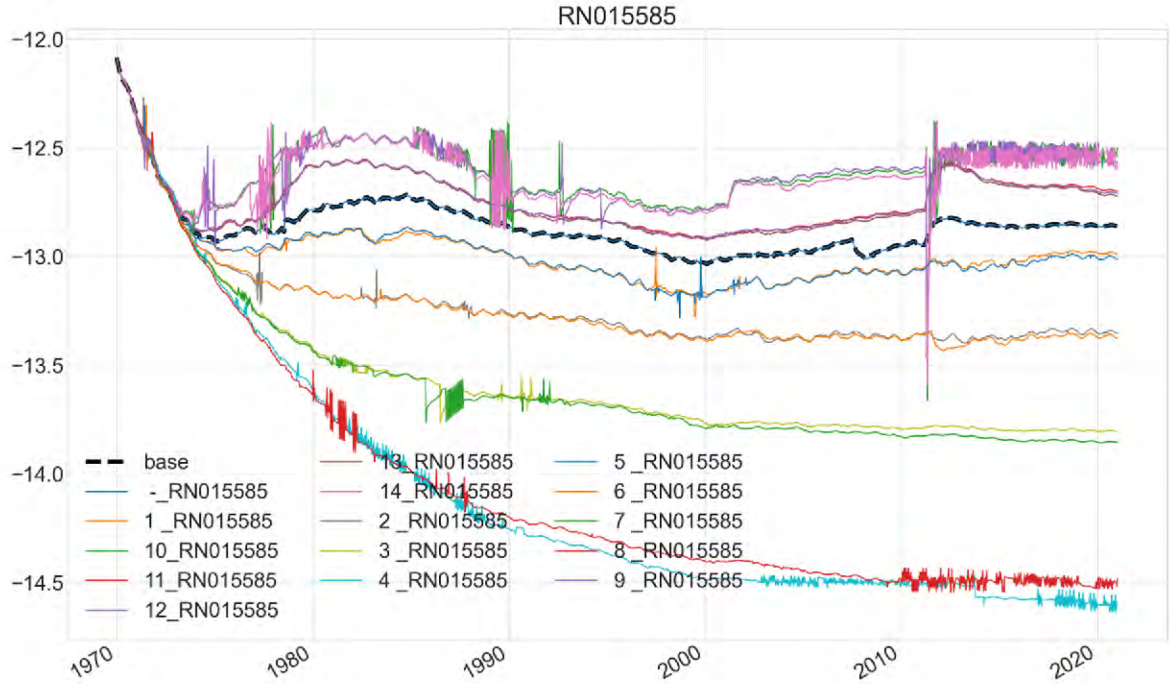

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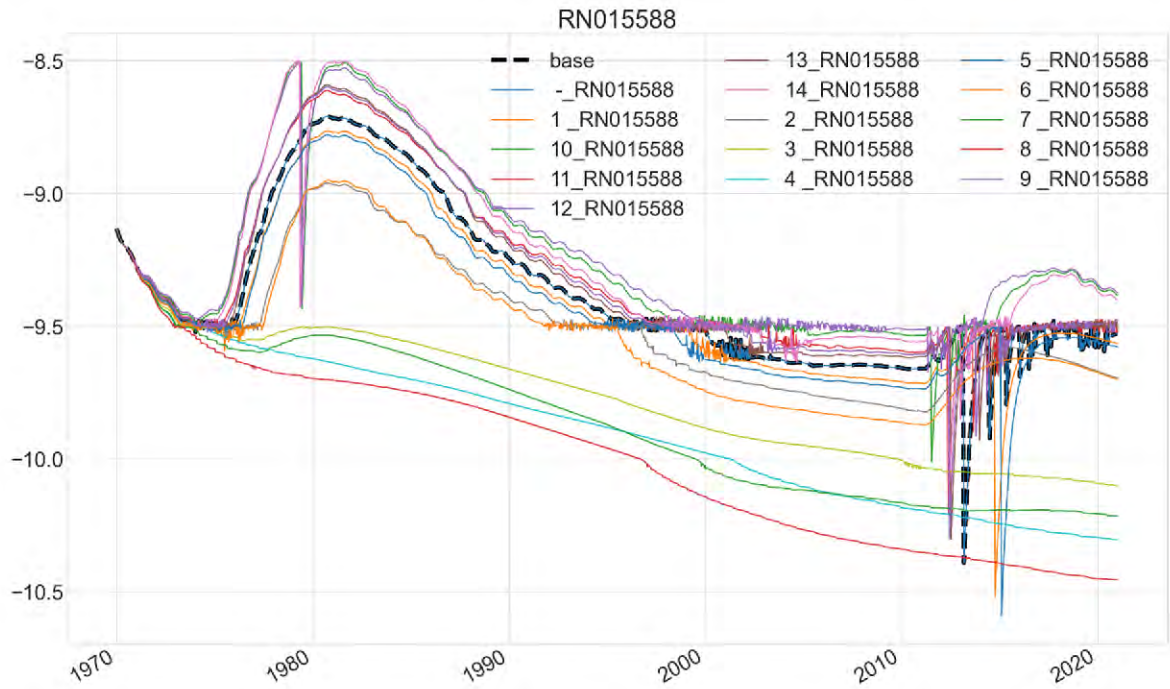

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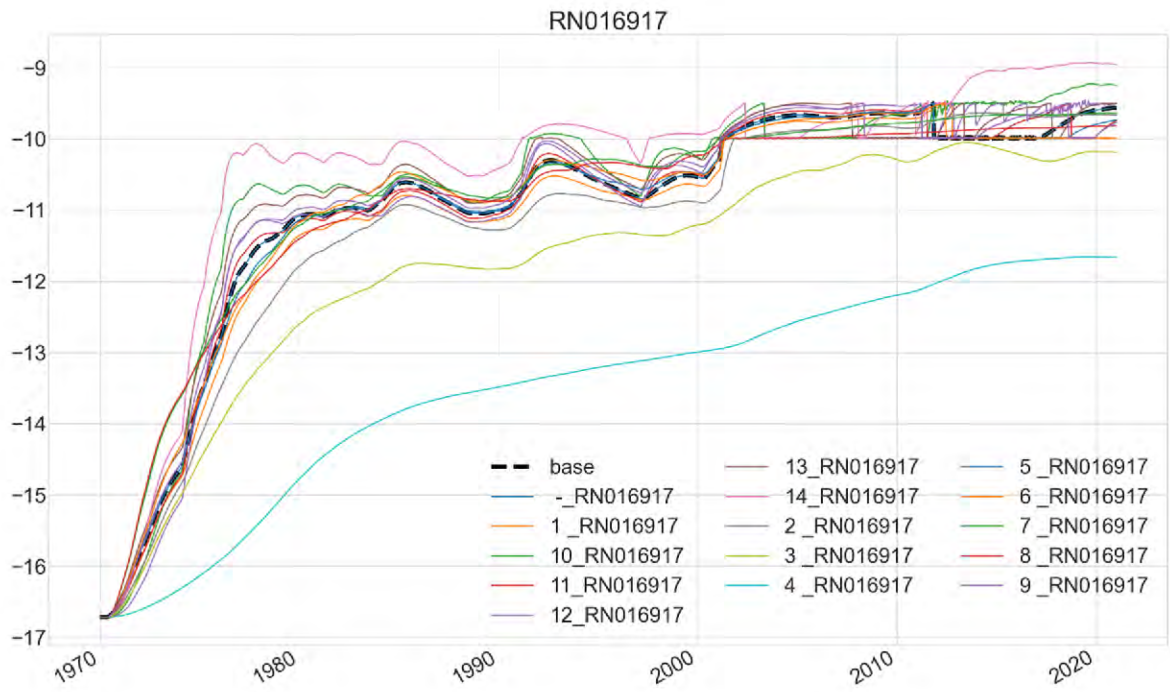
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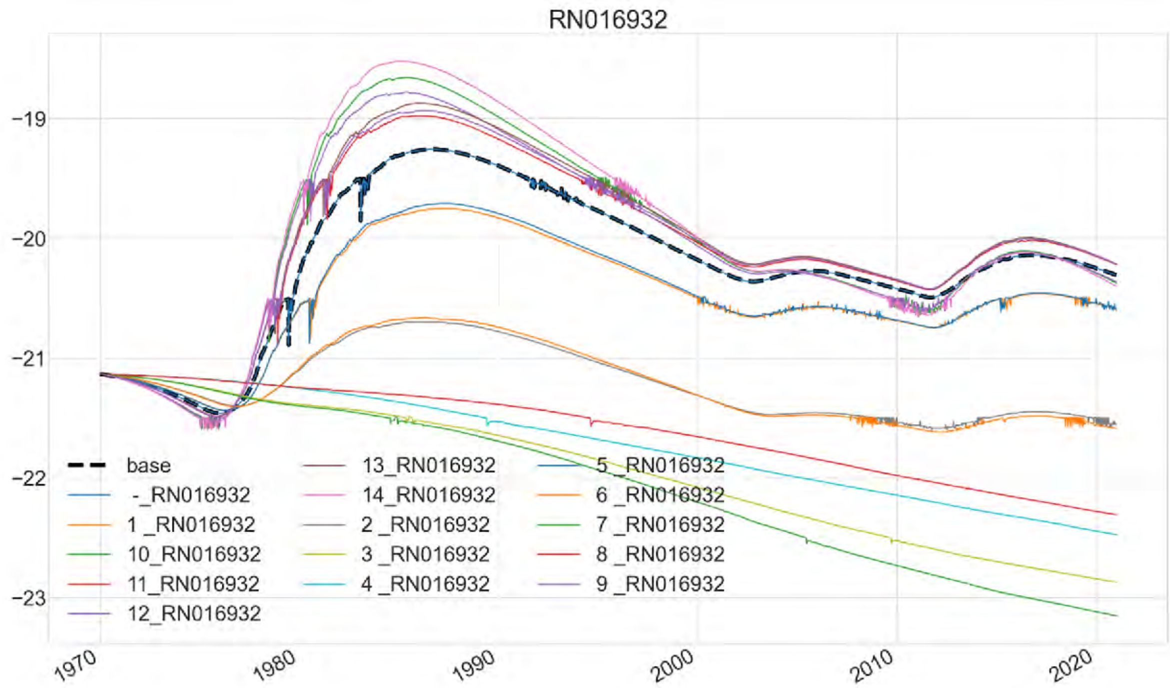
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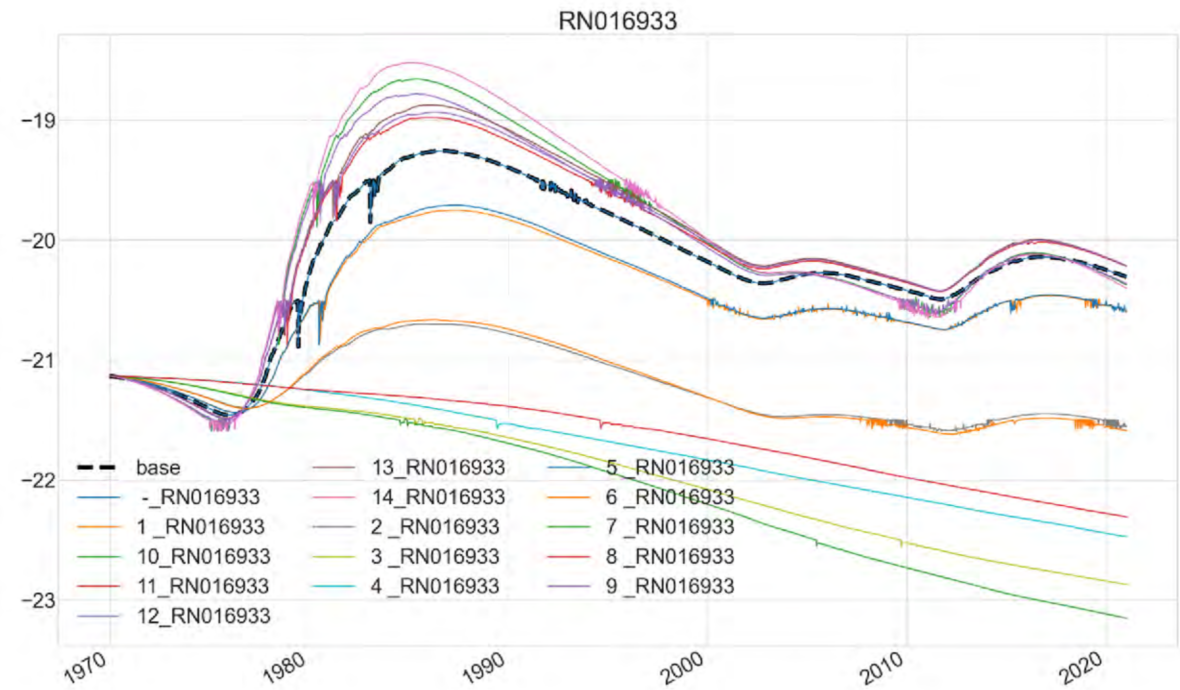
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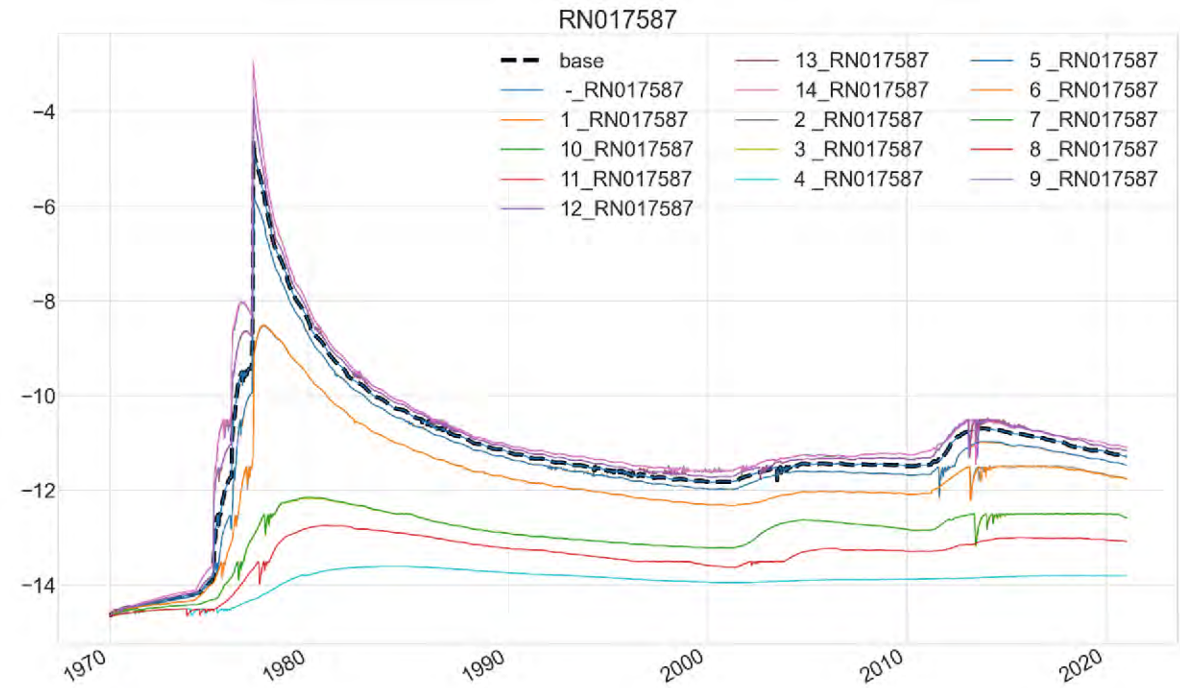
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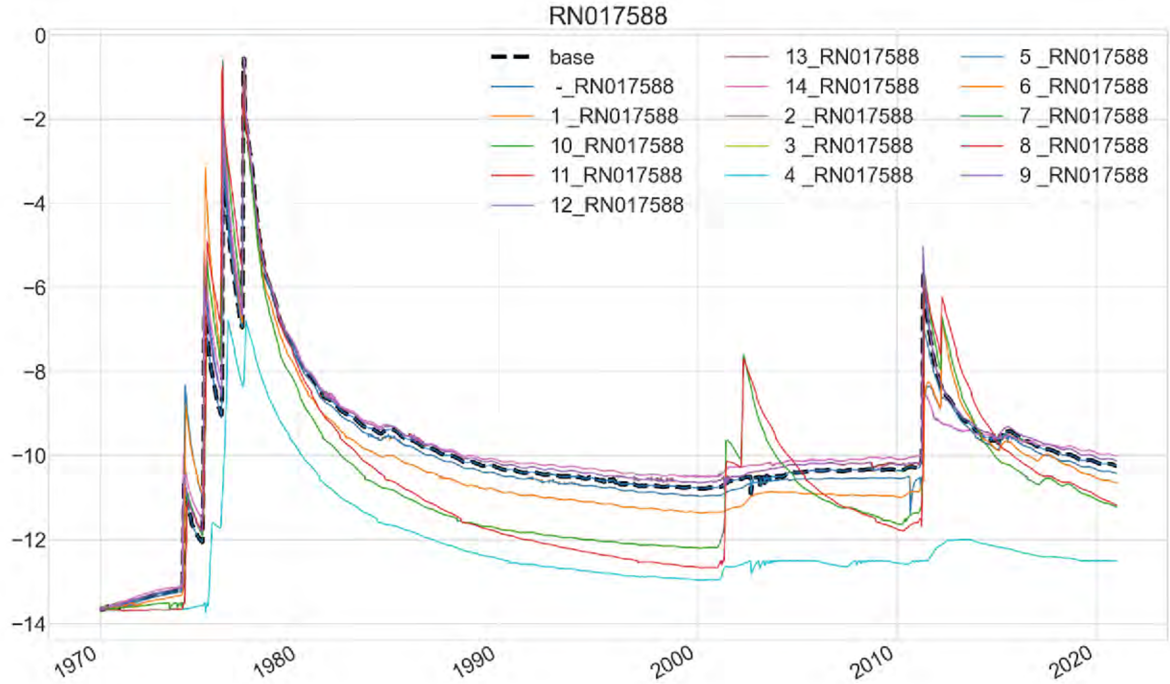
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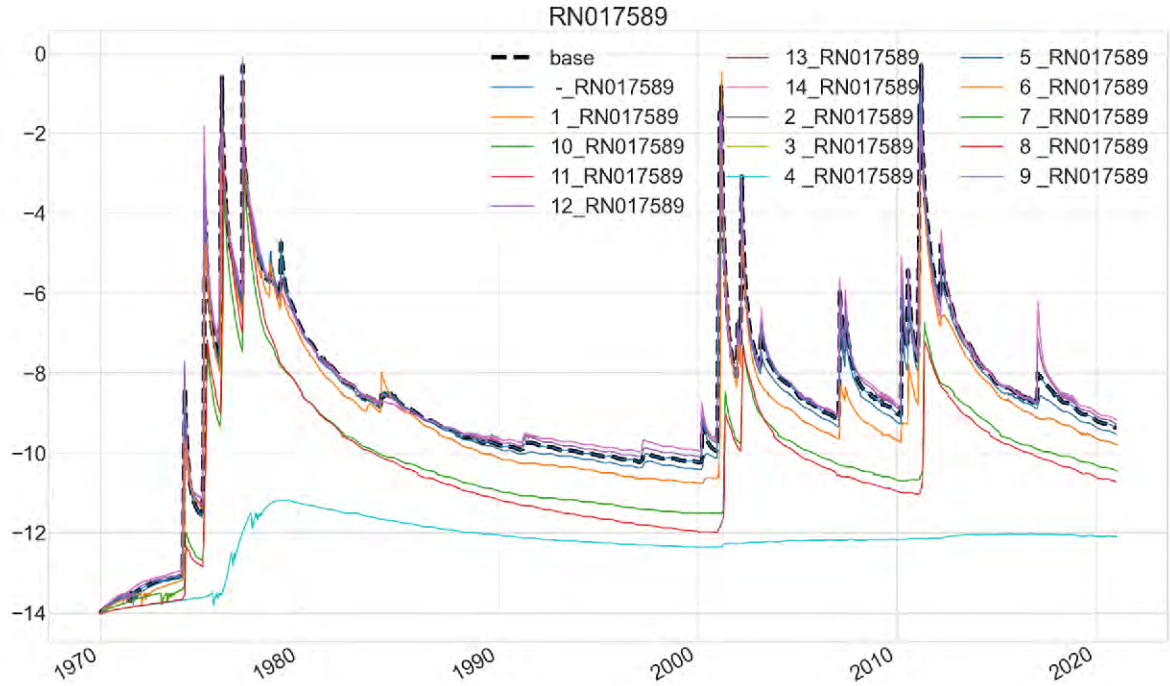
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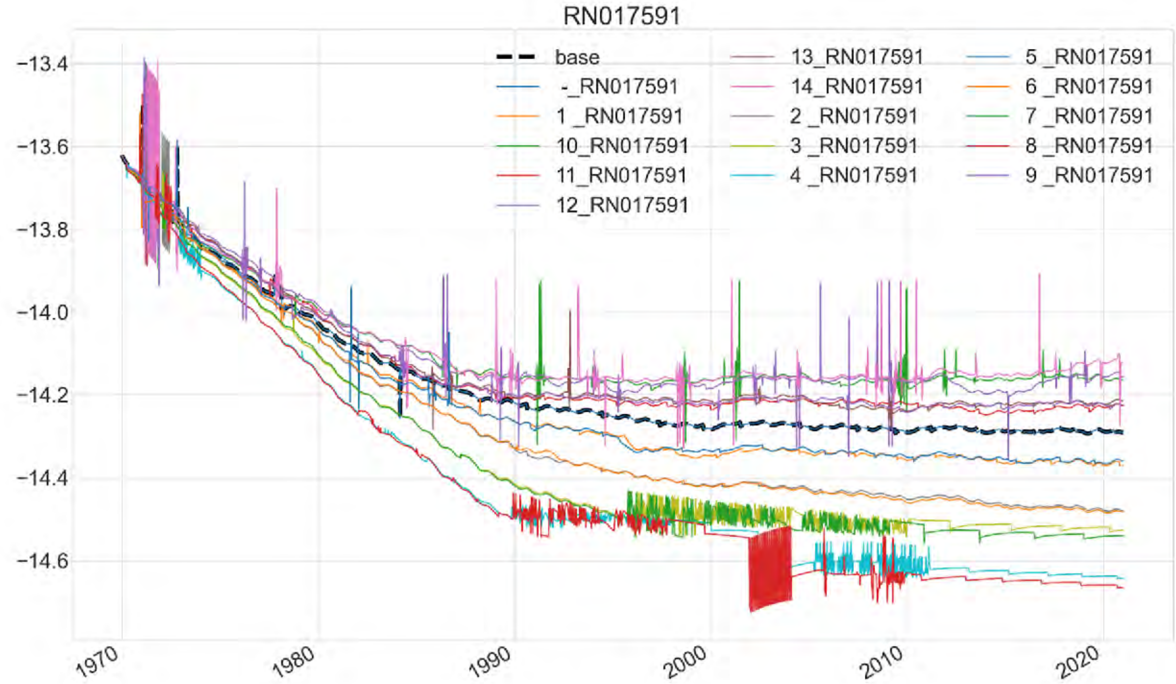
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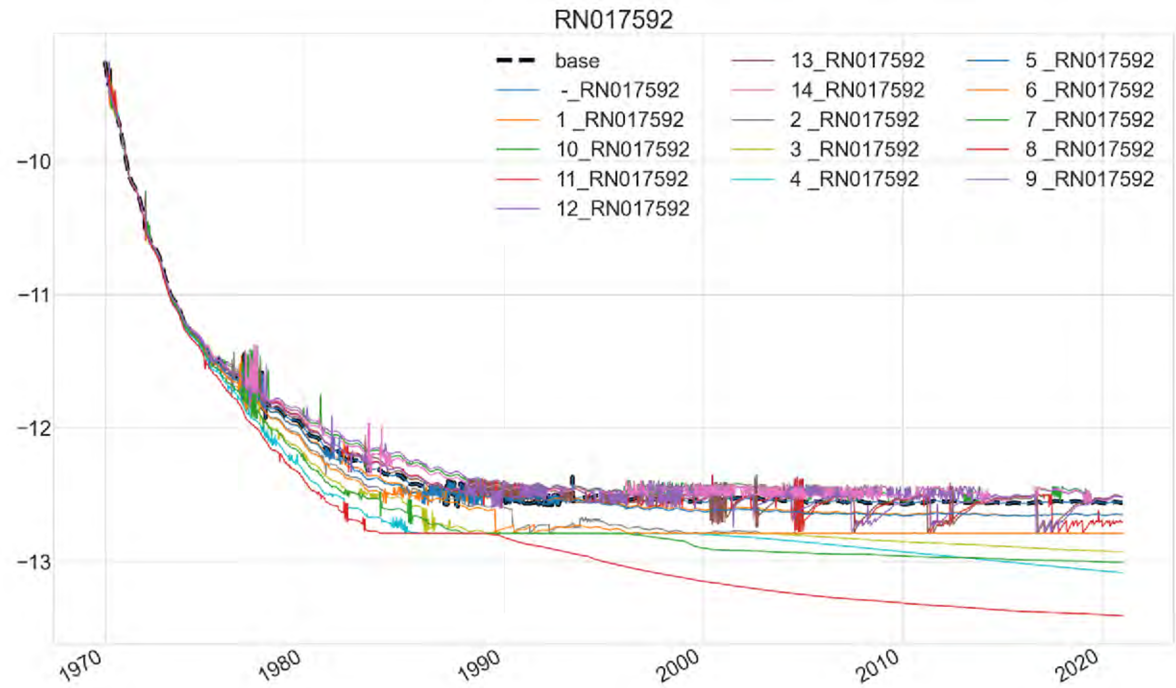
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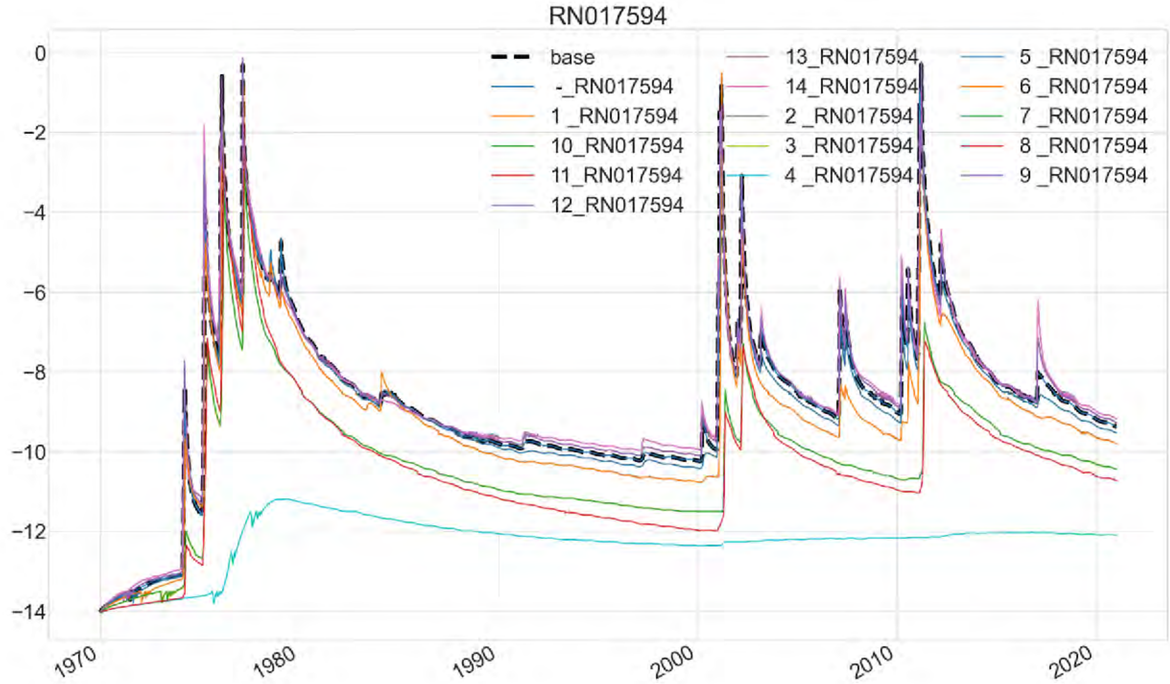
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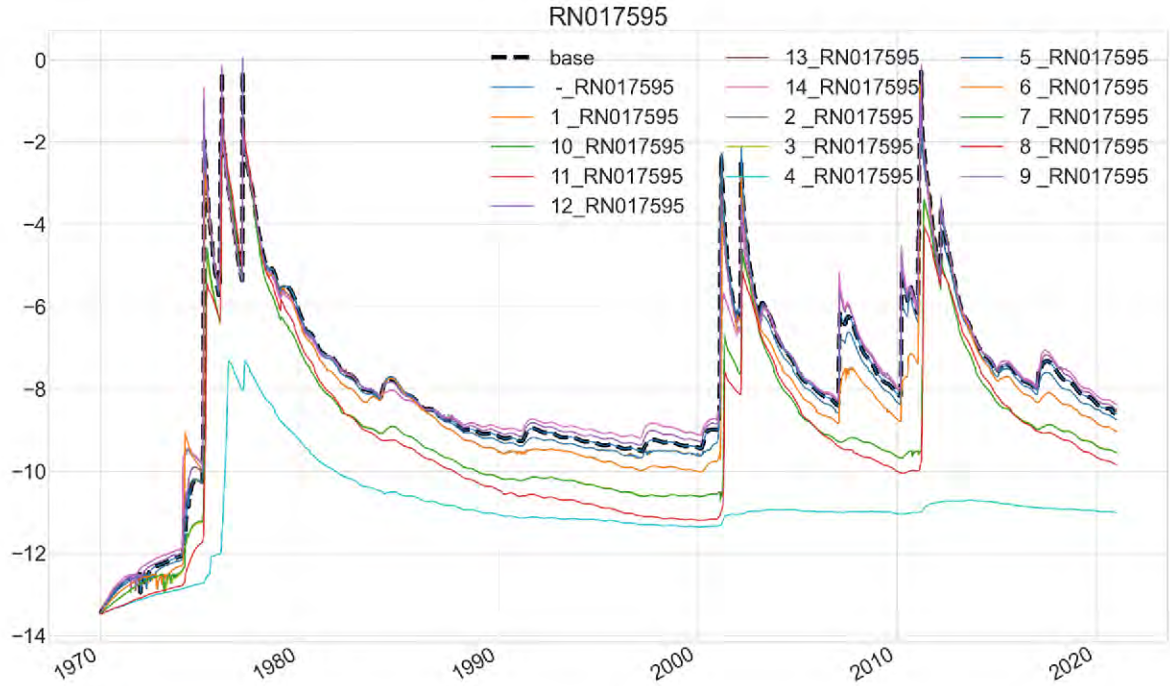
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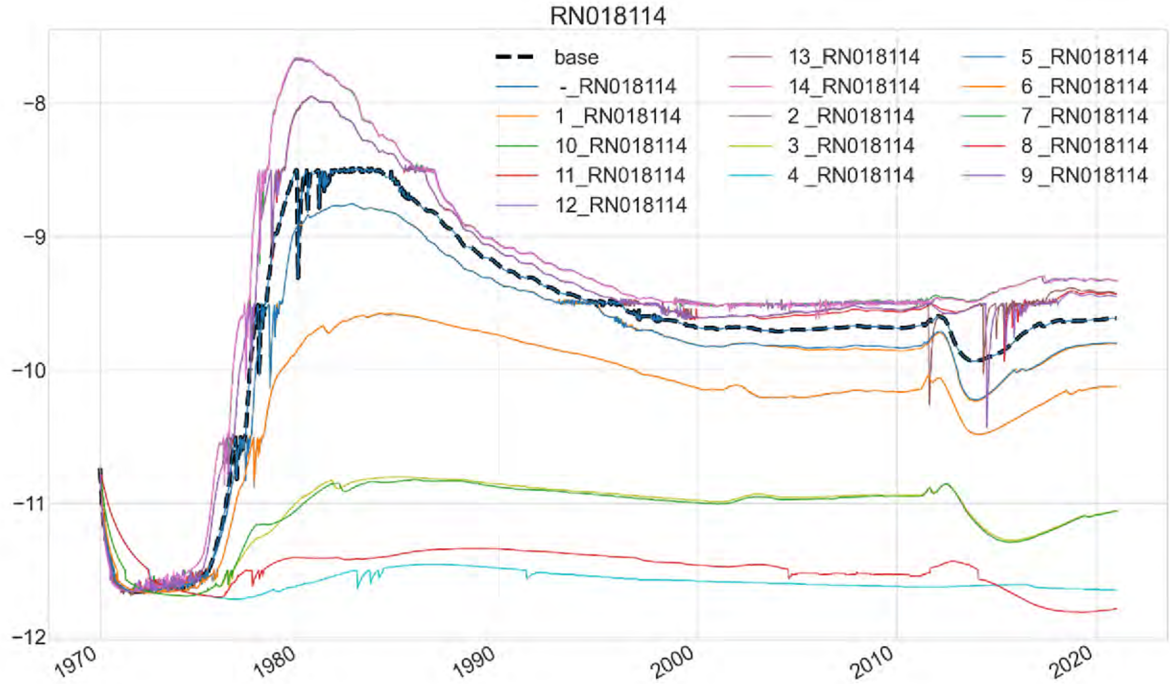
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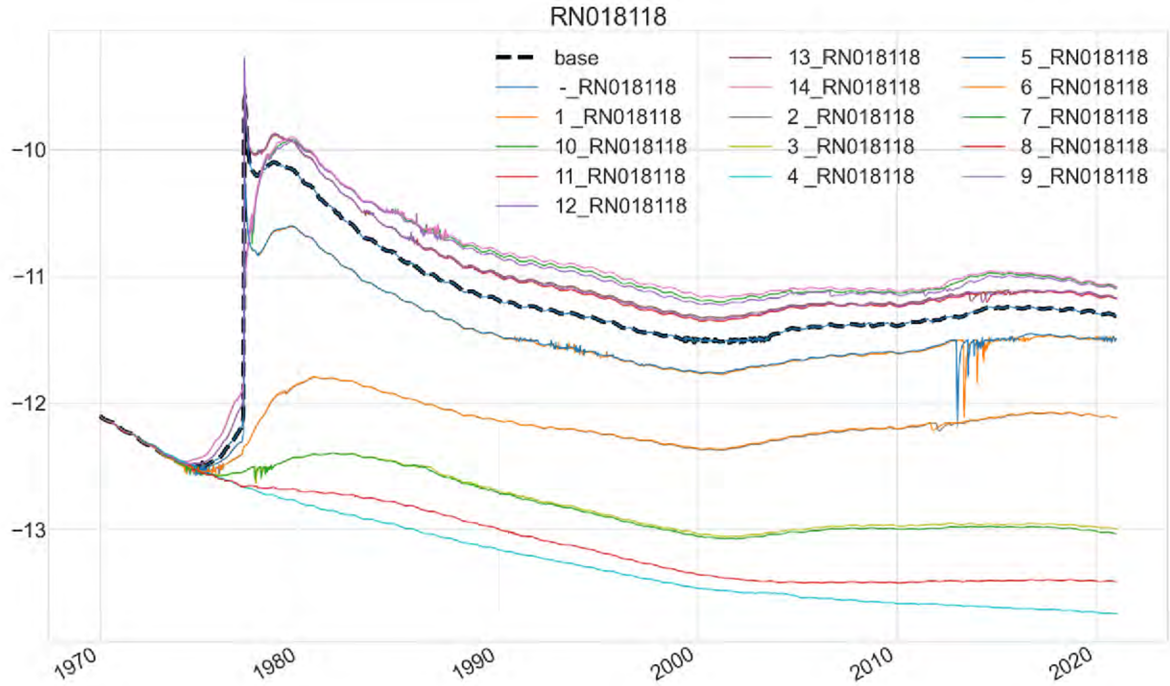
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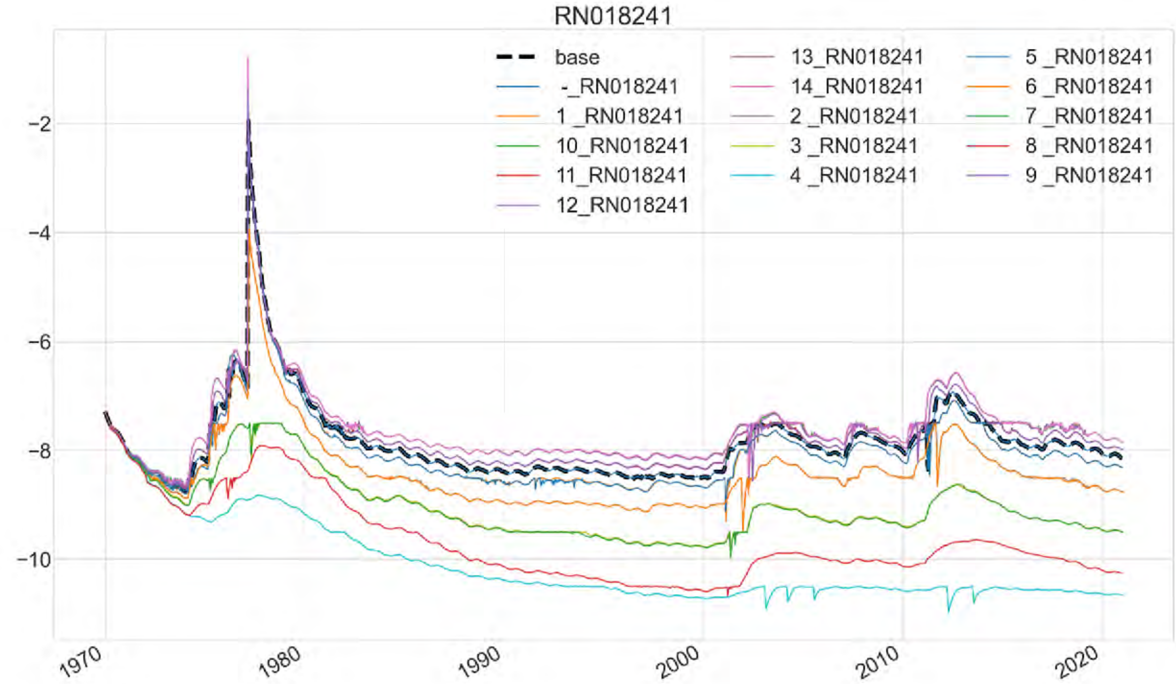
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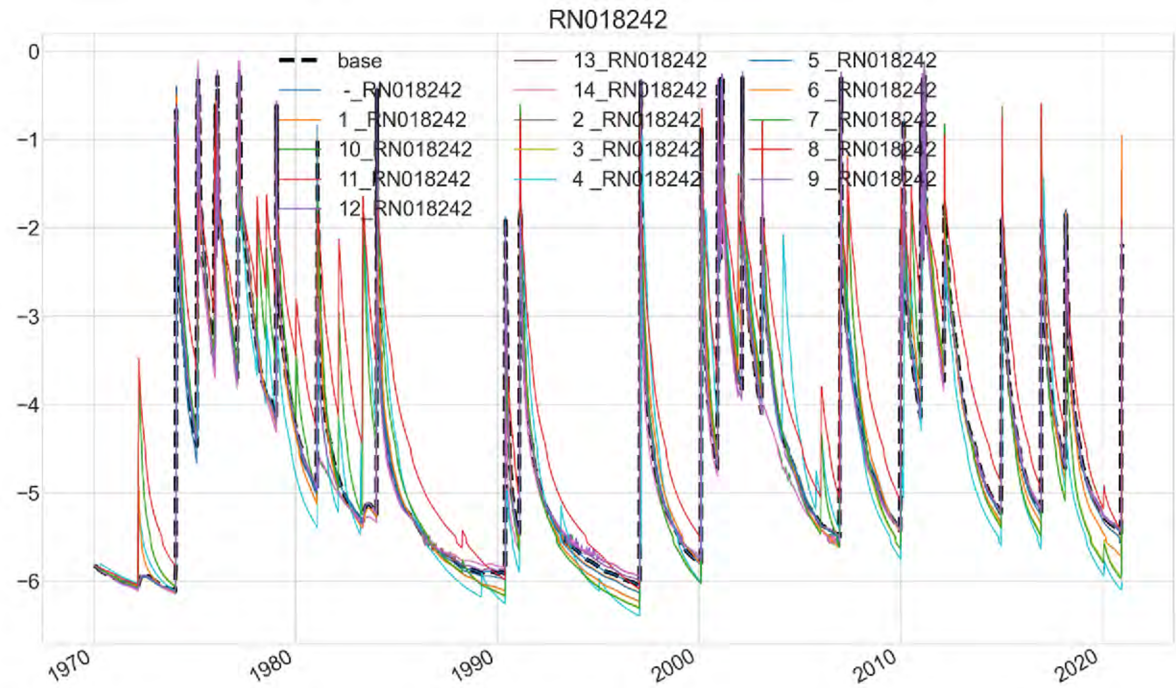
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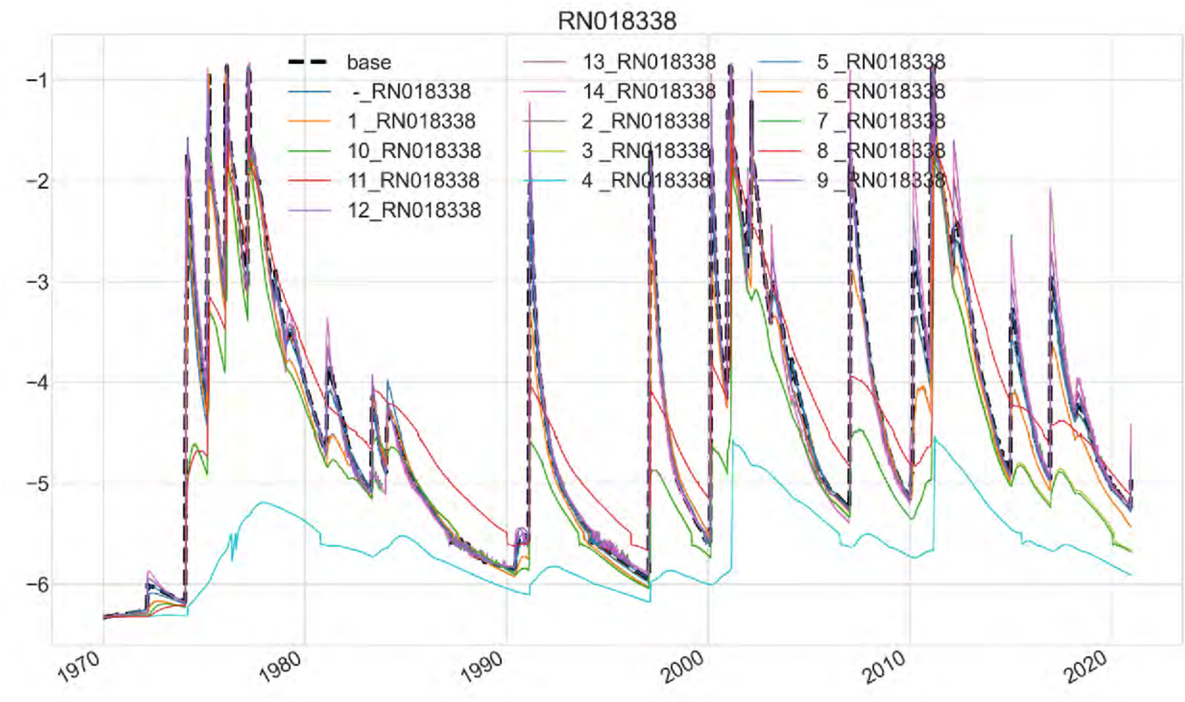
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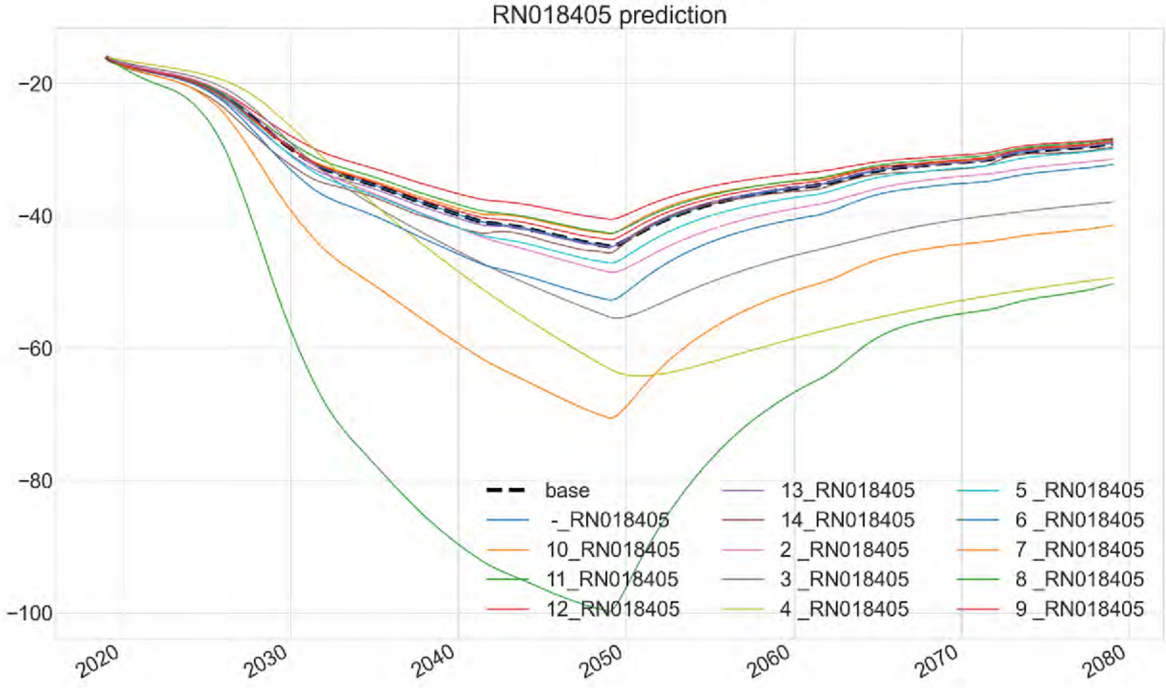
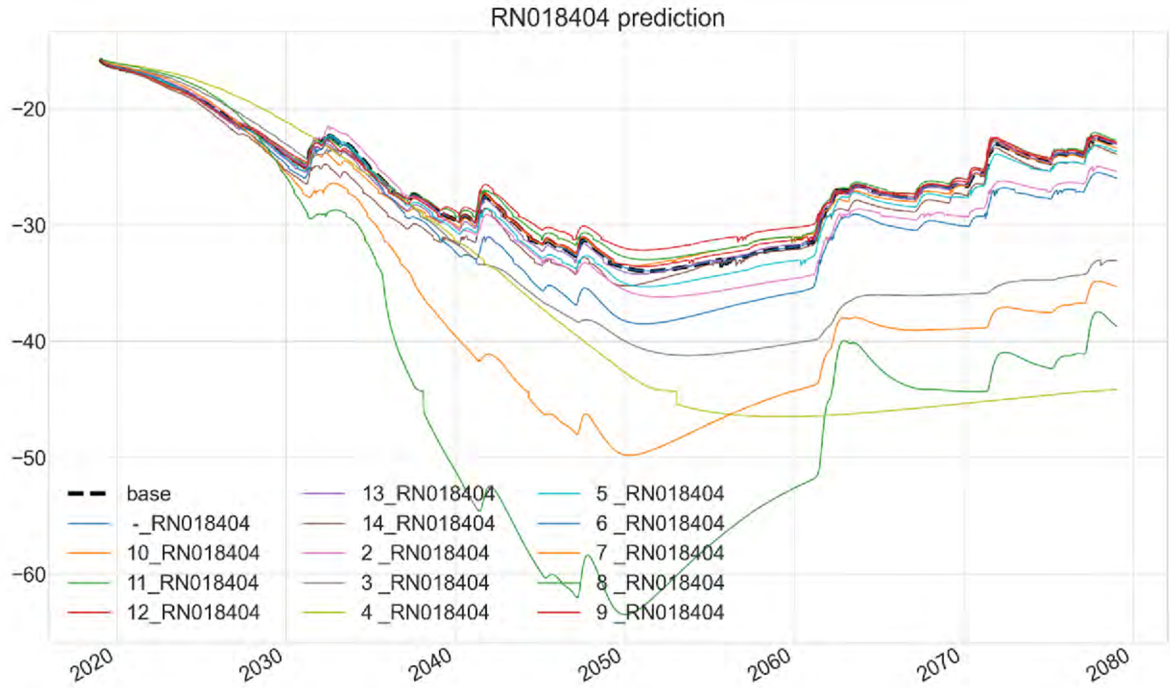
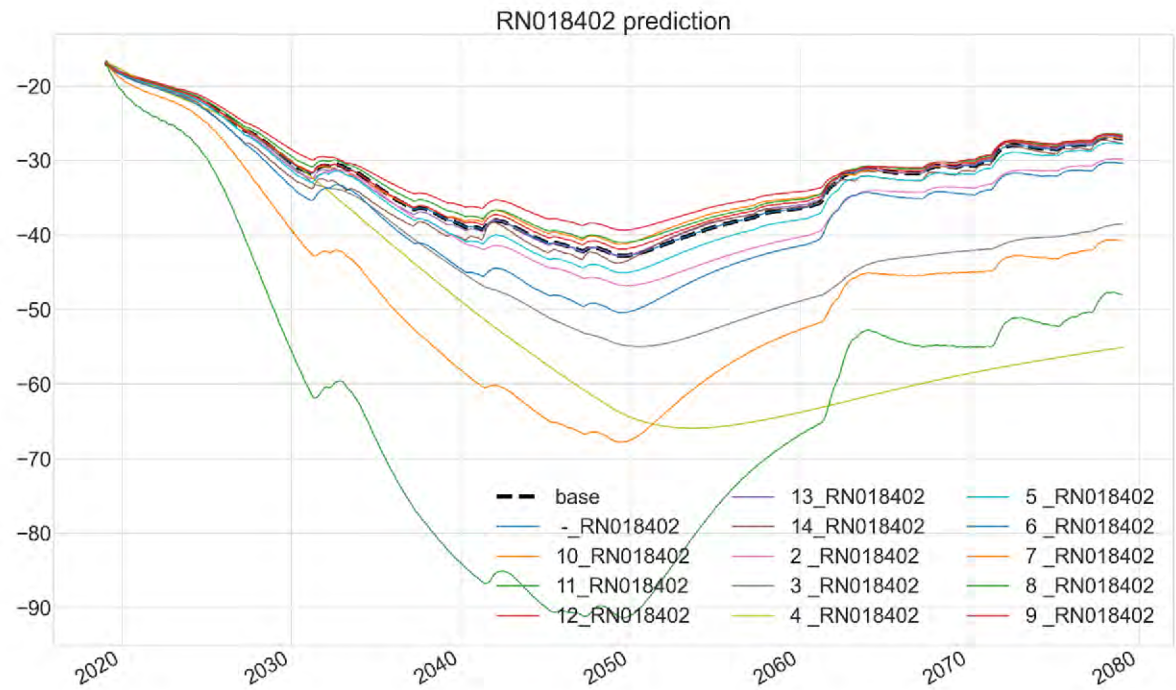
Appendix 2 - PREDICTIVE HYDROGRAPHS



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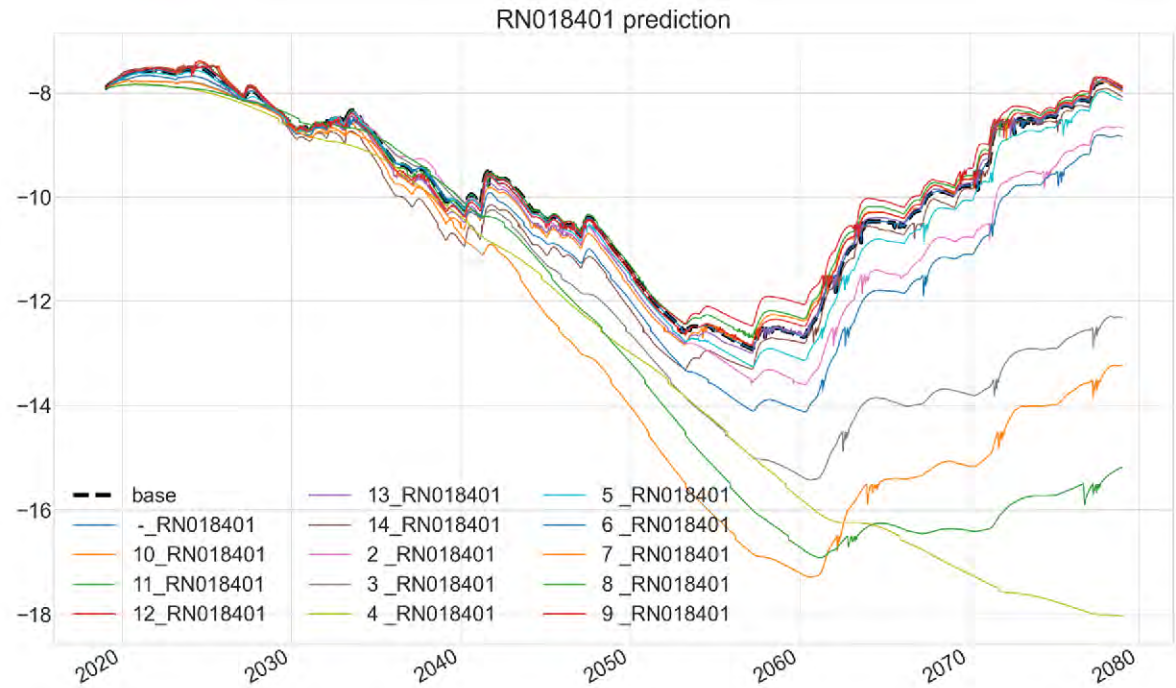
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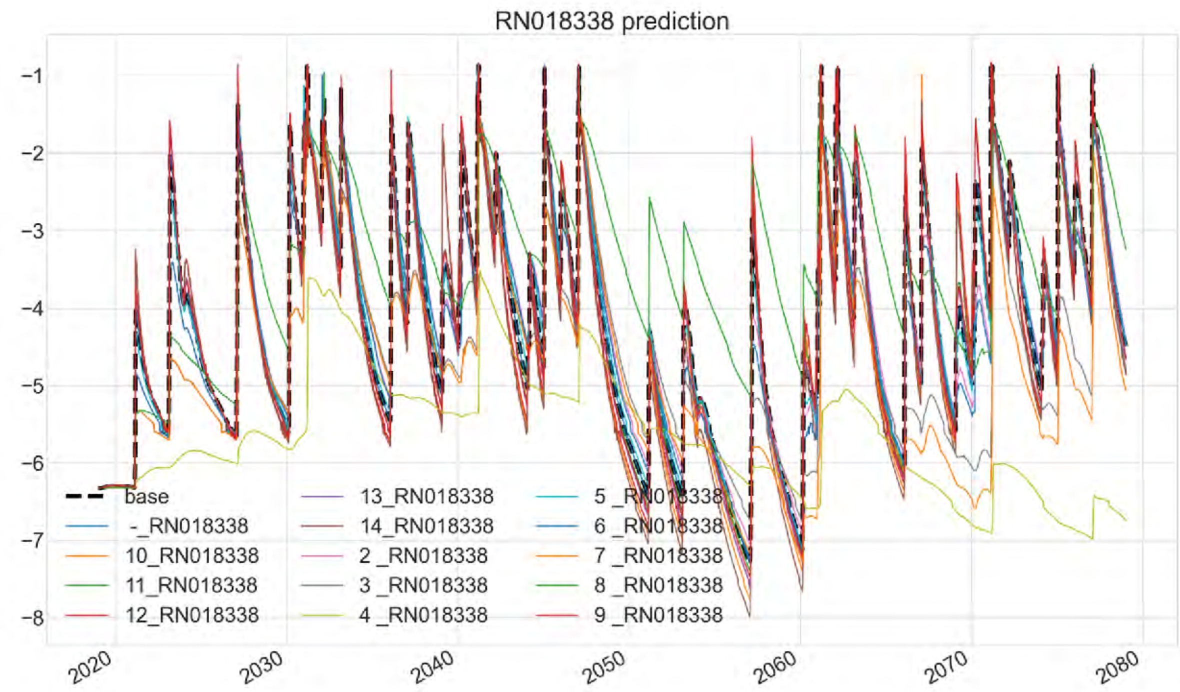

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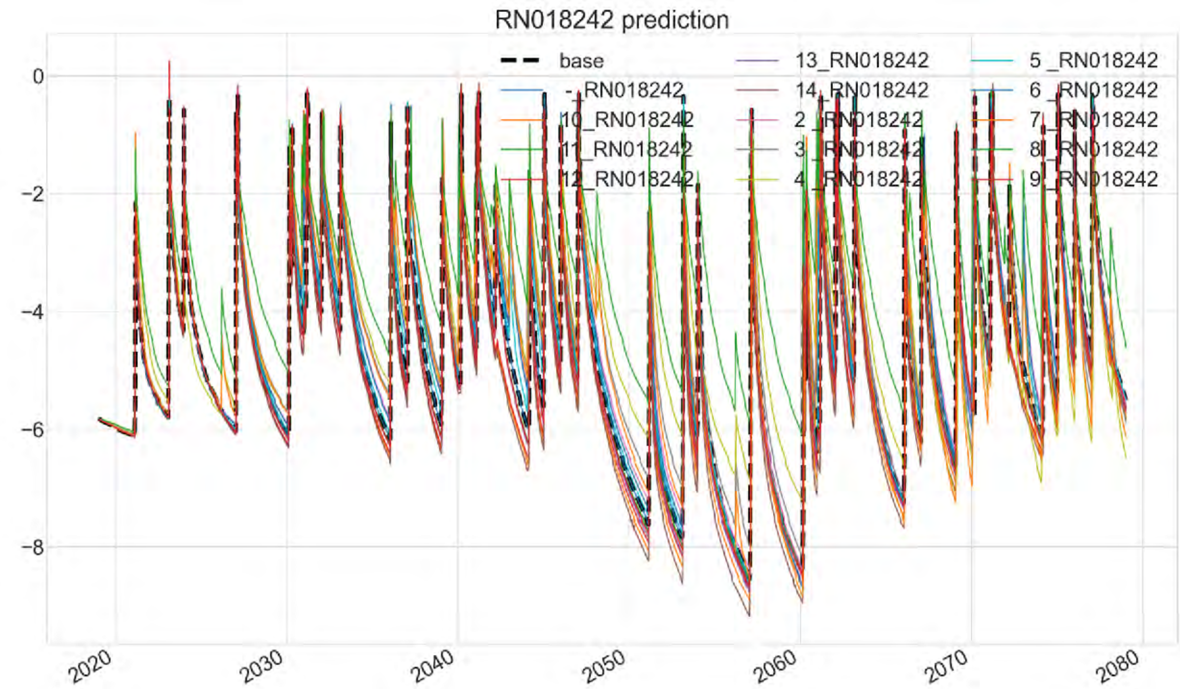

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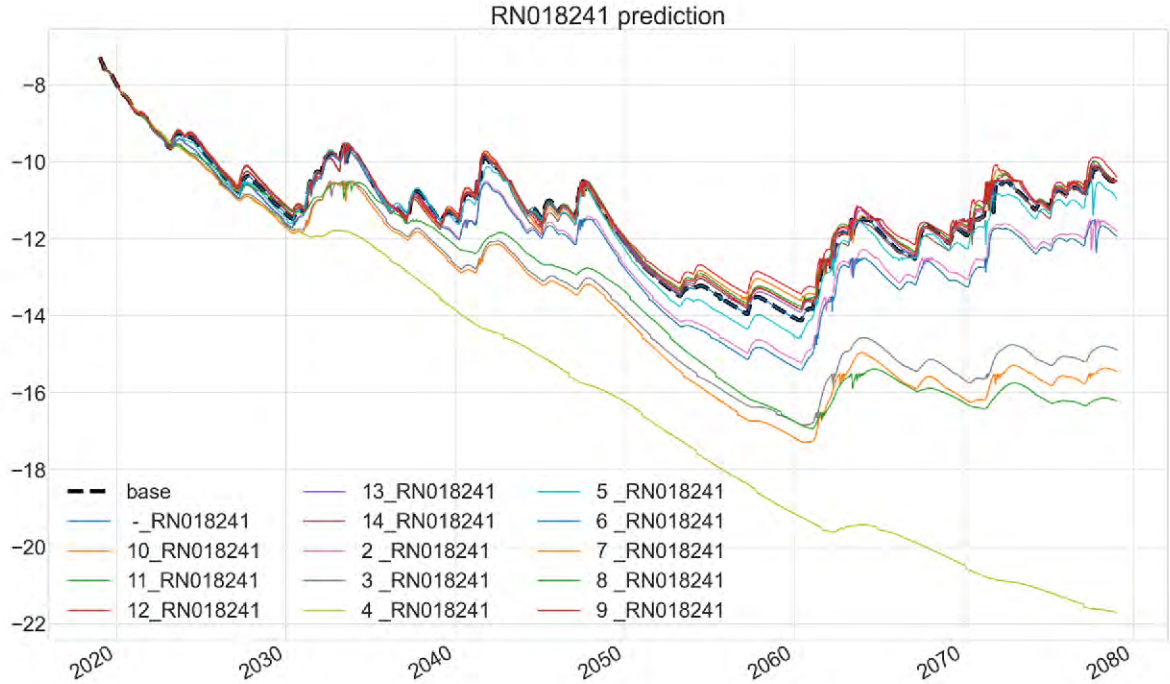
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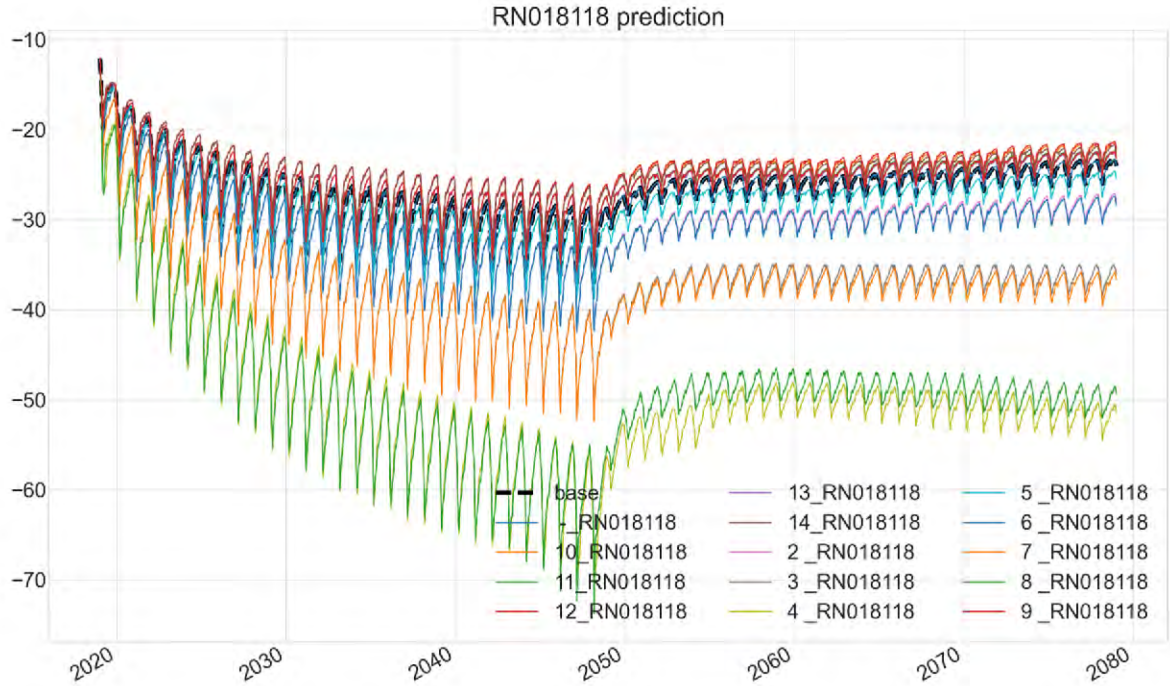
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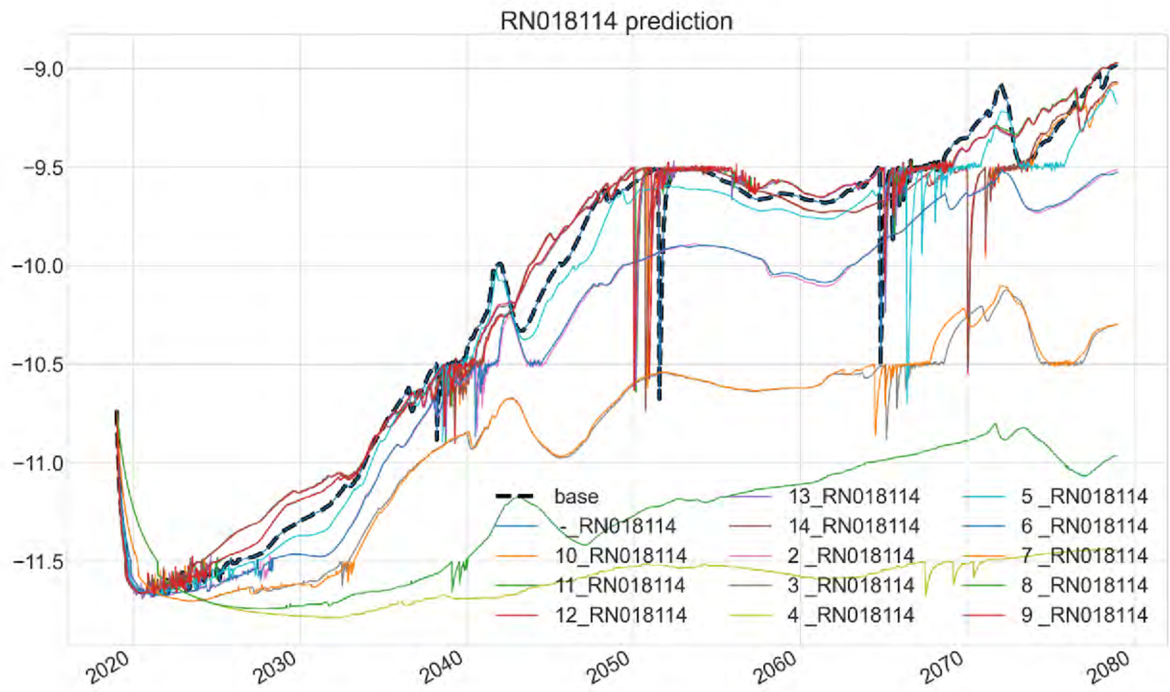
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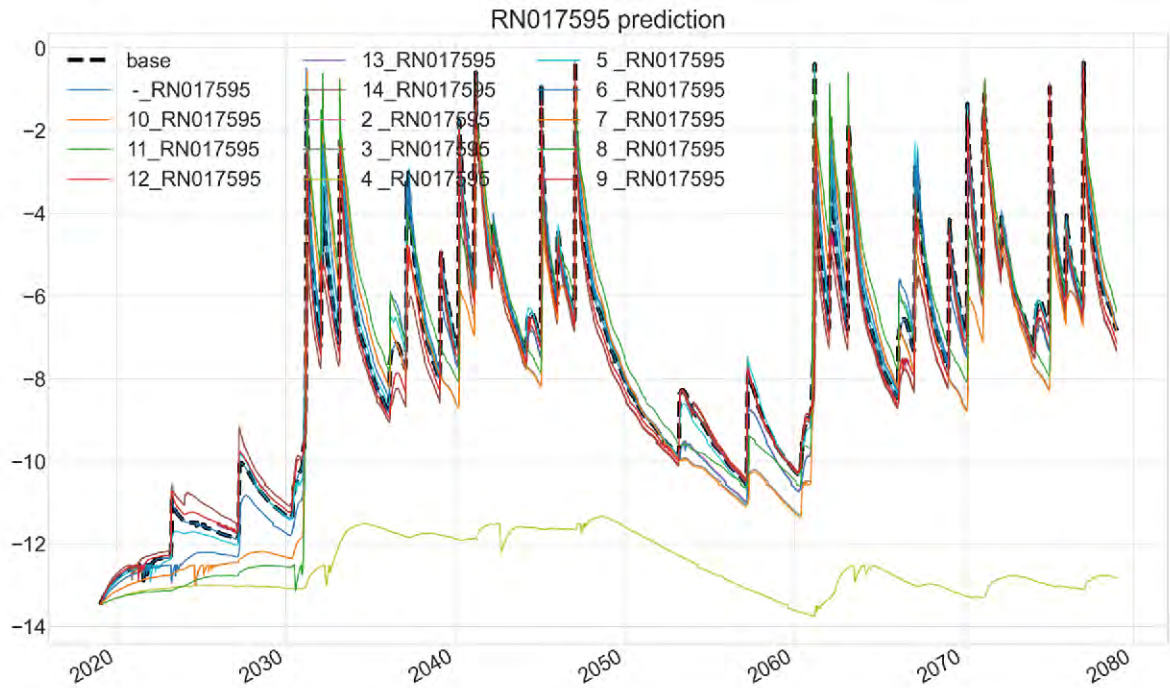
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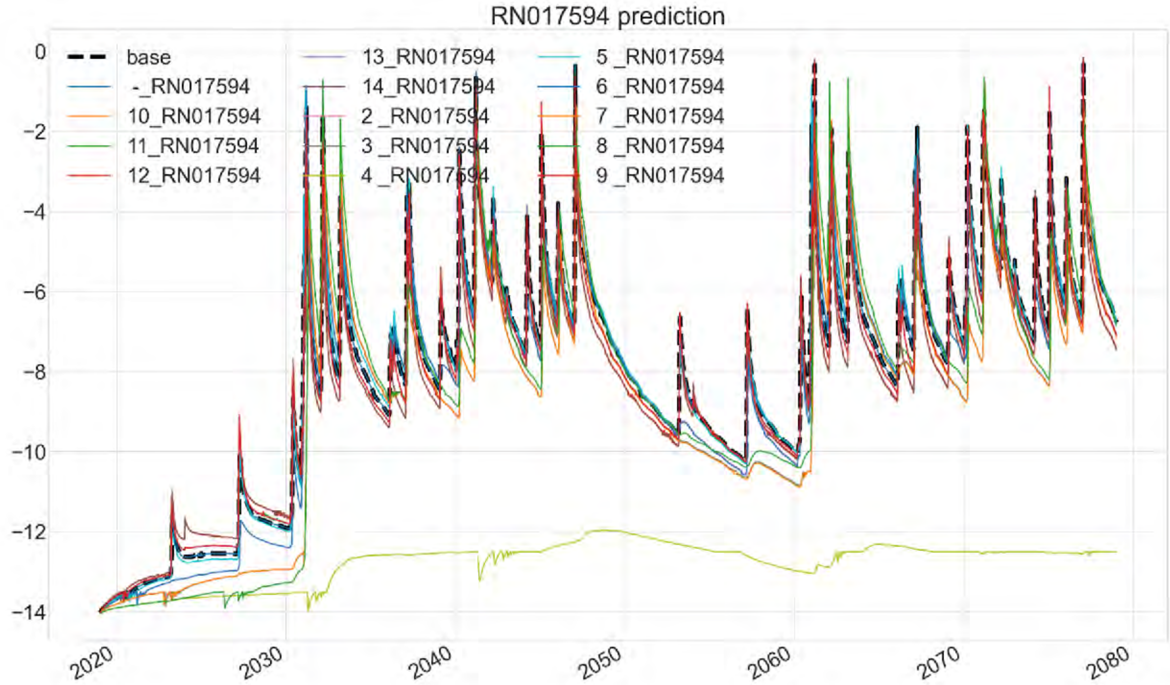
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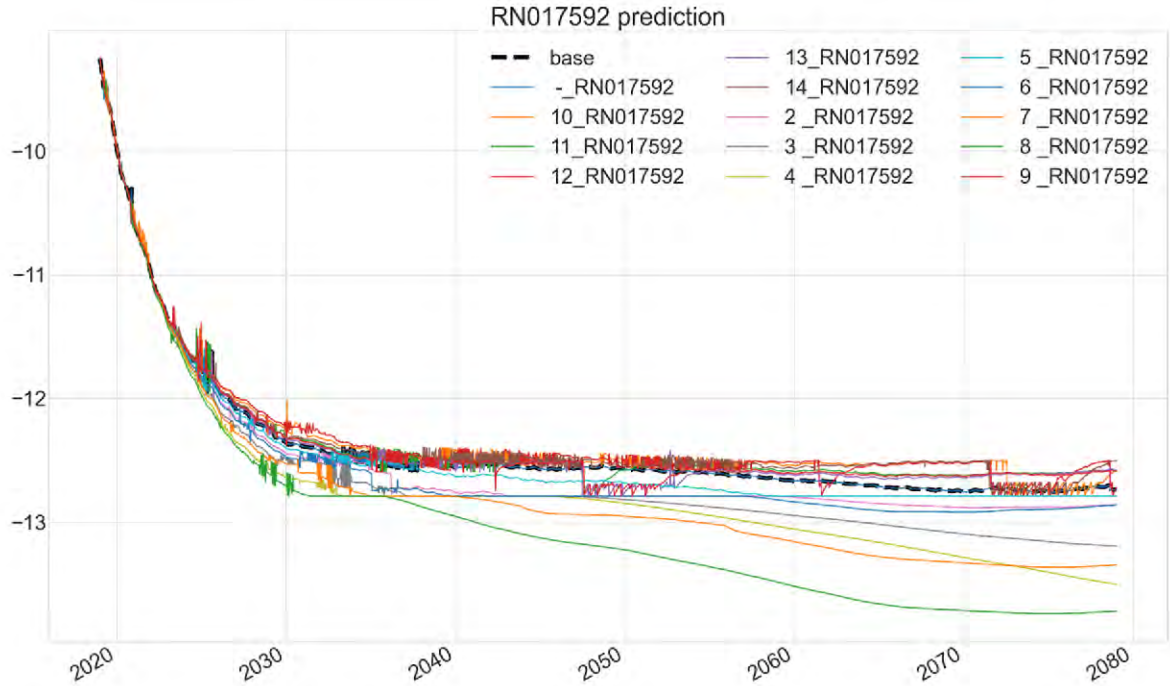
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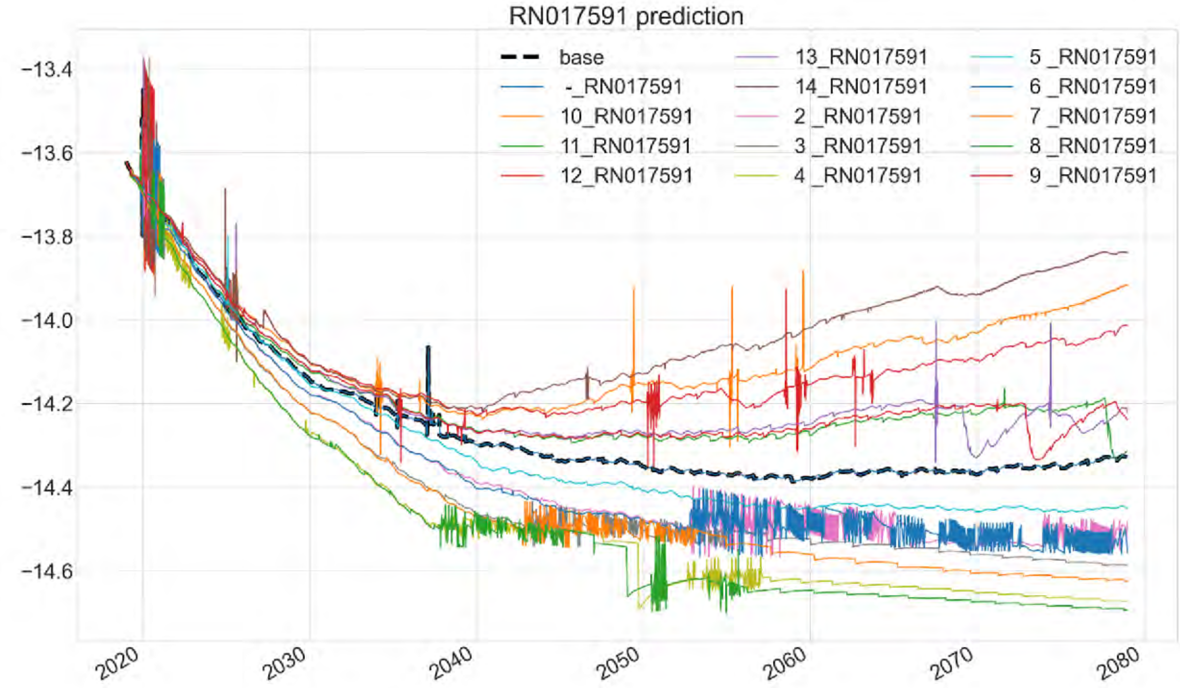

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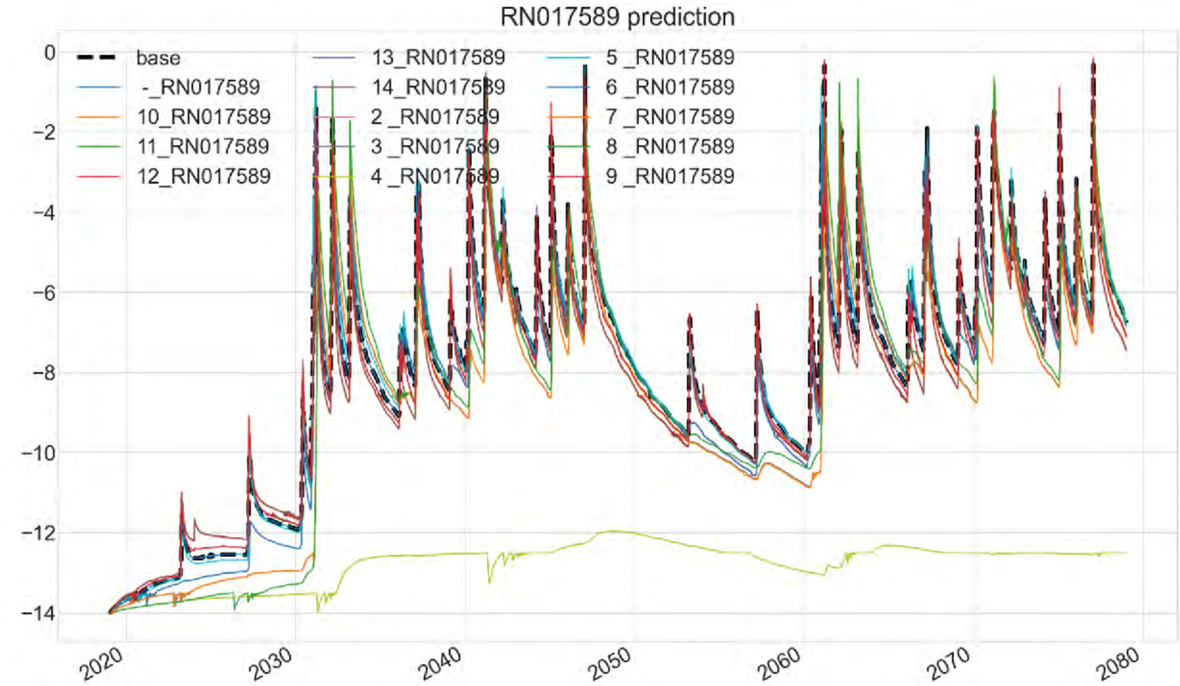

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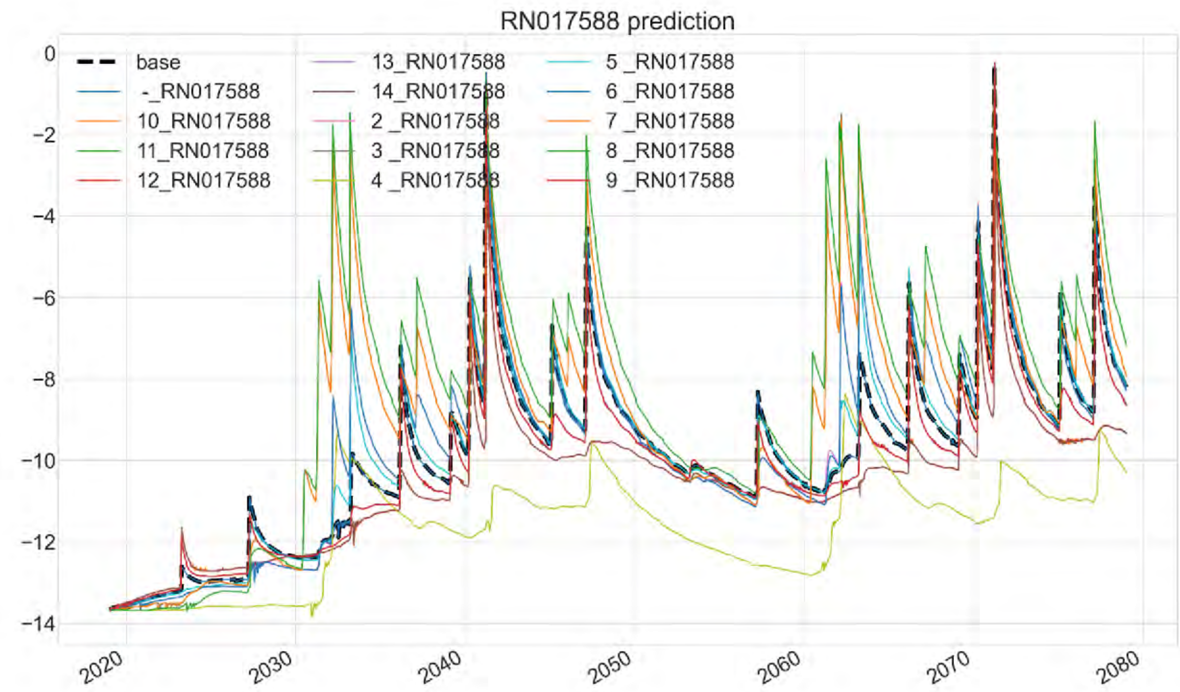
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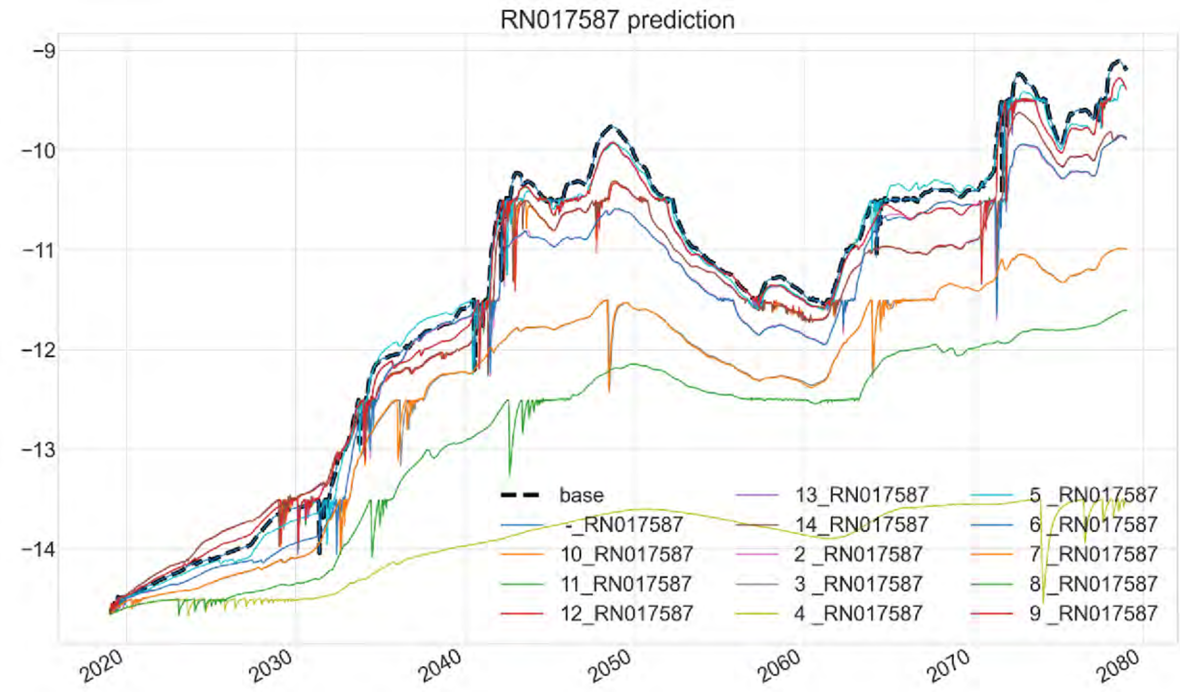
RN017587 prediction
base
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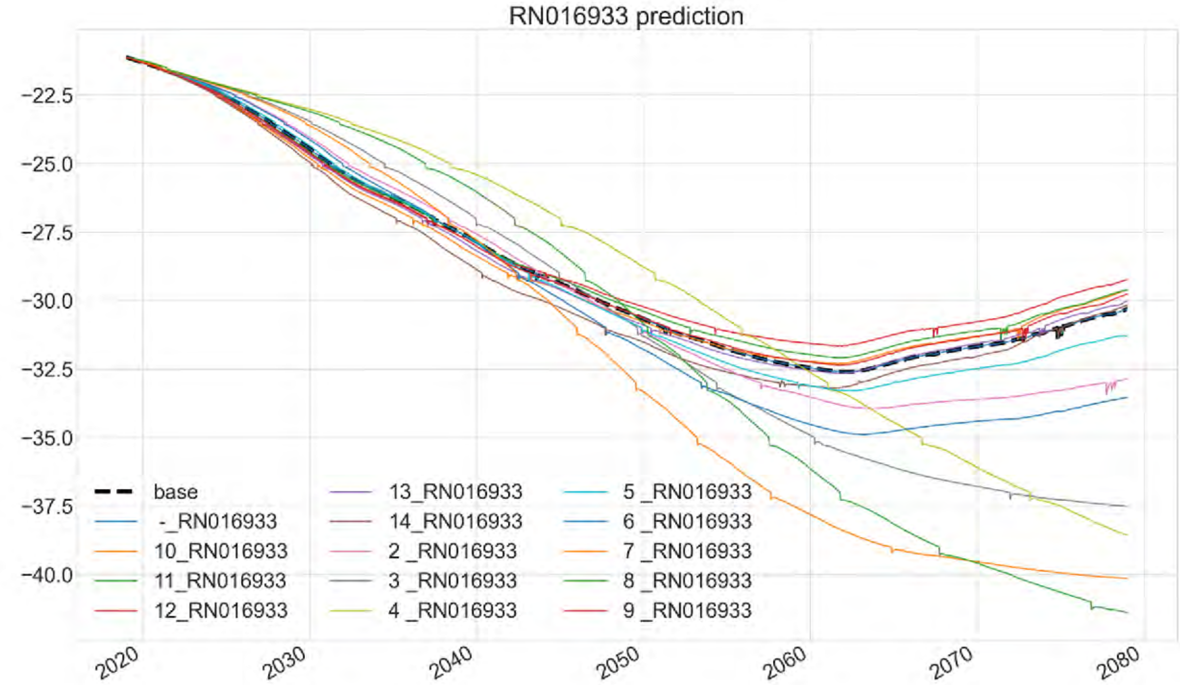
RN016933 prediction
−22.5
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−30.0
−32.5
−35.0
−37.5
−40.0
base
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14_RN016933
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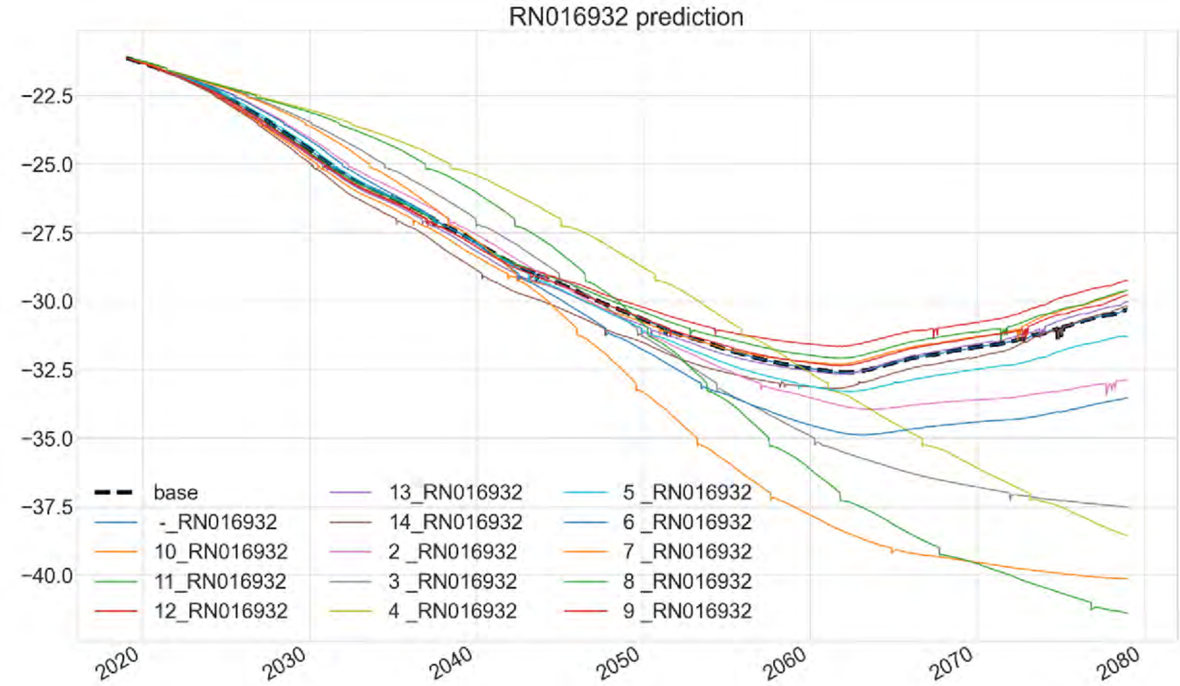
RN016932 prediction
−22.5
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−30.0
−32.5
−35.0
−37.5
−40.0
base
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10_RN016932
11_RN016932
12_RN016932
13_RN016932
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3 _RN016932
4 _RN016932
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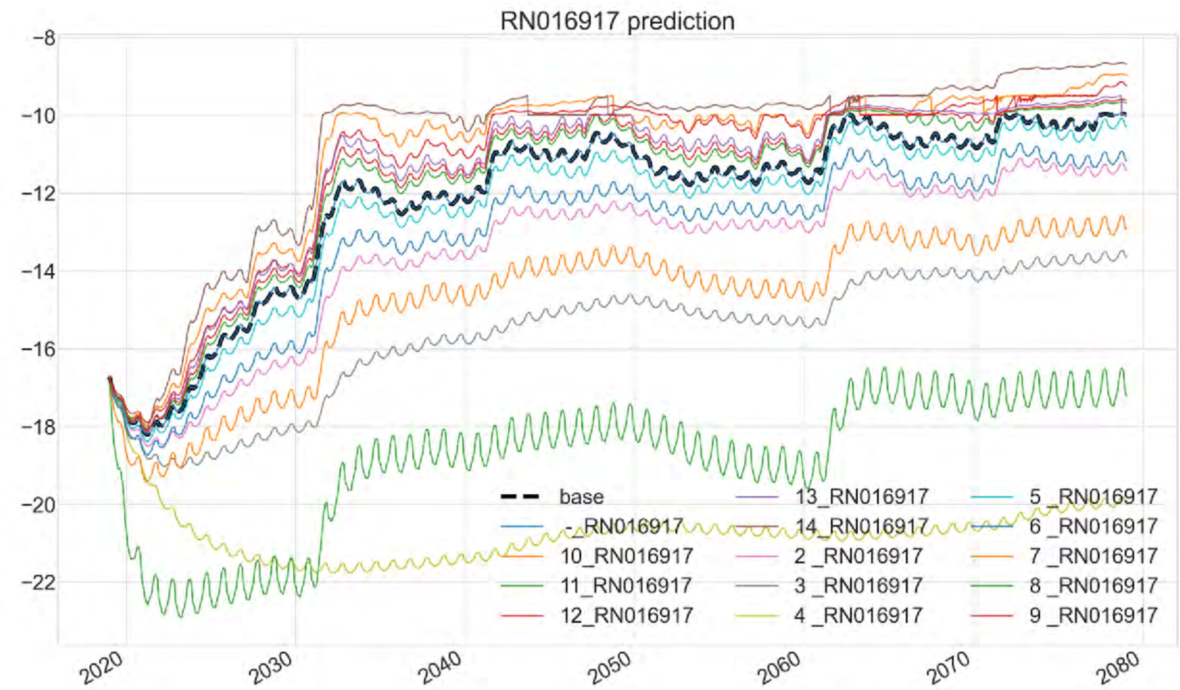
RN016917 prediction
base
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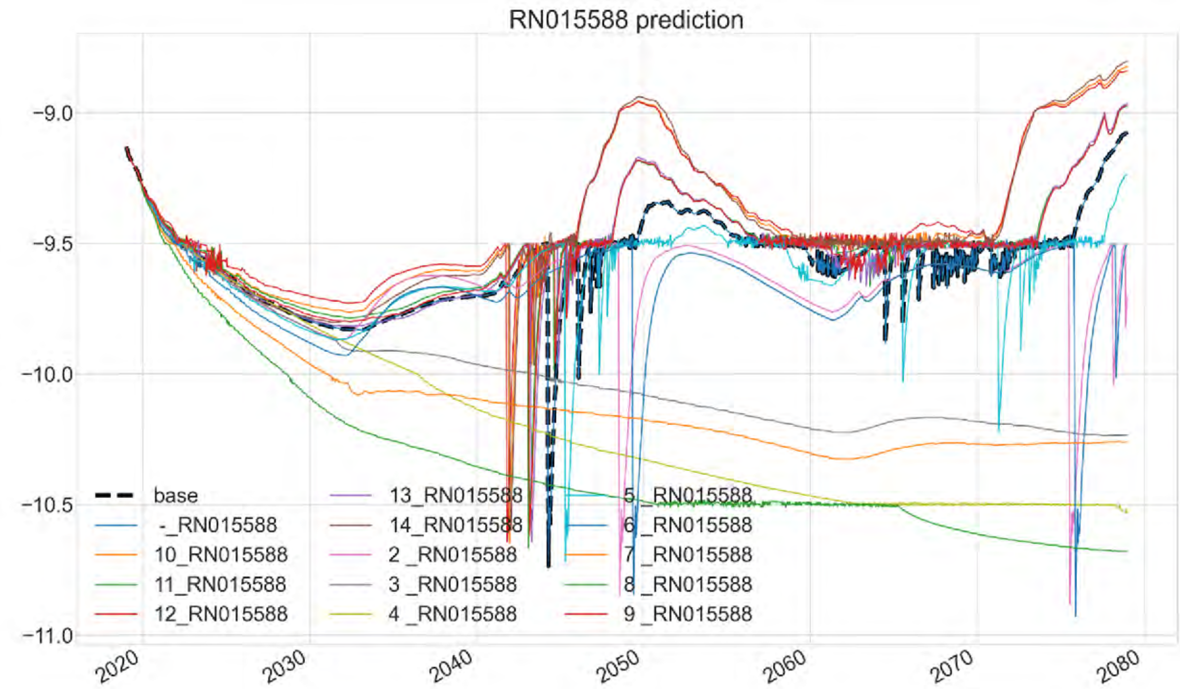
RN015588 prediction
base
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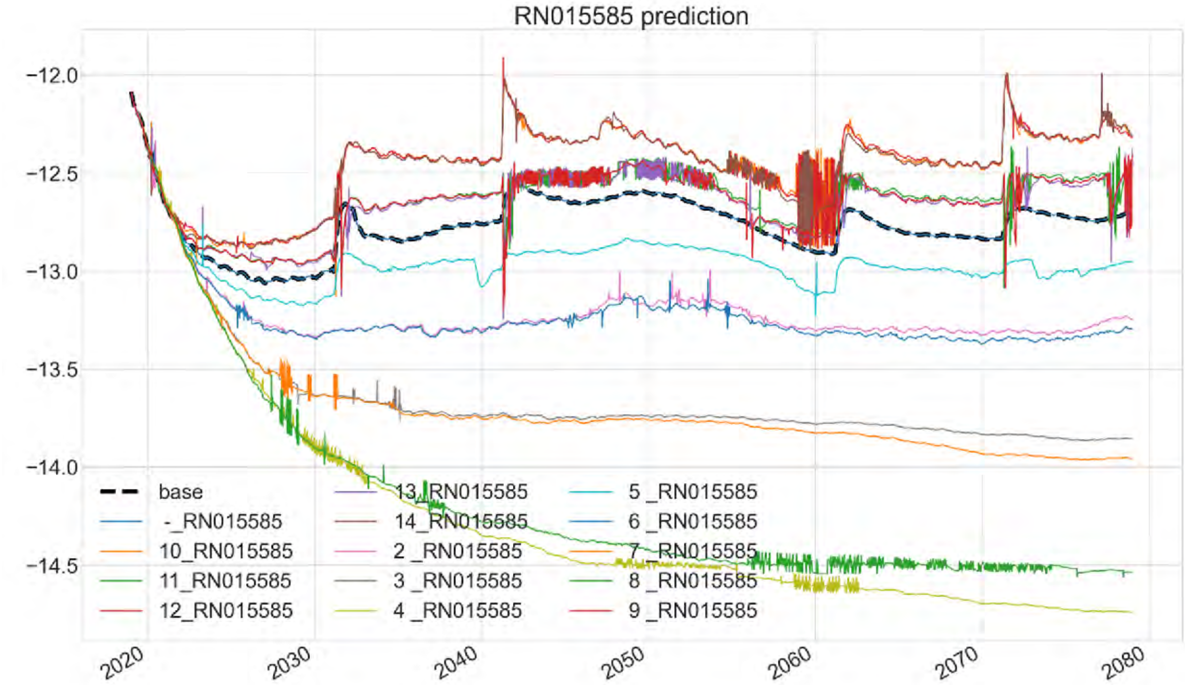

RN015585 prediction
-12.0
-12.5
-13.0
-13.5
-14.0
-14.5
base
-_RN015585
10_RN015585
11_RN015585
12_RN015585
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2 _RN015585
3 _RN015585
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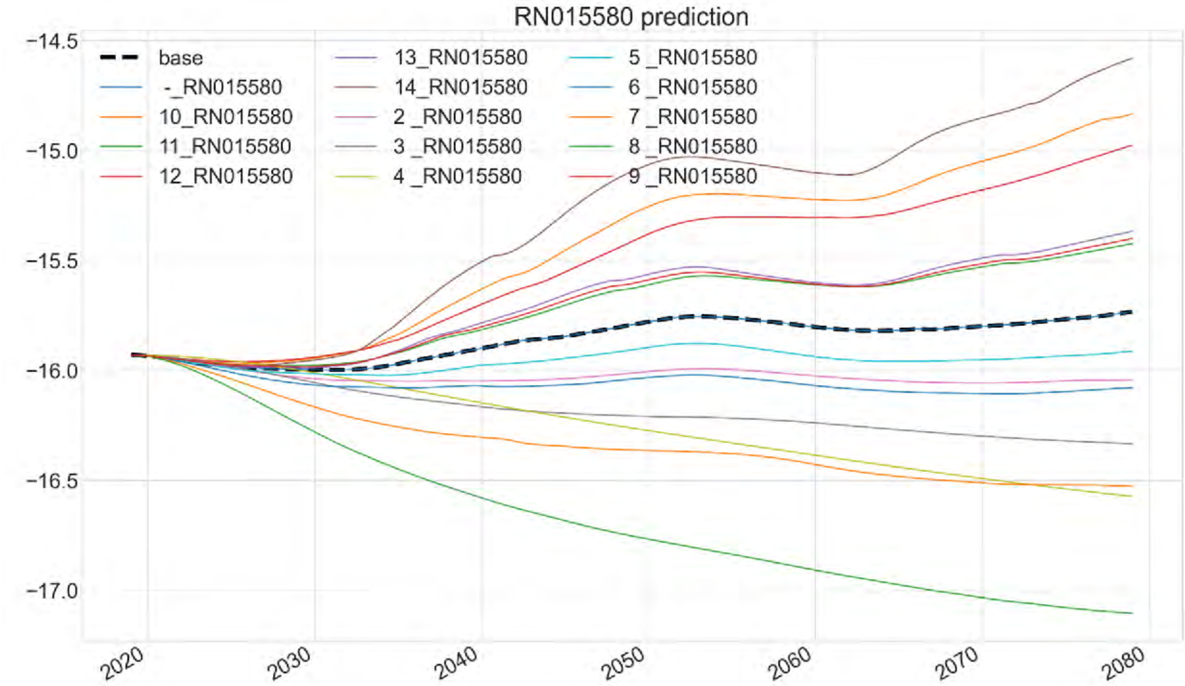

RN015580 prediction
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-15.0
-15.5
-16.0
-16.5
-17.0
base
-_RN015580
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12_RN015580
13_RN015580
14_RN015580
2 _RN015580
3 _RN015580
4 _RN015580
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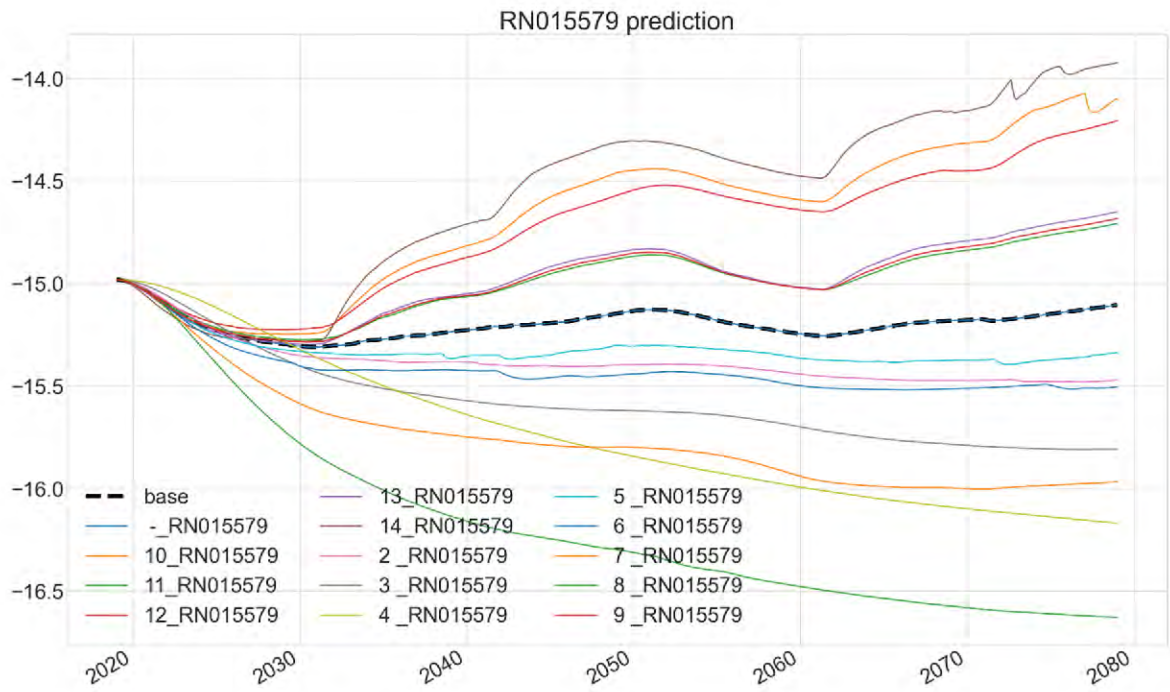
RN015579 prediction
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-14.5
-15.0
-15.5
-16.0
-16.5
base
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2 _RN015579
3 _RN015579
4 _RN015579
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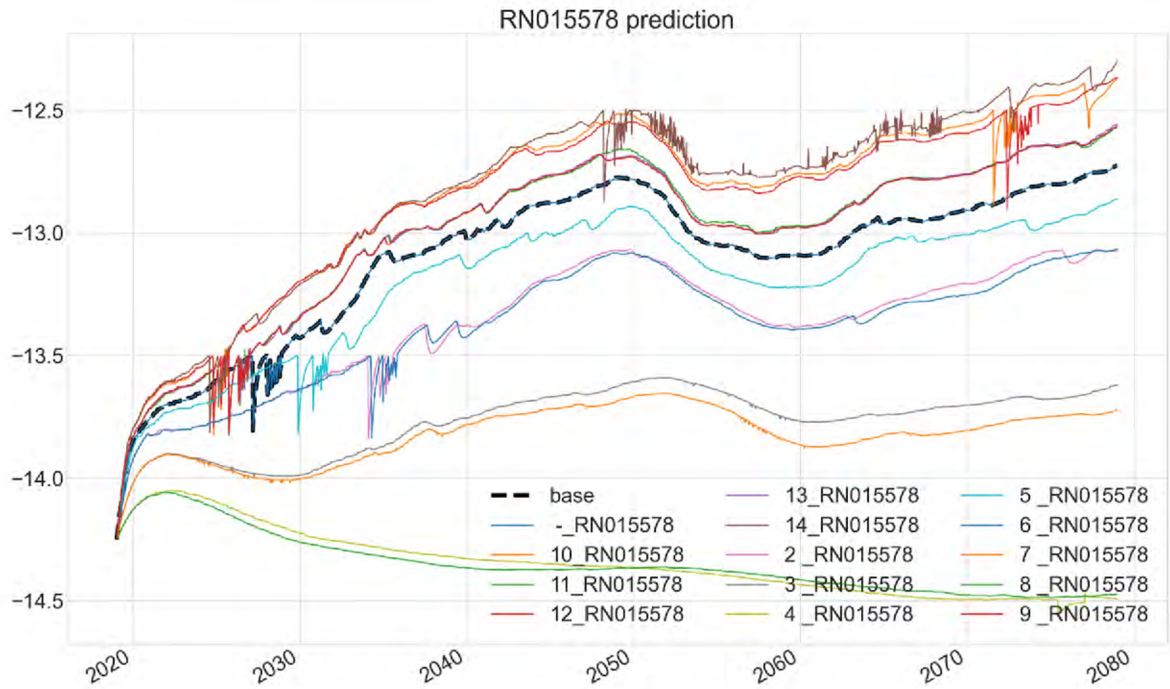
2080


RN015578 prediction
-12.5
-13.0
-13.5
-14.0
-14.5
base
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10_RN015578
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12_RN015578
13_RN015578
14_RN015578
2 _RN015578
3 _RN015578
4 _RN015578
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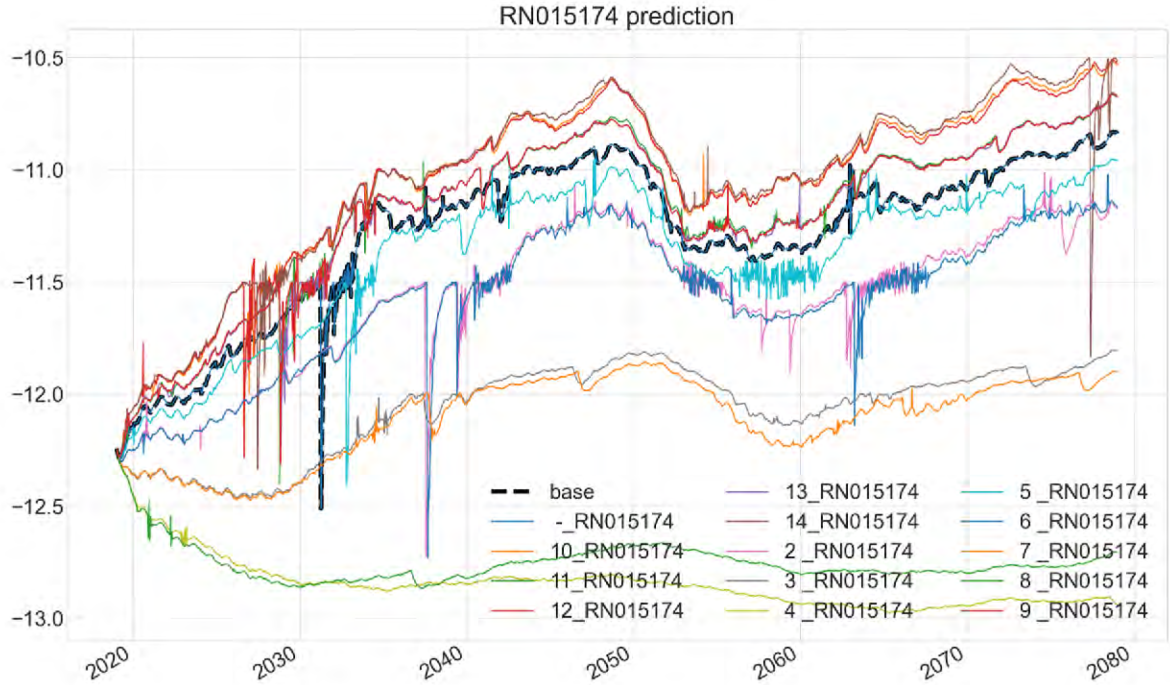
RN015174 prediction
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−11.5
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−12.5
−13.0
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2030
2040
2050
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base
-_RN015174
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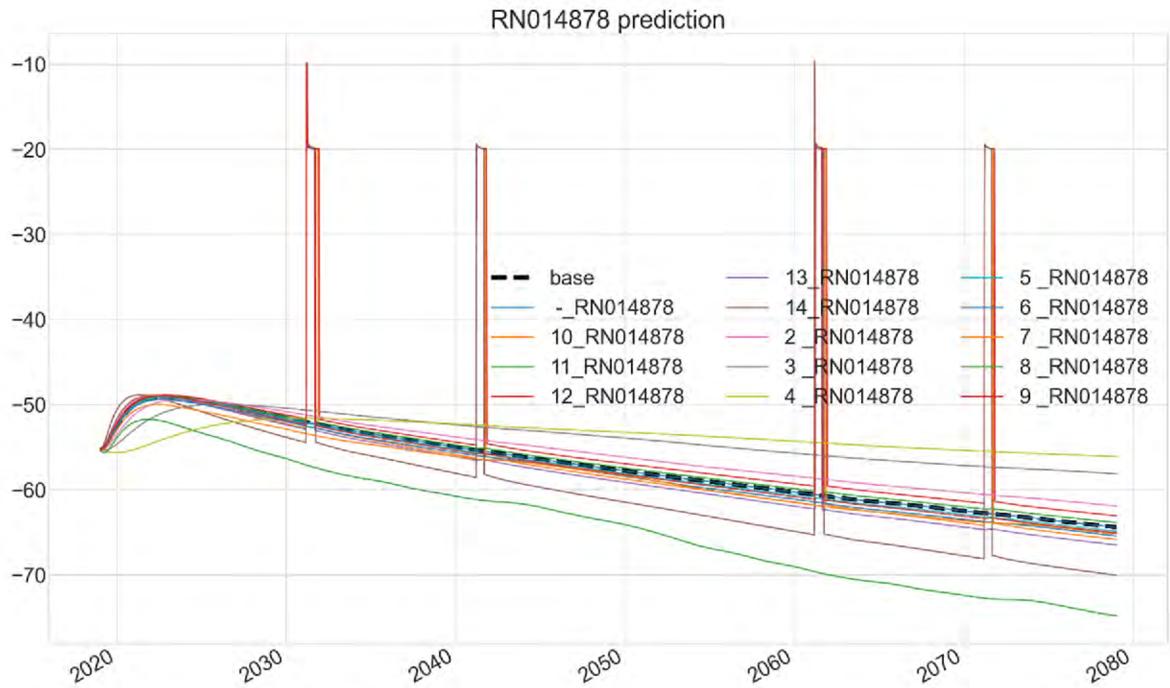
RN014878 prediction
−10
−20
−30
−40
−50
−60
−70
2020
2030
2040
2050
2060
2070
2080
base
-_RN014878
10_RN014878
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13_RN014878
14_RN014878
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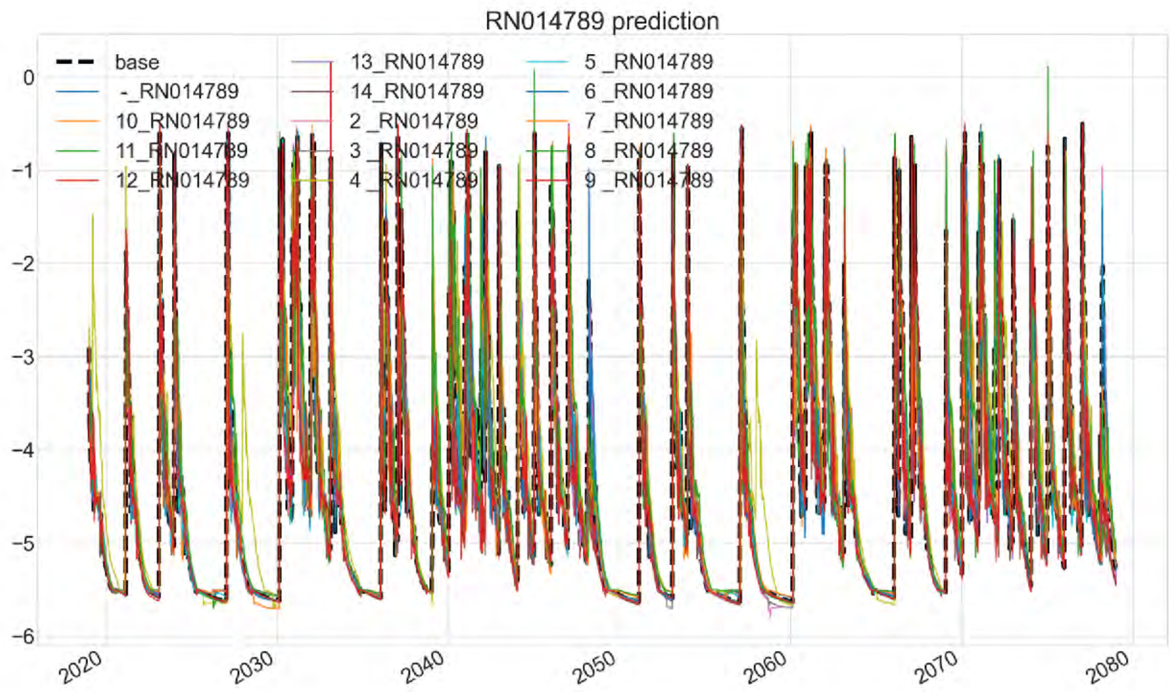
8 _RN014878
9 _RN014878


RN014789 prediction
base
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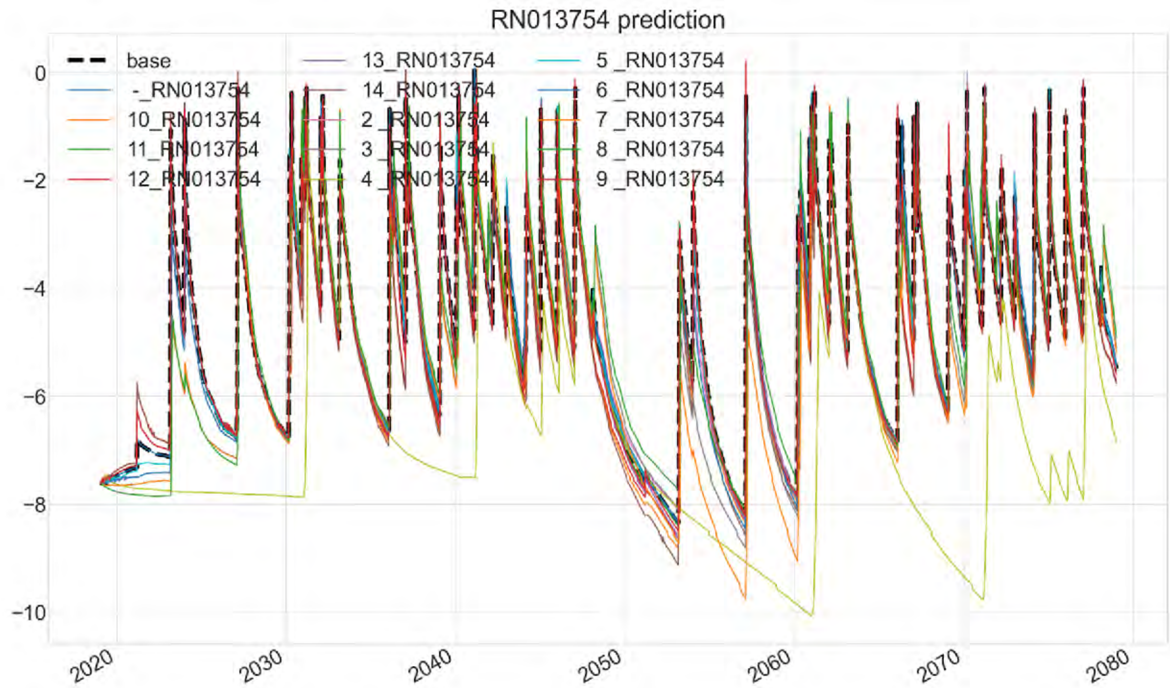
RN013754 prediction
base
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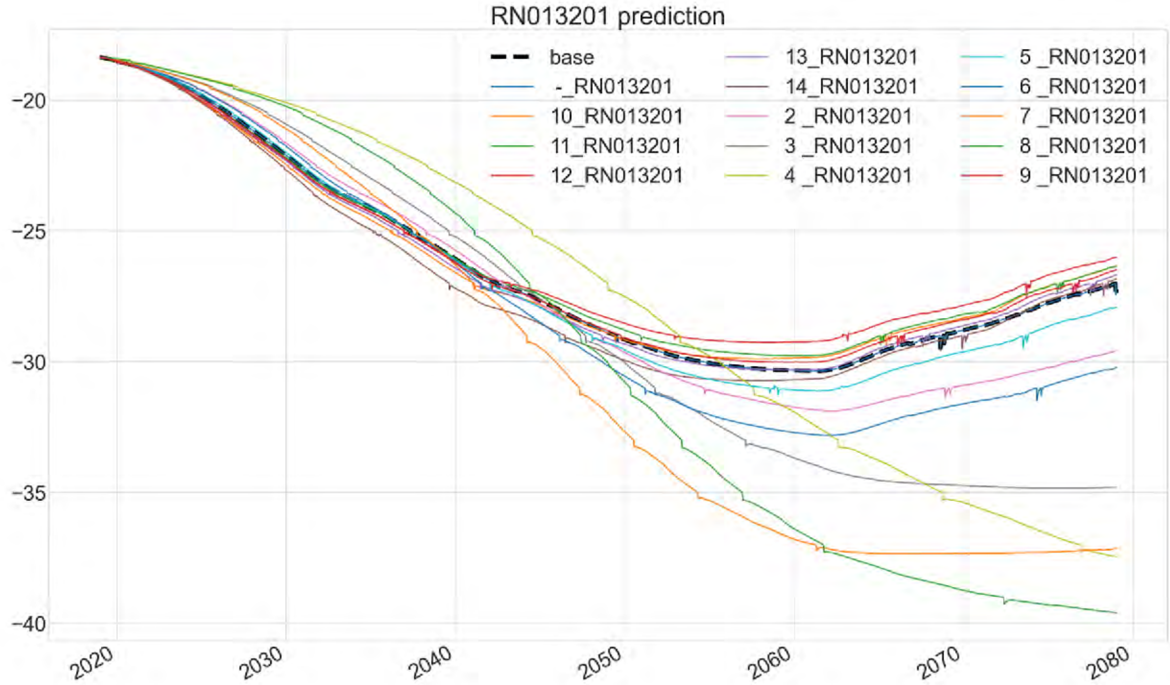

RN013201 prediction
base
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4 _RN013201
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7 _RN013201
8 _RN013201
9 _RN013201
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−40
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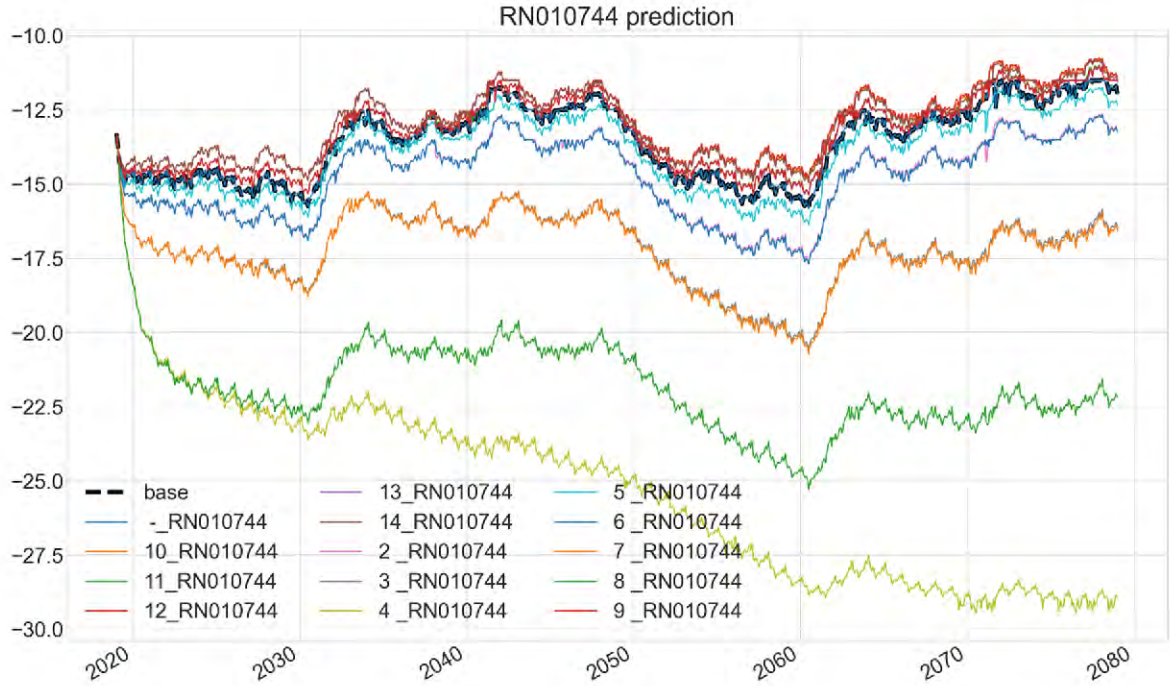
2060
2070
2080



RN010744 prediction
base
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4 _RN010744
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6 _RN010744
7 _RN010744
8 _RN010744
9 _RN010744
−10.0
−12.5
−15.0
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−20.0
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−25.0
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−30.0
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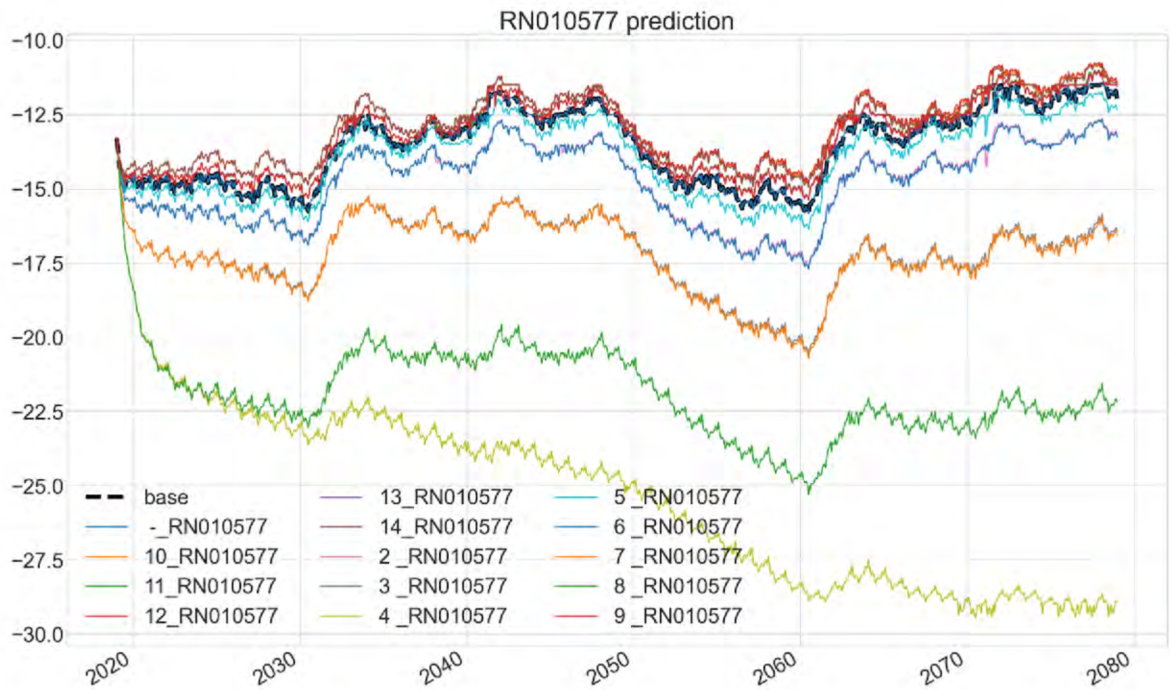
2080


RN010577 prediction
base
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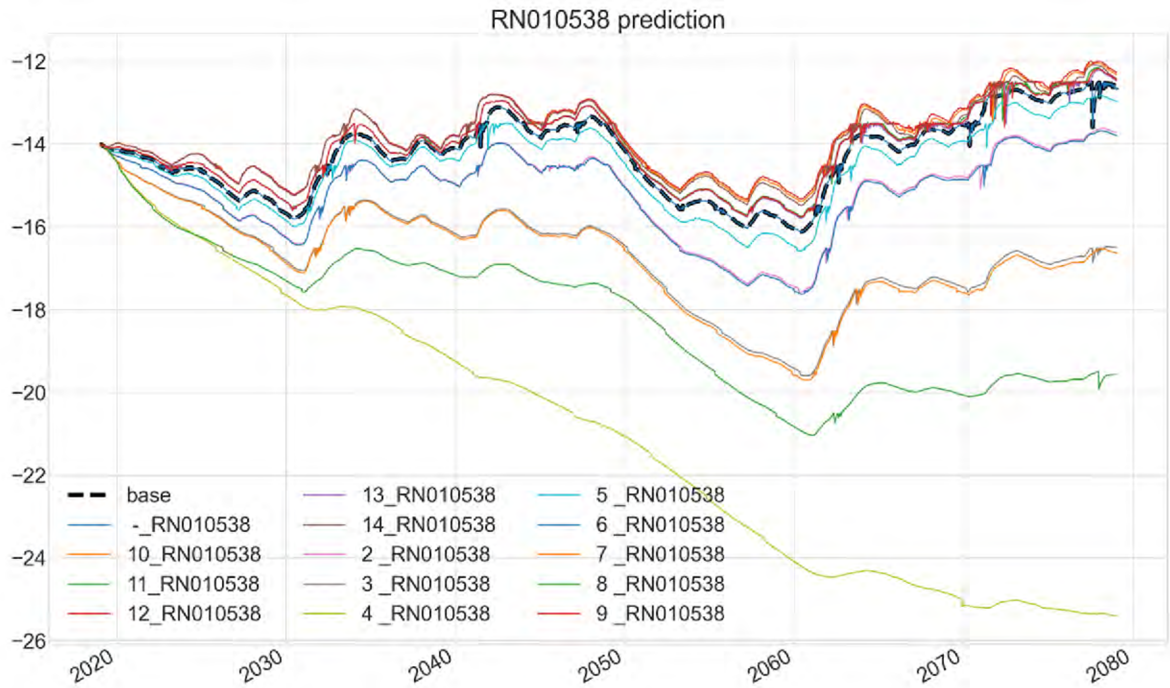
RN010538 prediction
base
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14_RN010538
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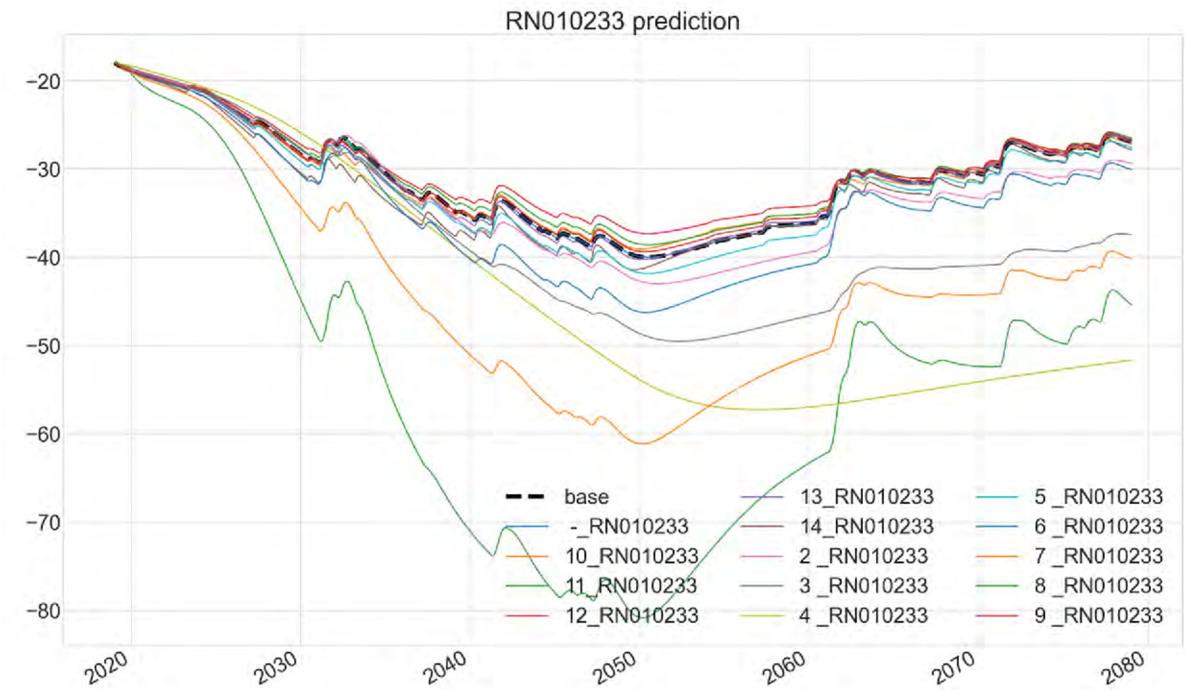
RN010233 prediction
-20
-30
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-60
-70
-80
base
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13_RN010233
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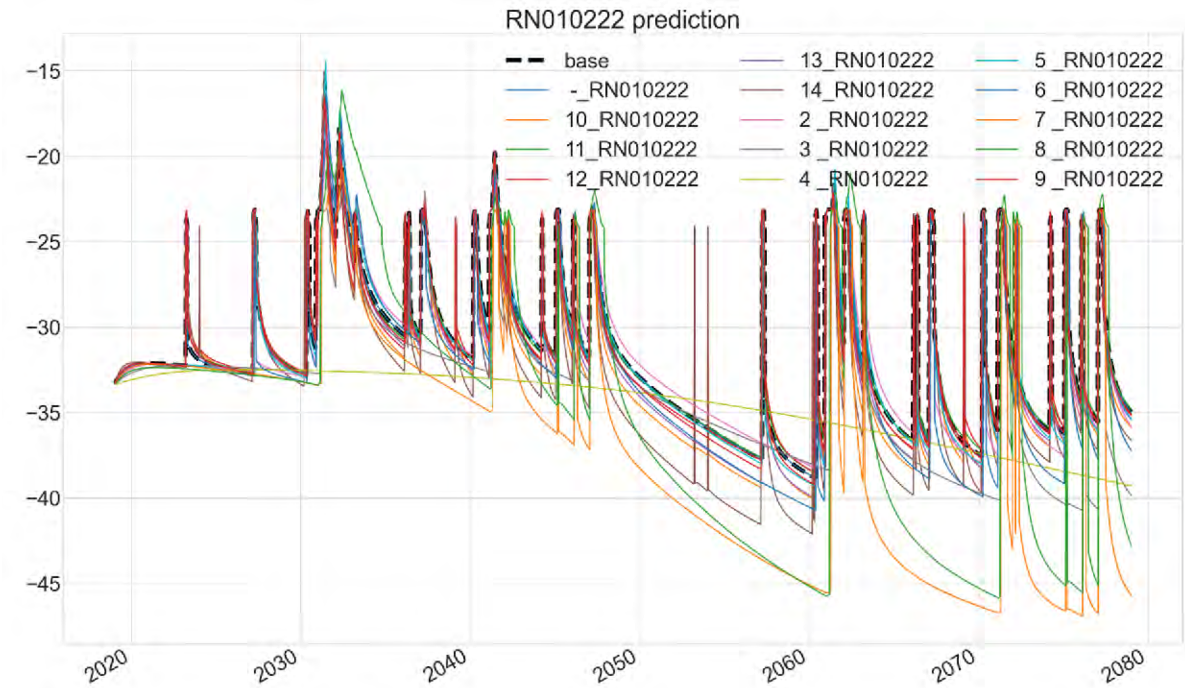
RN010222 prediction
-15
-20
-25
-30
-35
-40
-45
base
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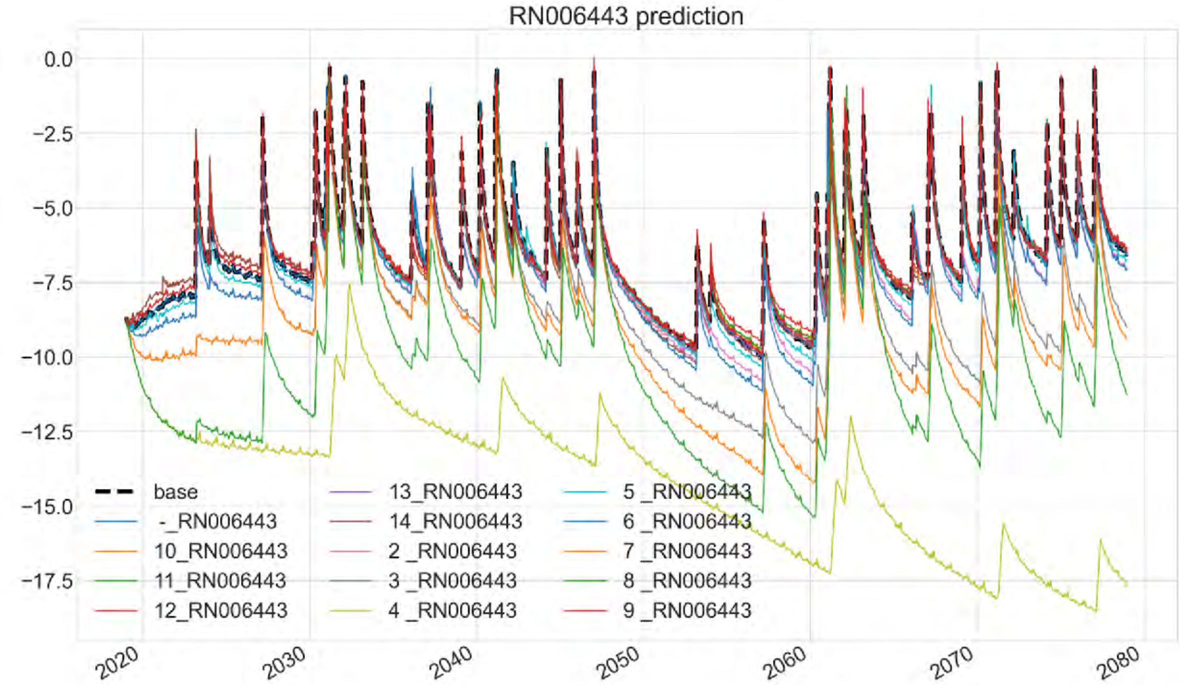
RN006443 prediction
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−2.5
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−10.0
−12.5
−15.0
−17.5
base
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10_RN006443
11_RN006443
12_RN006443
13_RN006443
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3 _RN006443
4 _RN006443
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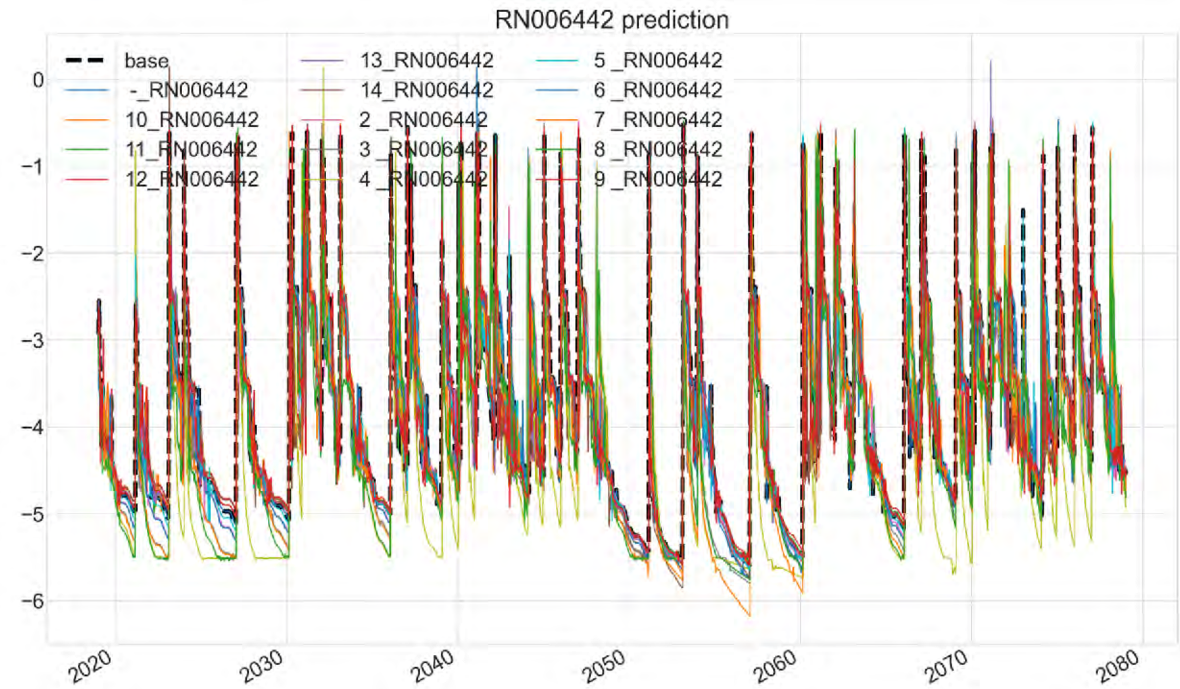
2080


RN006442 prediction
0
−1
−2
−3
−4
−5
−6
base
-_RN006442
10_RN006442
11_RN006442
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13_RN006442
14_RN006442
2 _RN006442
3 _RN006442
4 _RN006442
5 _RN006442
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2030
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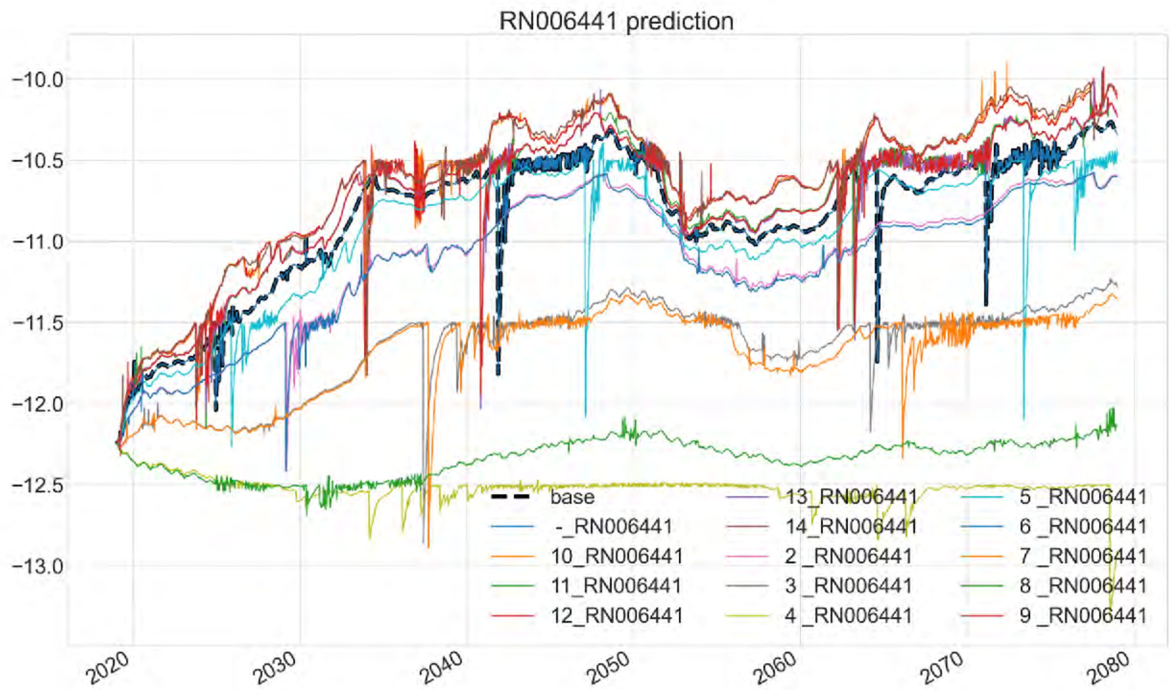
RN006441 prediction
−10.0
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−11.5
−12.0
−12.5
−13.0
2020
2030
2040
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2060
2070
2080
base
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10_RN006441
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12_RN006441
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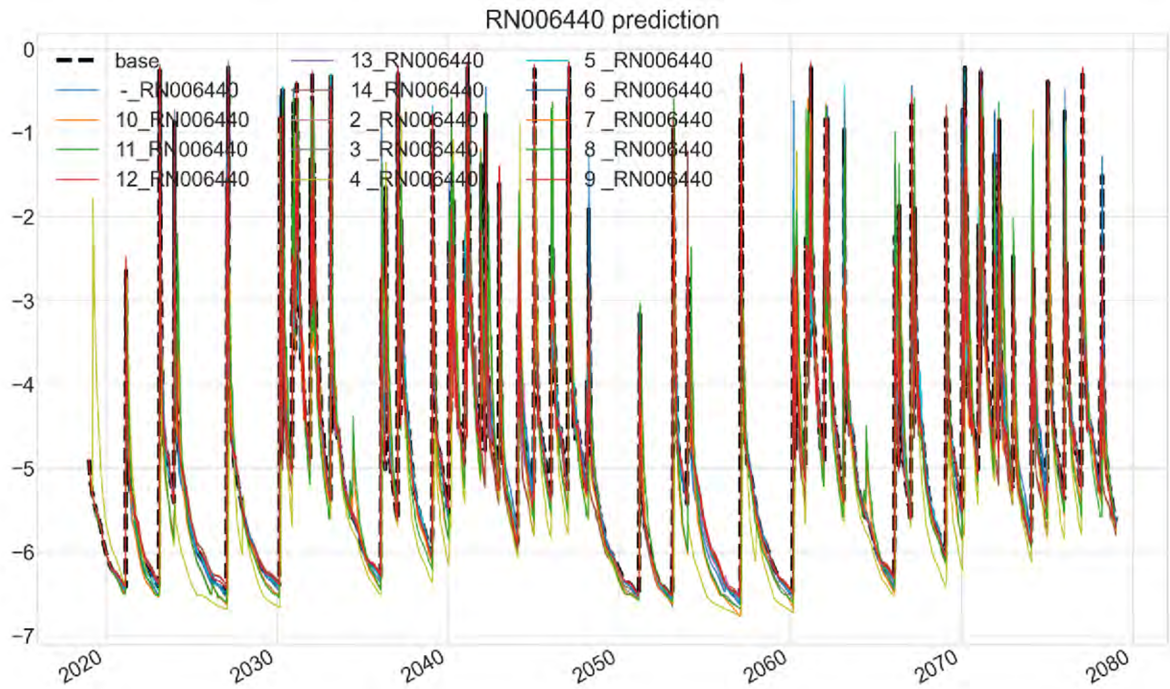
RN006440 prediction
0
−1
−2
−3
−4
−5
−6
−7
2020
2030
2040
2050
2060
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base
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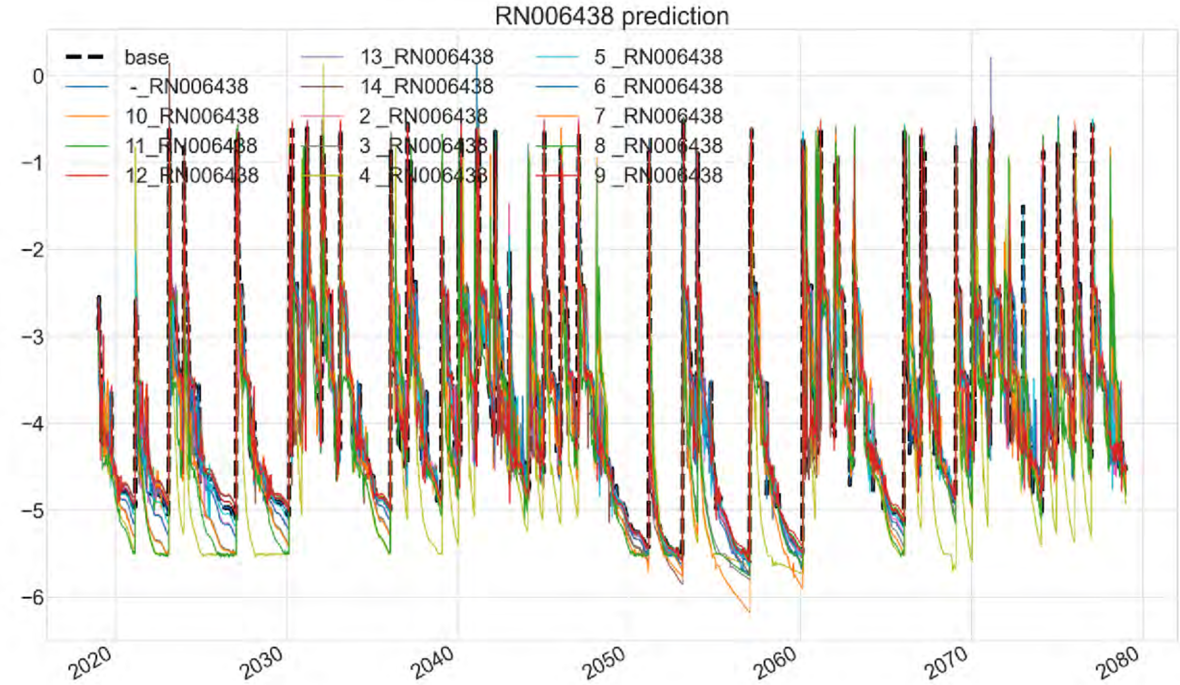
RN006438 prediction
base
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2_RN006438
3_RN006438
4_RN006438
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7_RN006438
8_RN006438
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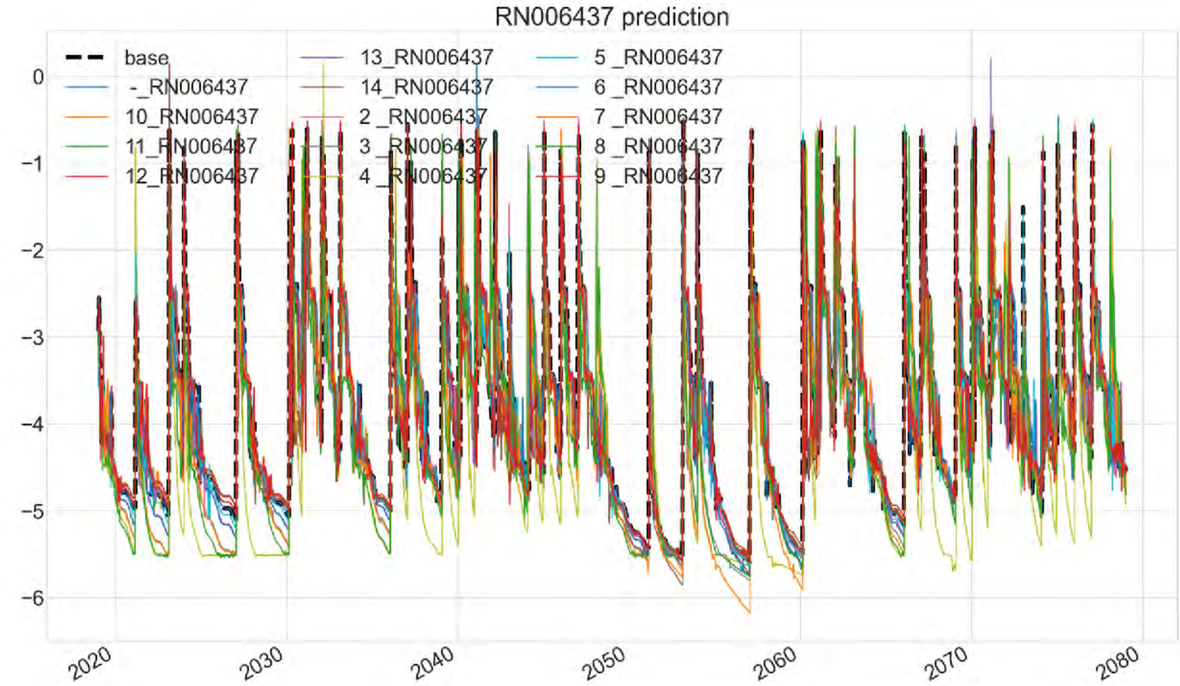
2080


RN006437 prediction
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4_RN006437
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7_RN006437
8_RN006437
9_RN006437
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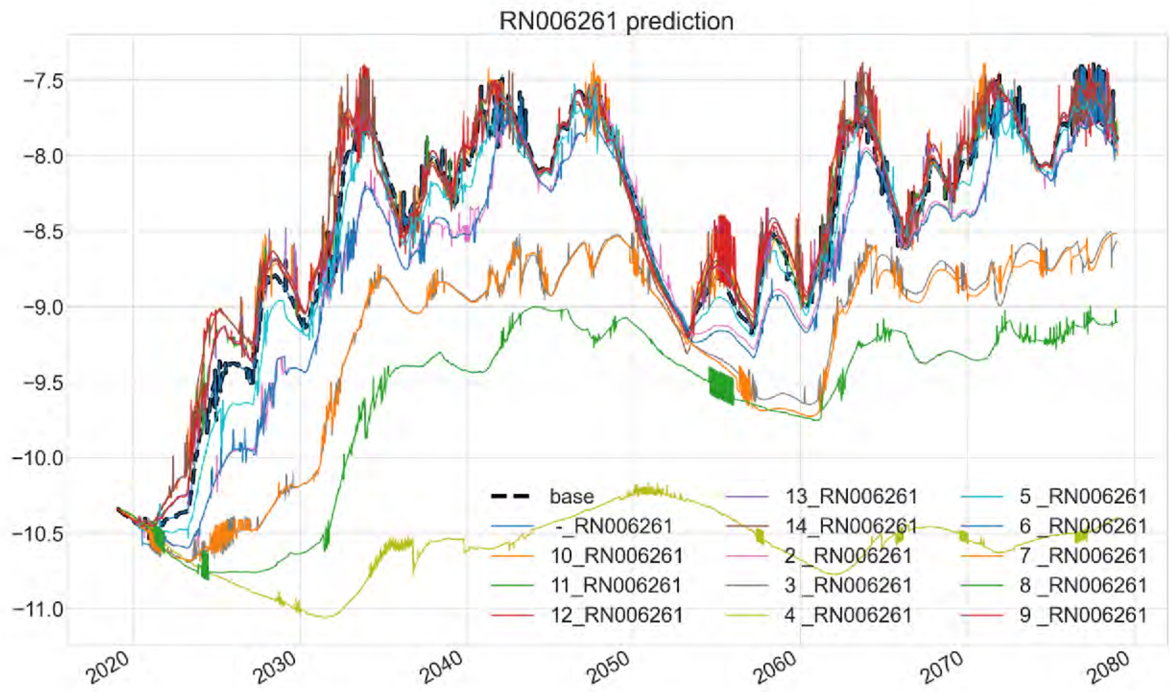
2080


RN006261 prediction
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-8.5
-9.0
-9.5
-10.0
-10.5
-11.0
2020
2030
2040
2050
2060
2070
2080
base
-_RN006261
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13_RN006261
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8 _RN006261
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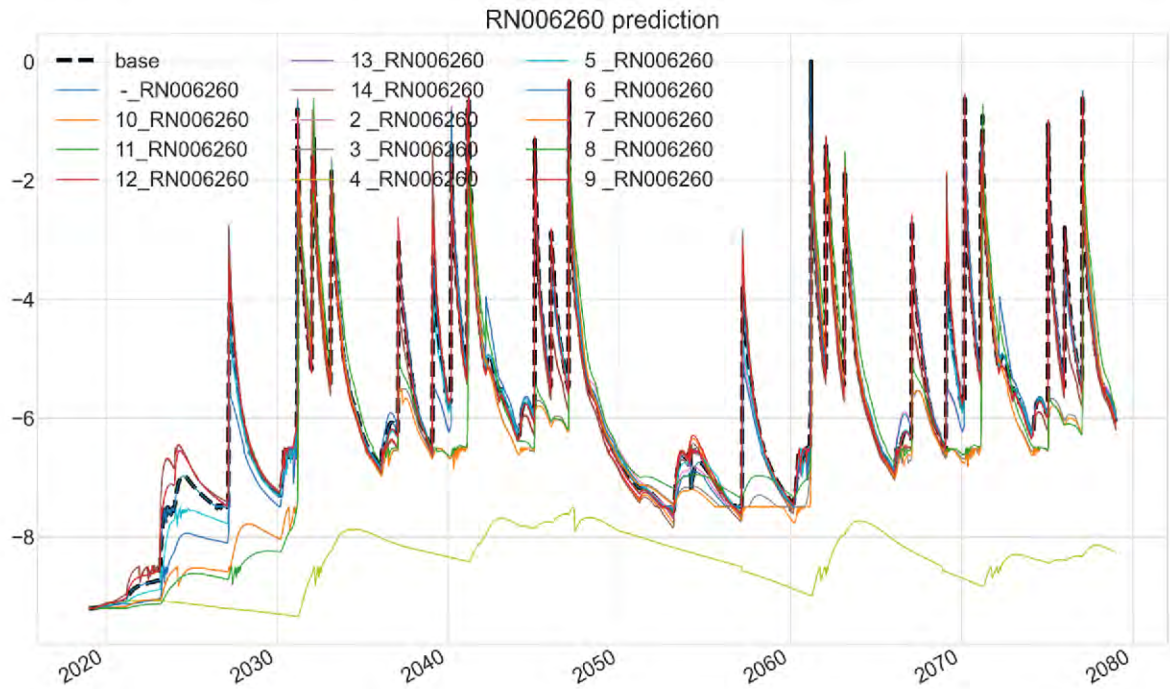
RN006260 prediction
0
-2
-4
-6
-8
2020
2030
2040
2050
2060
2070
2080
base
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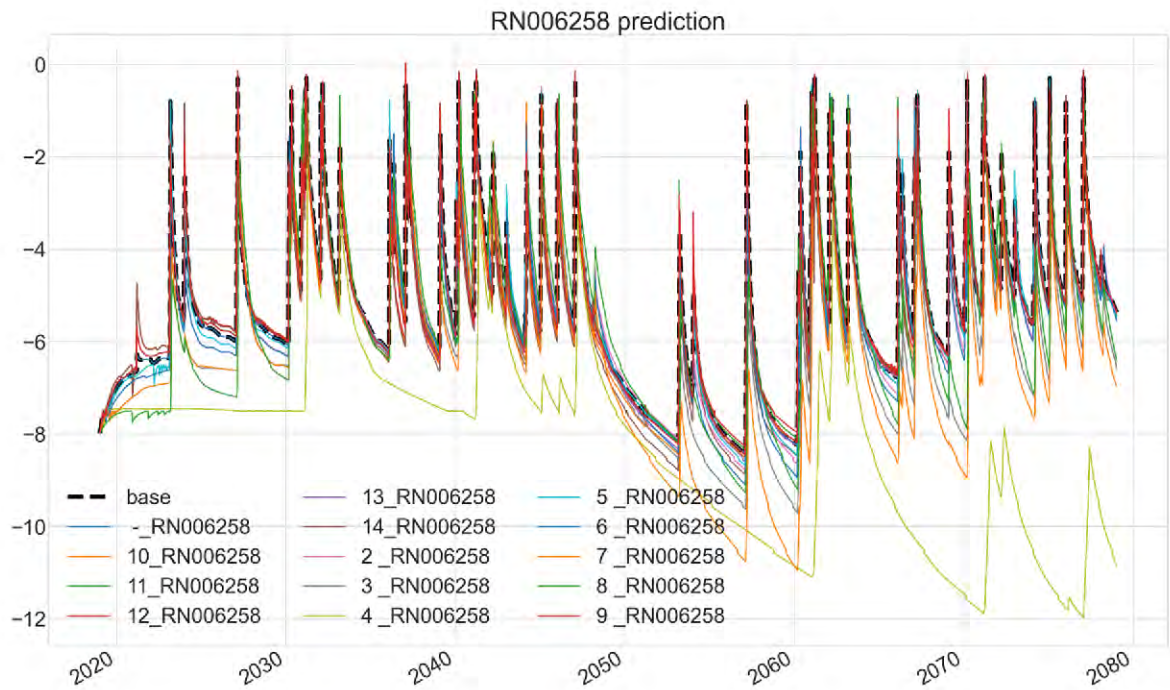
RN006258 prediction
0
−2
−4
−6
−8
−10
−12
base
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13_RN006258
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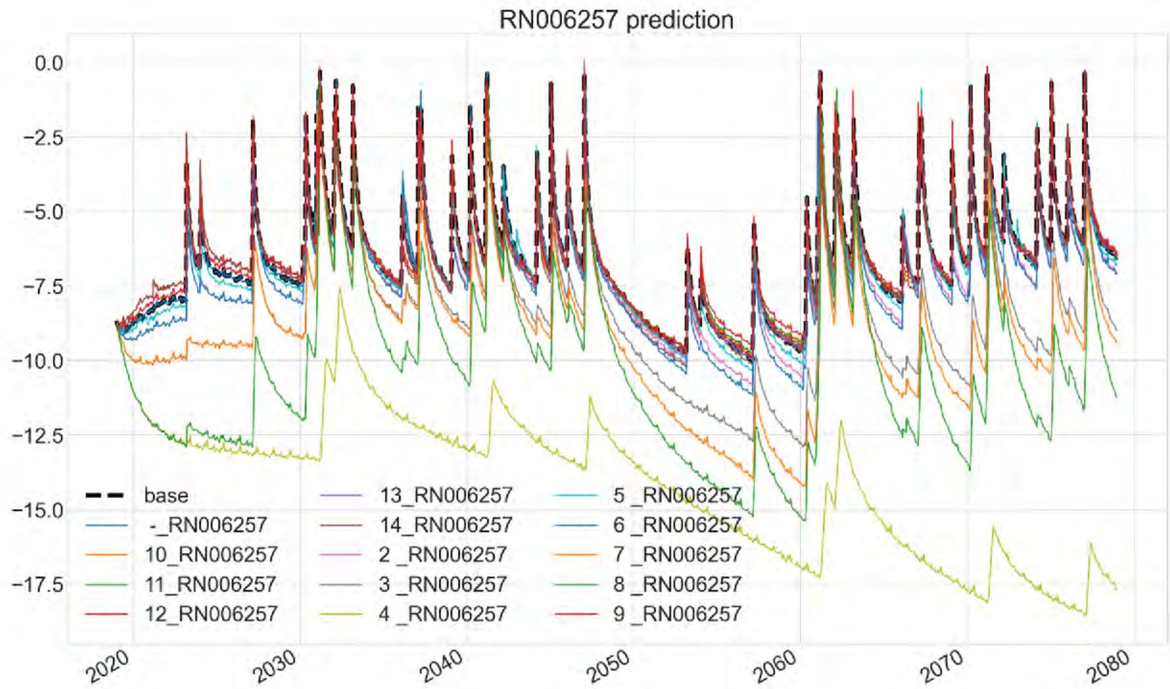
2080


RN006257 prediction
0.0
−2.5
−5.0
−7.5
−10.0
−12.5
−15.0
−17.5
base
-_RN006257
10_RN006257
11_RN006257
12_RN006257
13_RN006257
14_RN006257
2 _RN006257
3 _RN006257
4 _RN006257
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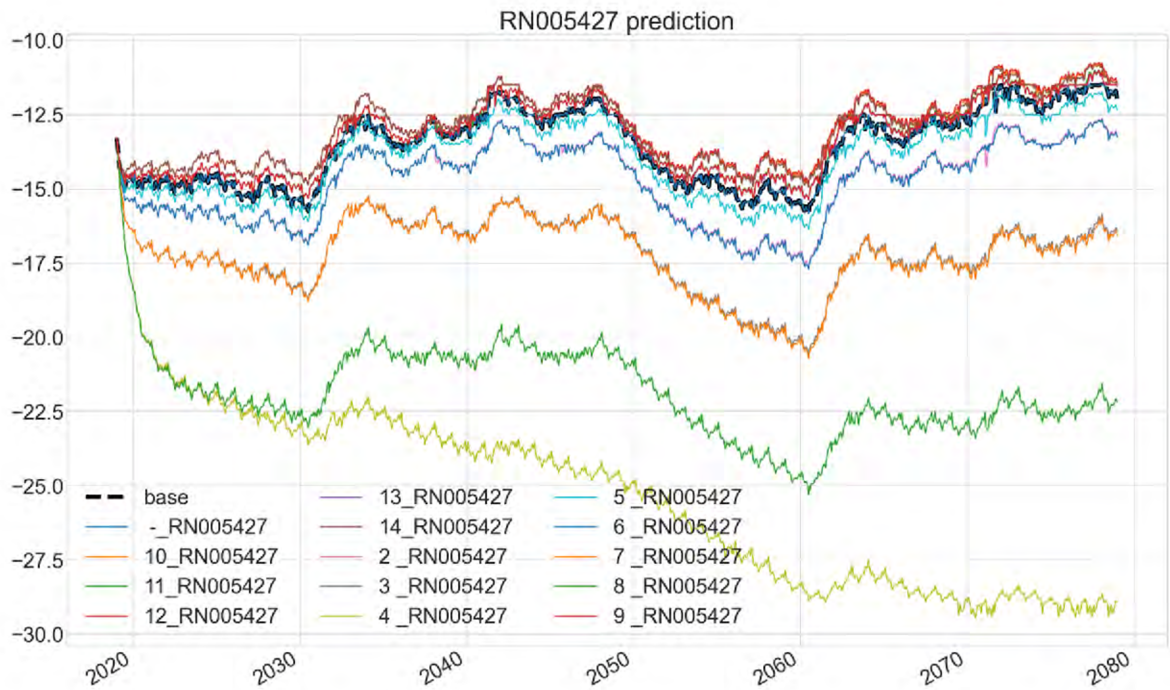
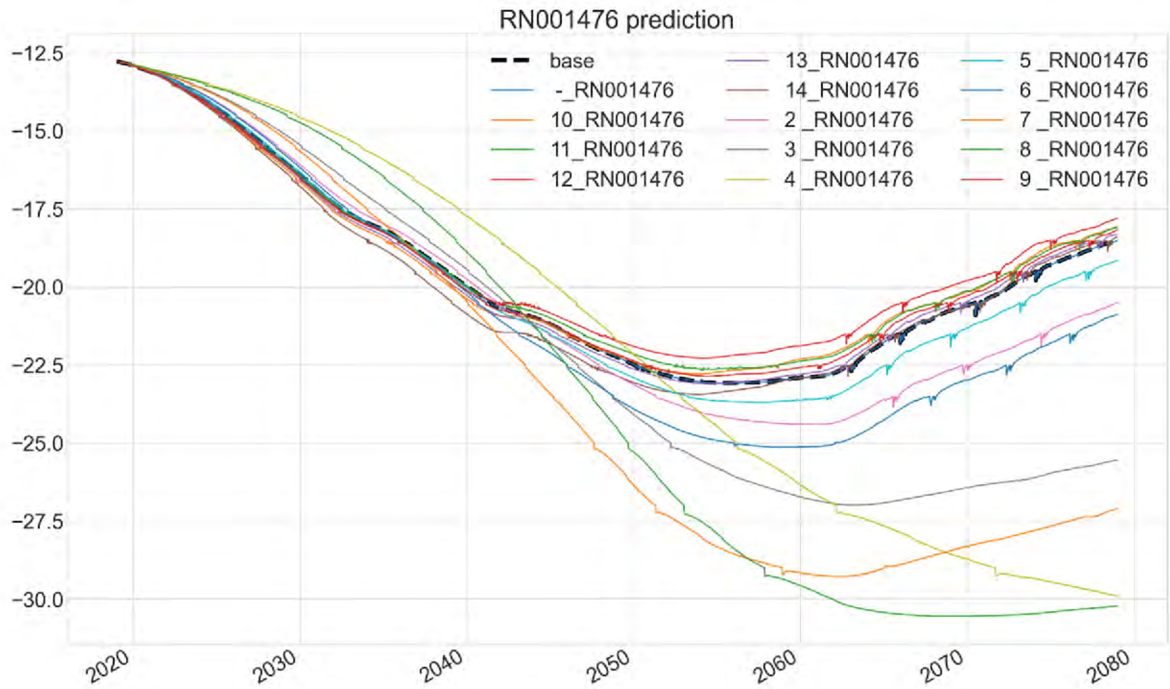
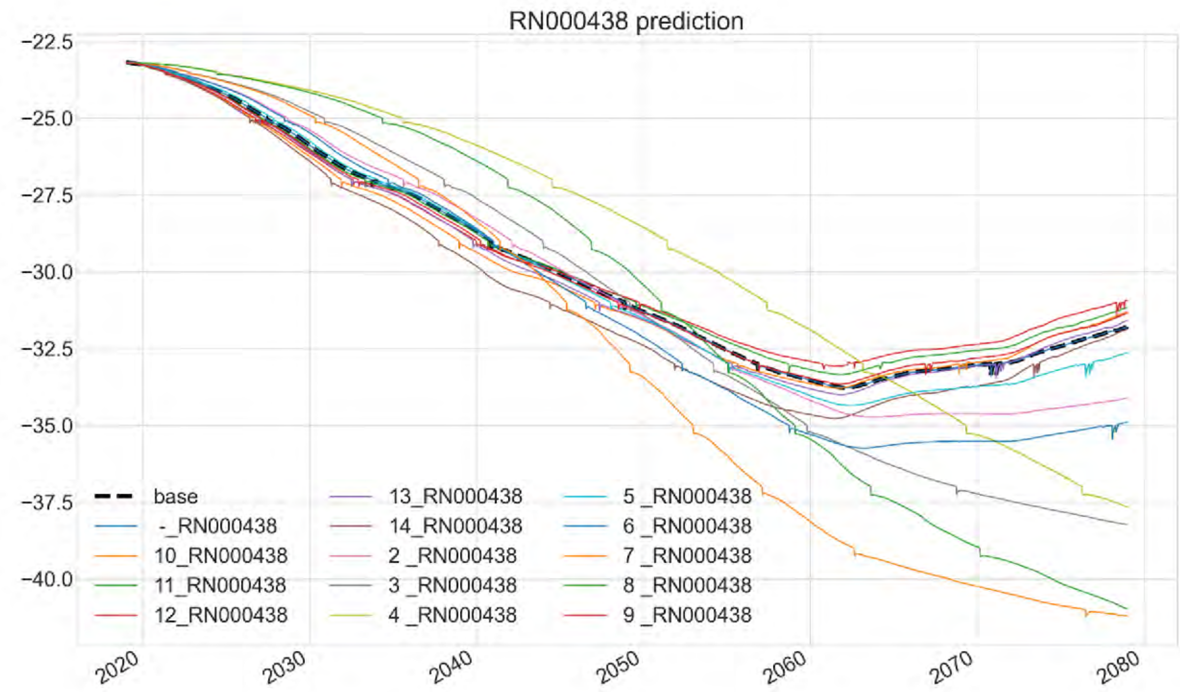
2080

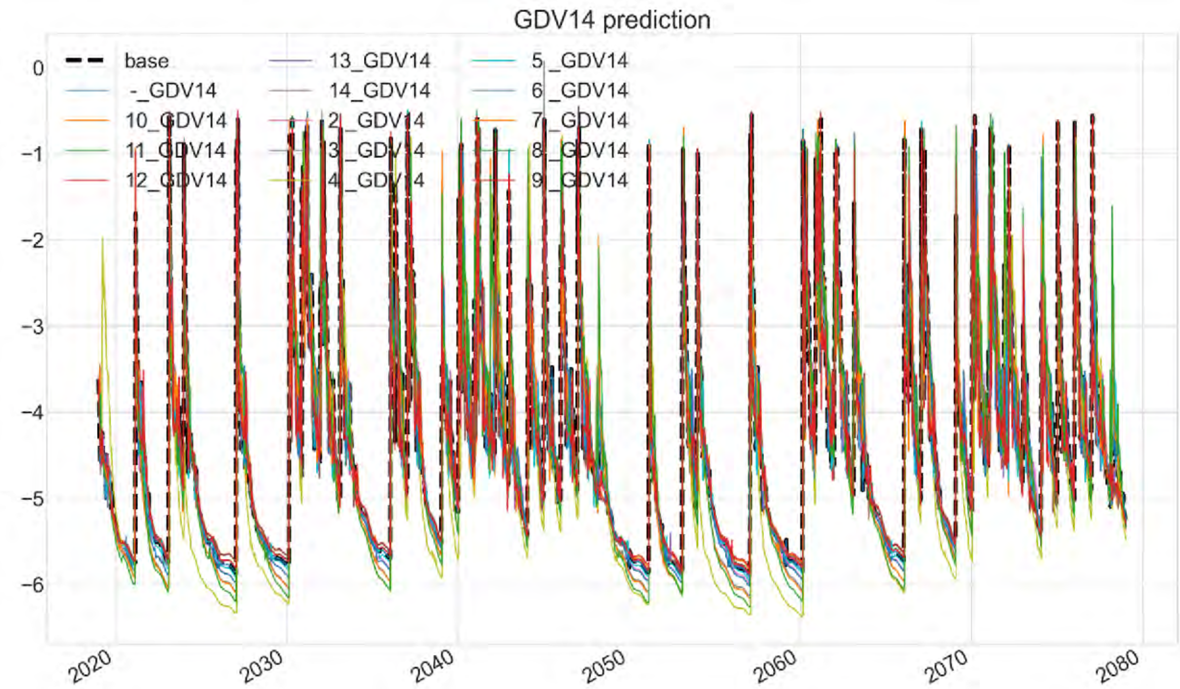


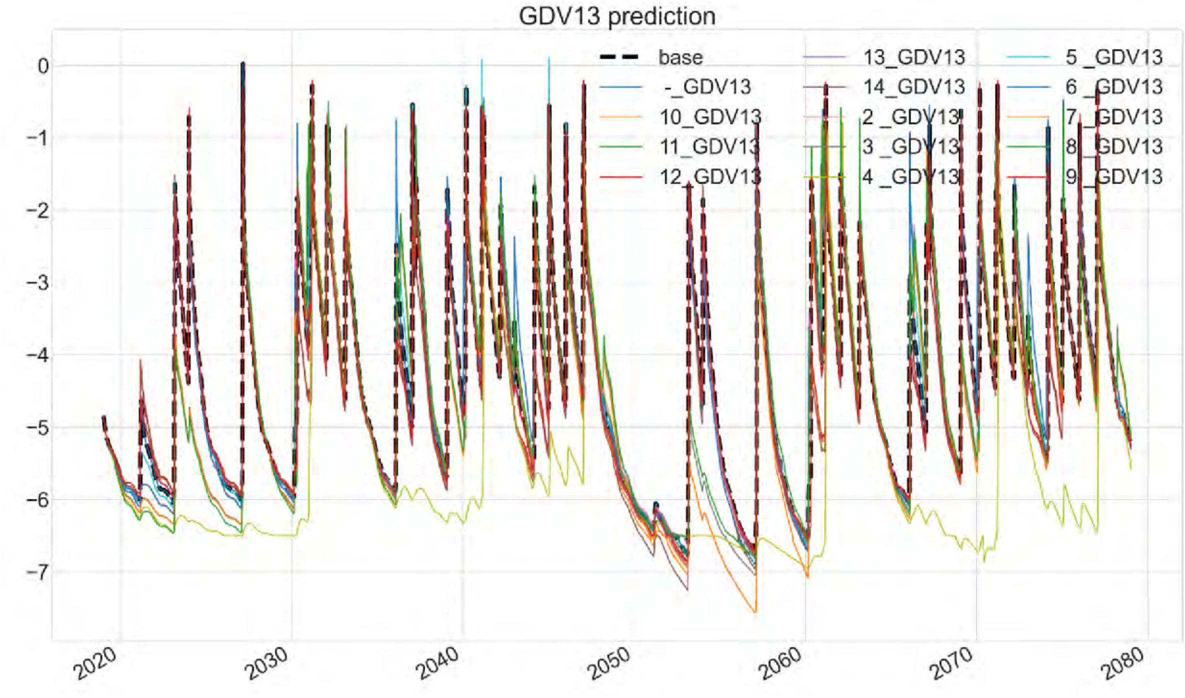
RN005427 prediction
−10.0
−12.5
−15.0
−17.5
−20.0
−22.5
−25.0
−27.5
−30.0
2020
2030
2040
2050
2060
2070
2080
base
-_RN005427
10_RN005427
11_RN005427
12_RN005427
13_RN005427
14_RN005427
2 _RN005427
3 _RN005427
4 _RN005427
5 _RN005427
6 _RN005427
7 _RN005427
8 _RN005427
9 _RN005427

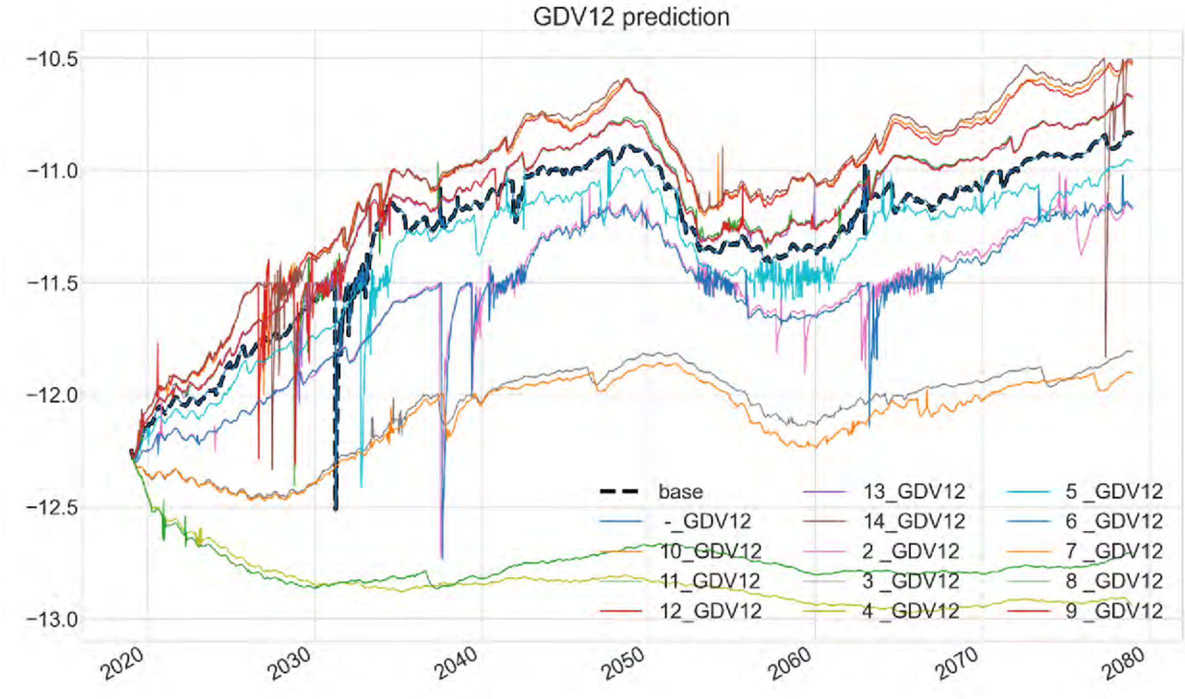


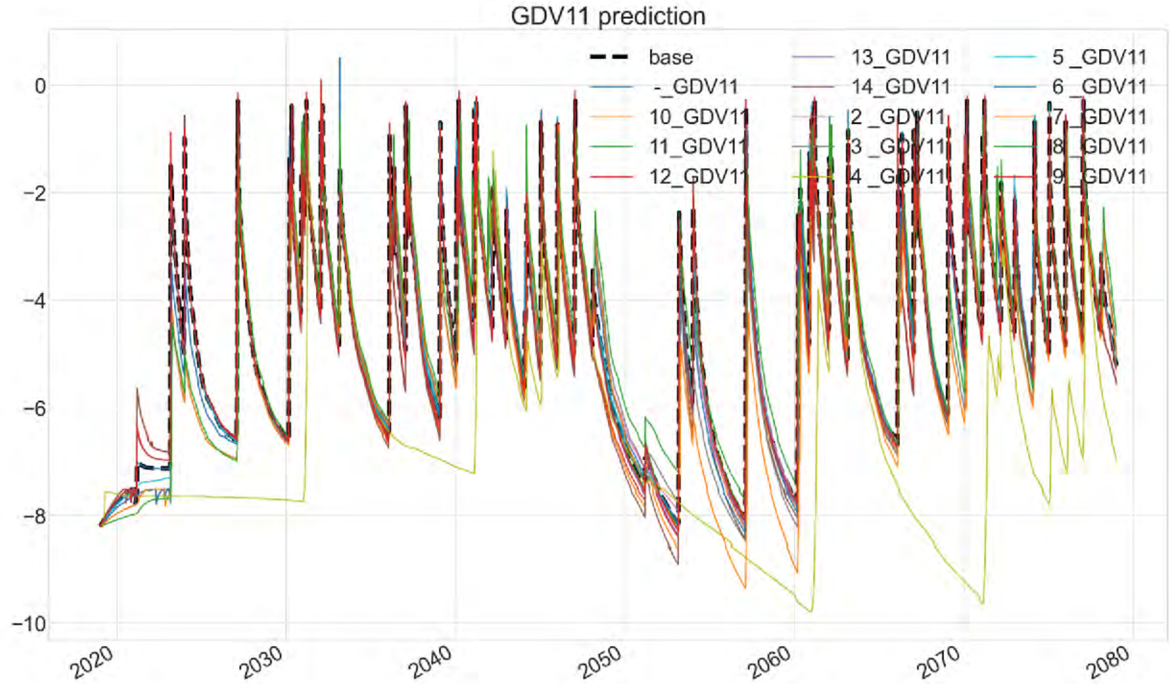
RN001476 prediction
−12.5
−15.0
−17.5
−20.0
−22.5
−25.0
−27.5
−30.0
2020
2030
2040
2050
2060
2070
2080
base
-_RN001476
10_RN001476
11_RN001476
12_RN001476
13_RN001476
14_RN001476
2 _RN001476
3 _RN001476
4 _RN001476
5 _RN001476
6 _RN001476
7 _RN001476
8 _RN001476
9 _RN001476

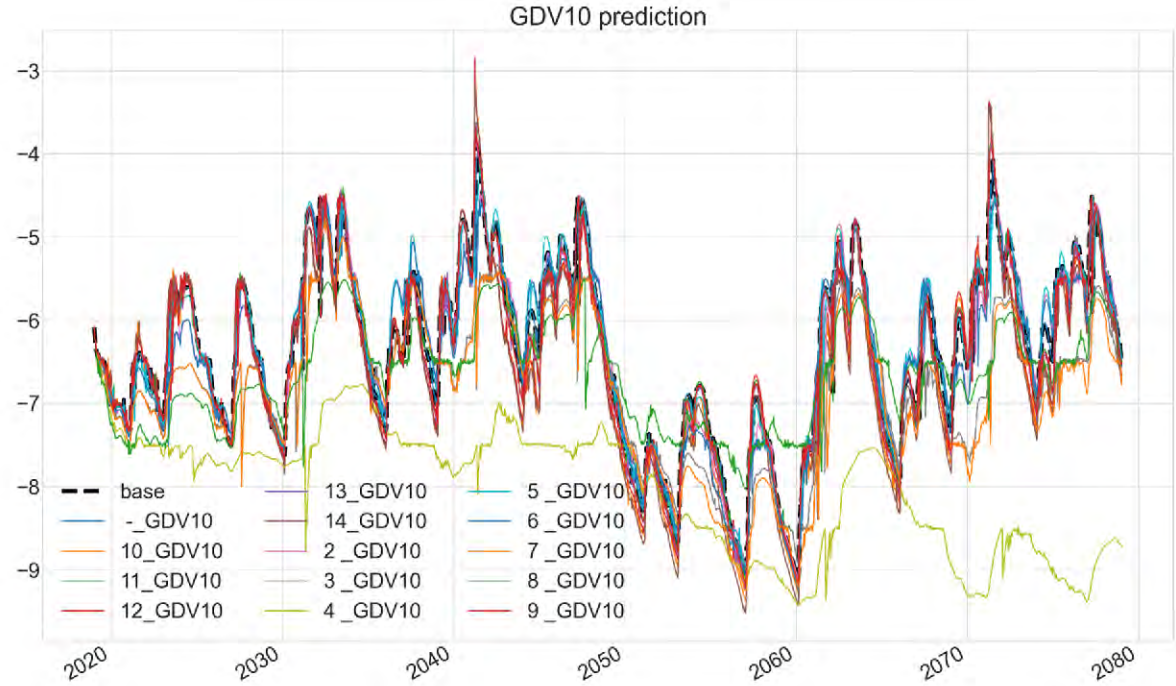

RN000438 prediction
−22.5
−25.0
−27.5
−30.0
−32.5
−35.0
−37.5
−40.0
base
-_RN000438
10_RN000438
11_RN000438
12_RN000438
13_RN000438
14_RN000438
2 _RN000438
3 _RN000438
4 _RN000438
5 _RN000438
6 _RN000438
7 _RN000438
8 _RN000438
9 _RN000438
2020
2030
2040
2050
2060
2070
2080

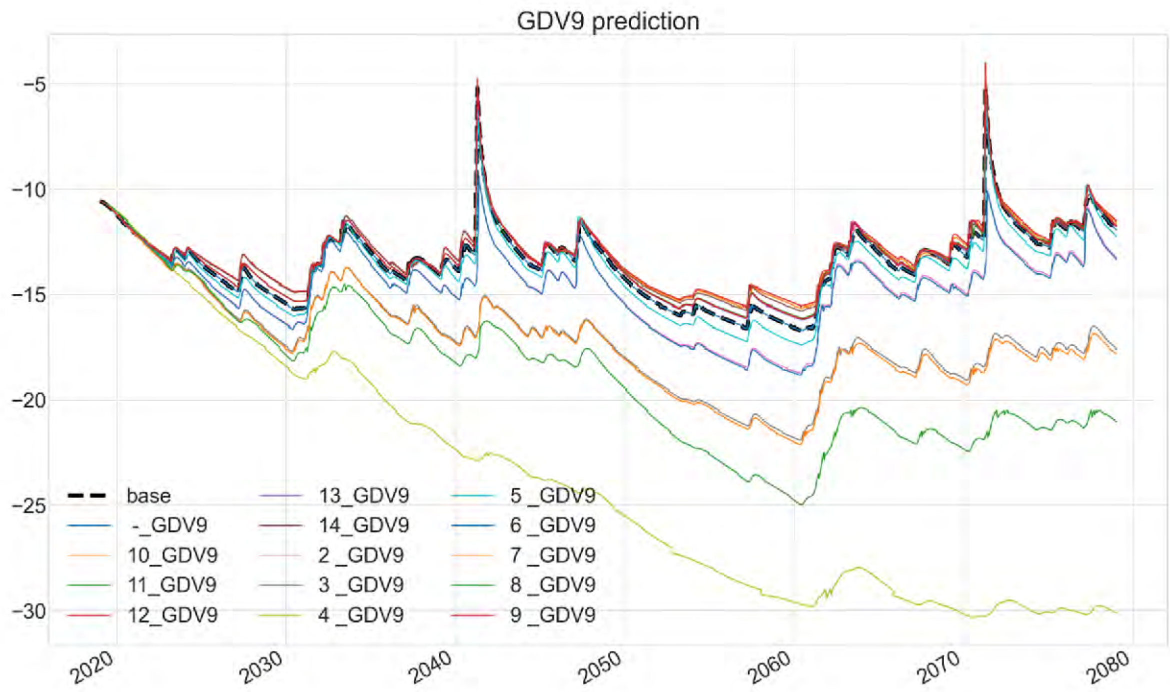

GDV14 prediction
0
−1
−2
−3
−4
−5
−6
base
-_GDV14
10_GDV14
11_GDV14
12_GDV14
13_GDV14
14_GDV14
2 _GDV14
3 _GDV14
4 _GDV14
5 _GDV14
6 _GDV14
7 _GDV14
8 _GDV14
9 _GDV14
2020
2030
2040
2050
2060
2070
2080

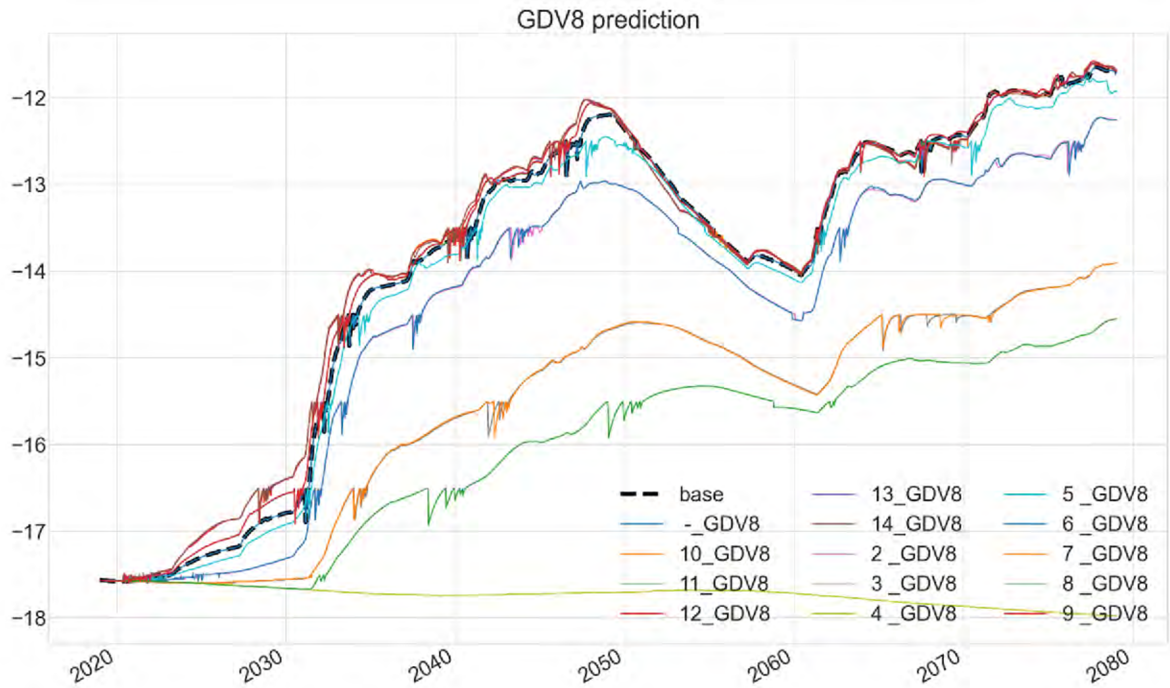

GDV13 prediction
base
-_GDV13
10_GDV13
11_GDV13
12_GDV13
13_GDV13
14_GDV13
2 _GDV13
3 _GDV13
4 _GDV13
5 _GDV13
6 _GDV13
7 _GDV13
8 _GDV13
9 _GDV13
0
−1
−2
−3
−4
−5
−6
−7
2020
2030
2040
2050
2060
2070
2080

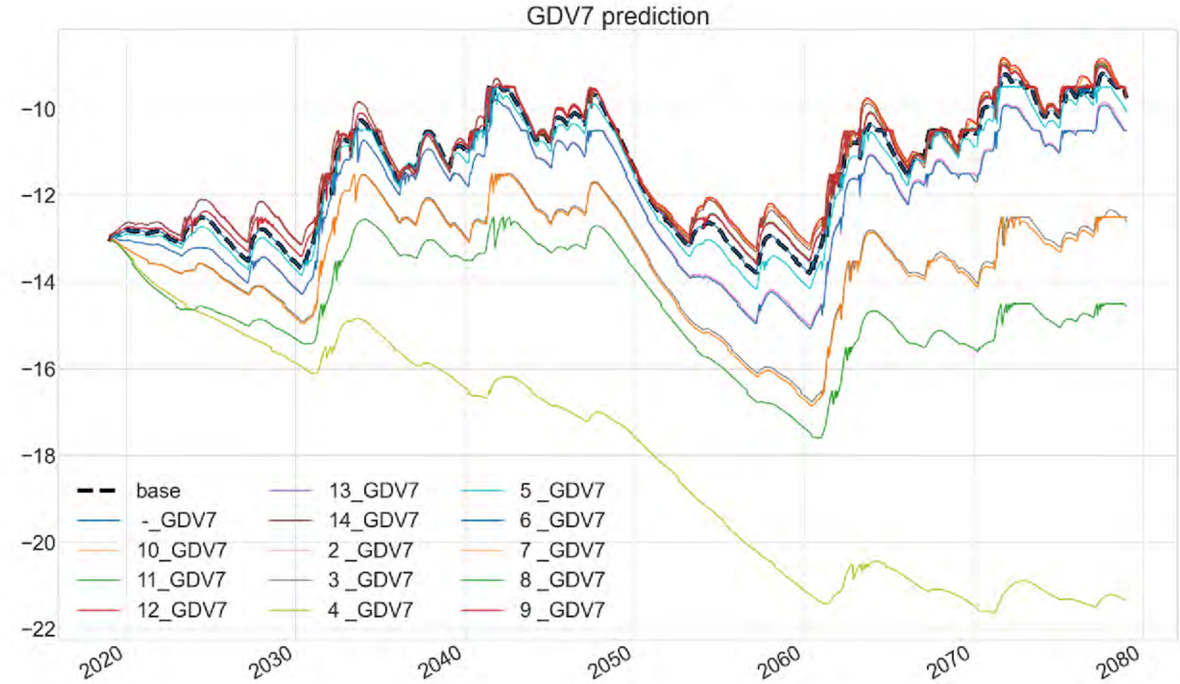

GDV12 prediction
base
-_GDV12
10_GDV12
11_GDV12
12_GDV12
13_GDV12
14_GDV12
2 _GDV12
3 _GDV12
4 _GDV12
5 _GDV12
6 _GDV12
7 _GDV12
8 _GDV12
9 _GDV12
−10.5
−11.0
−11.5
−12.0
−12.5
−13.0
2020
2030
2040
2050
2060
2070
2080

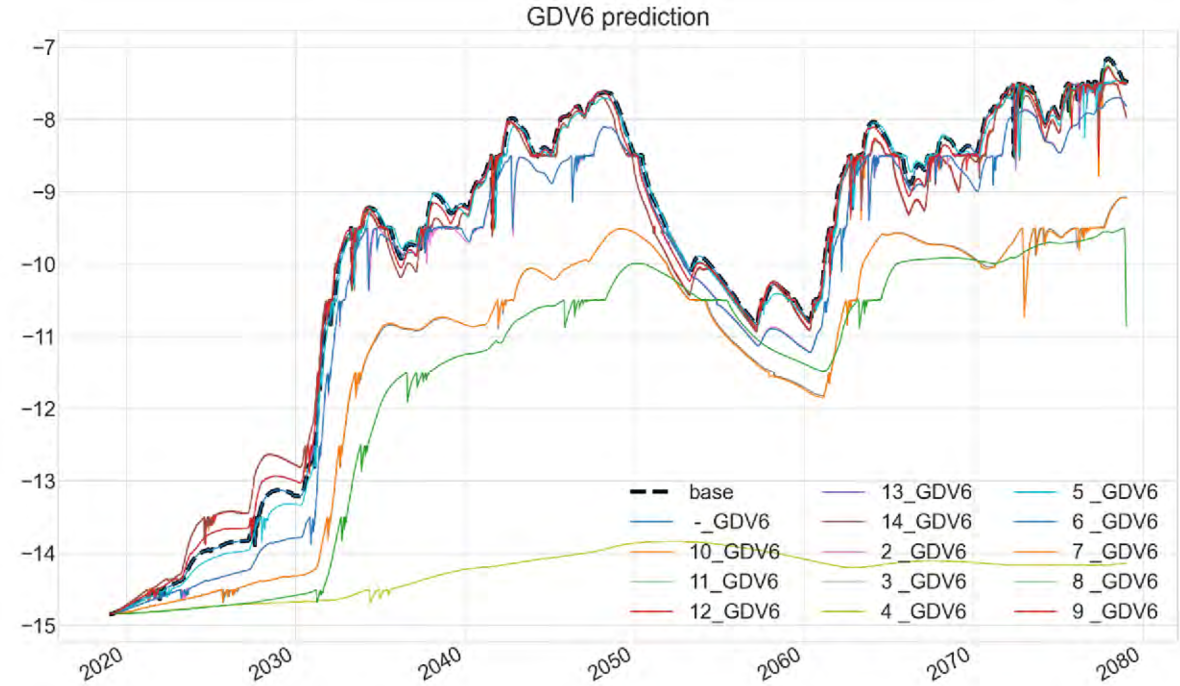

GDV11 prediction
base
-_GDV11
10_GDV11
11_GDV11
12_GDV11
13_GDV11
14_GDV11
2 _GDV11
3 _GDV11
4 _GDV11
5 _GDV11
6 _GDV11
7 _GDV11
8 _GDV11
9 _GDV11
0
−2
−4
−6
−8
−10
2020
2030
2040
2050
2060
2070
2080

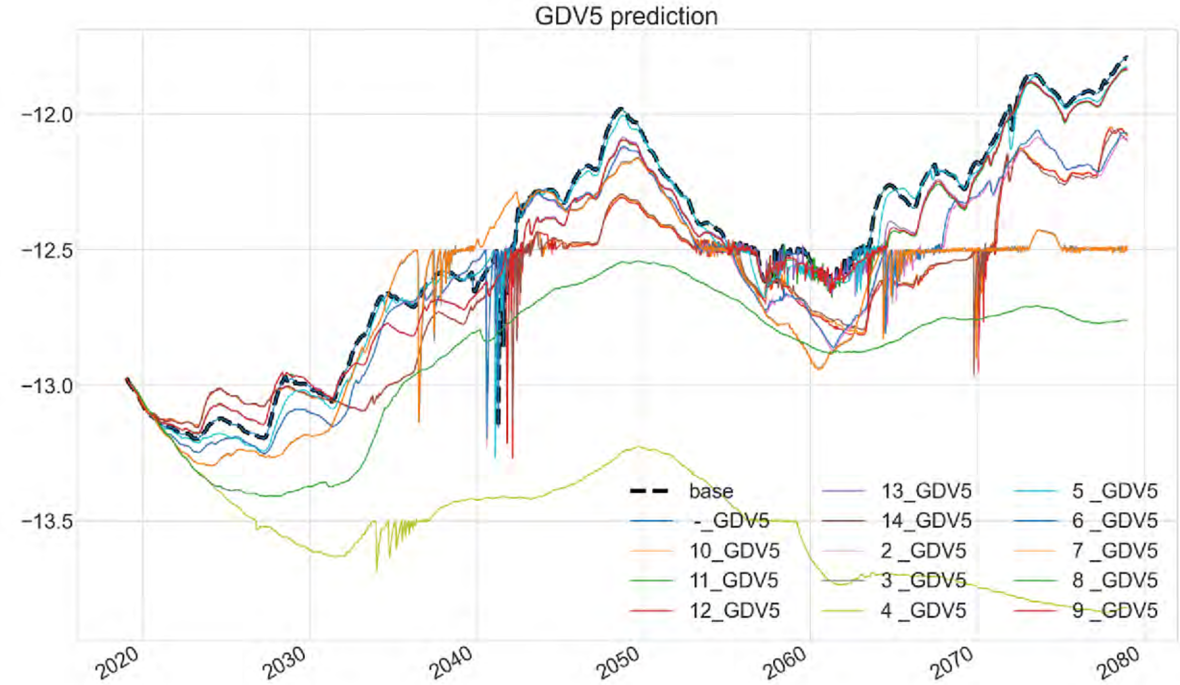

GDV10 prediction
base
-_GDV10
10_GDV10
11_GDV10
12_GDV10
13_GDV10
14_GDV10
2 _GDV10
3 _GDV10
4 _GDV10
5 _GDV10
6 _GDV10
7 _GDV10
8 _GDV10
9 _GDV10
−3
−4
−5
−6
−7
−8
−9
2020
2030
2040
2050
2060
2070
2080

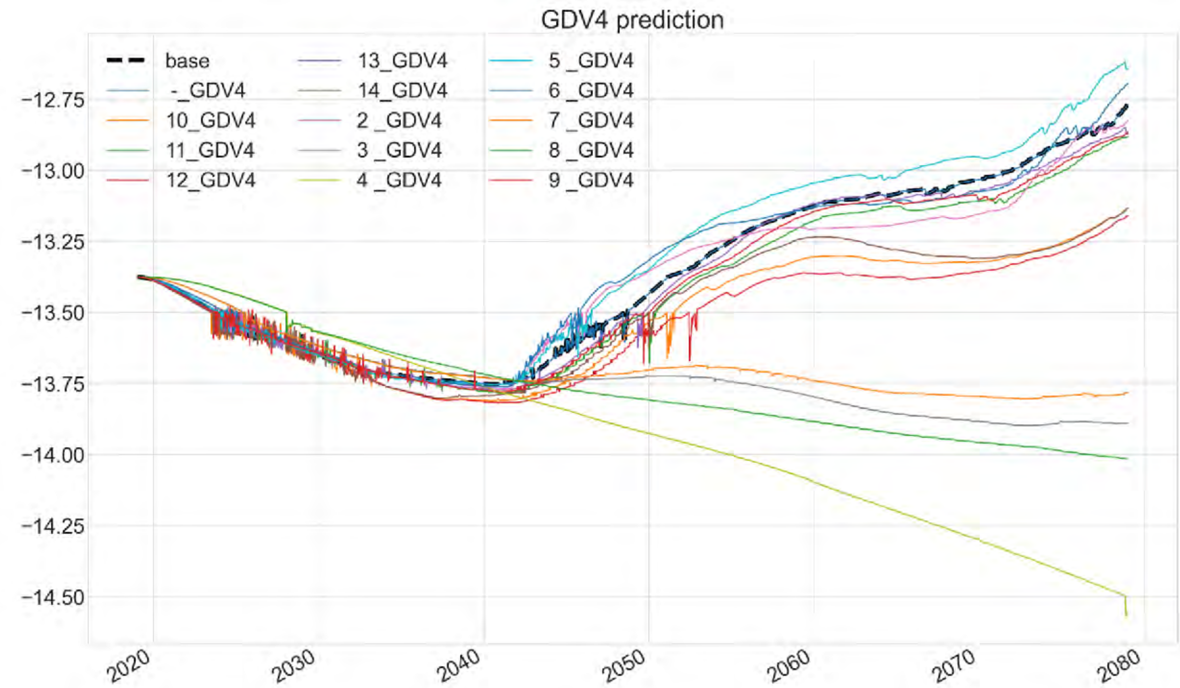

GDV9 prediction
−5
−10
−15
−20
−25
−30
2020
2030
2040
2050
2060
2070
2080
base
-_GDV9
10_GDV9
11_GDV9
12_GDV9
13_GDV9
14_GDV9
2 _GDV9
3 _GDV9
4 _GDV9
5 _GDV9
6 _GDV9
7 _GDV9
8 _GDV9
9 _GDV9

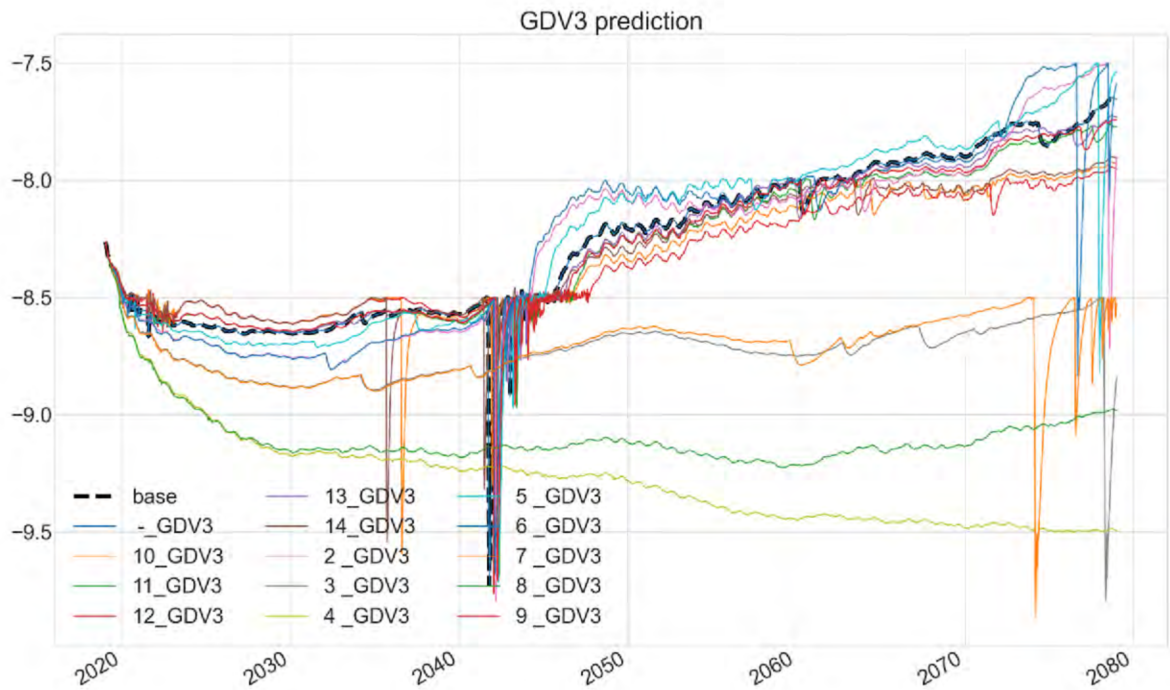

GDV8 prediction
−12
−13
−14
−15
−16
−17
−18
2020
2030
2040
2050
2060
2070
2080
base
-_GDV8
10_GDV8
11_GDV8
12_GDV8
13_GDV8
14_GDV8
2 _GDV8
3 _GDV8
4 _GDV8
5 _GDV8
6 _GDV8
7 _GDV8
8 _GDV8
9 _GDV8

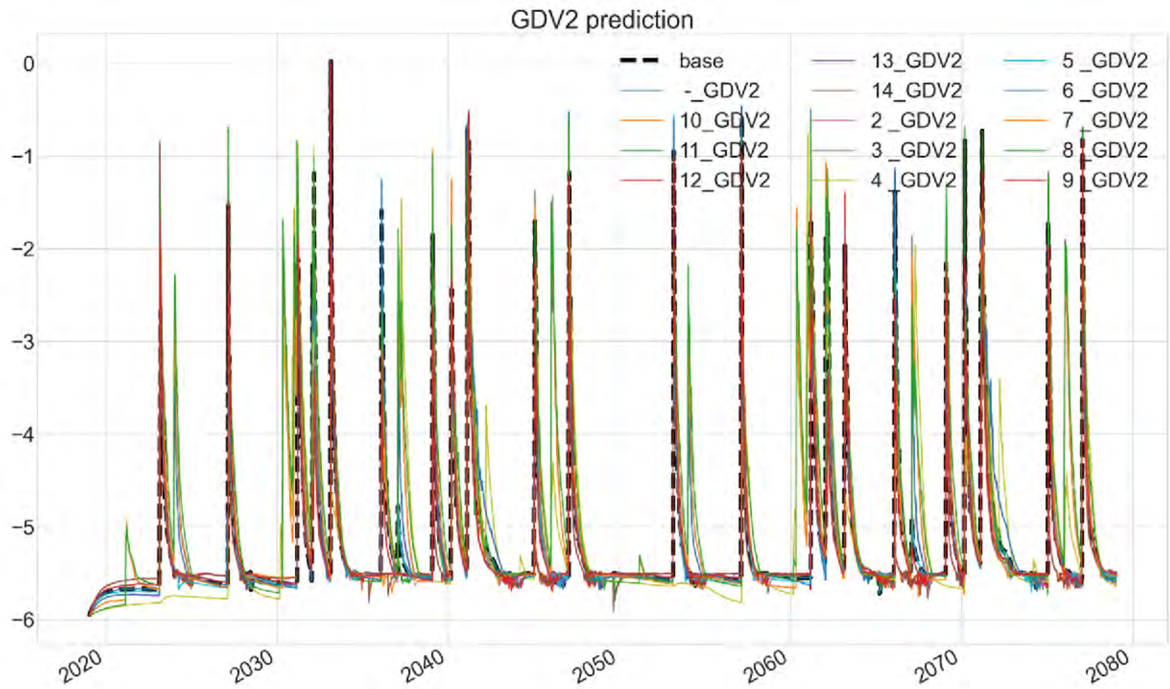

GDV7 prediction
−10
−12
−14
−16
−18
−20
−22
2020
2030
2040
2050
2060
2070
2080
base
-_GDV7
10_GDV7
11_GDV7
12_GDV7
13_GDV7
14_GDV7
2 _GDV7
3 _GDV7
4 _GDV7
5 _GDV7
6 _GDV7
7 _GDV7
8 _GDV7
9 _GDV7

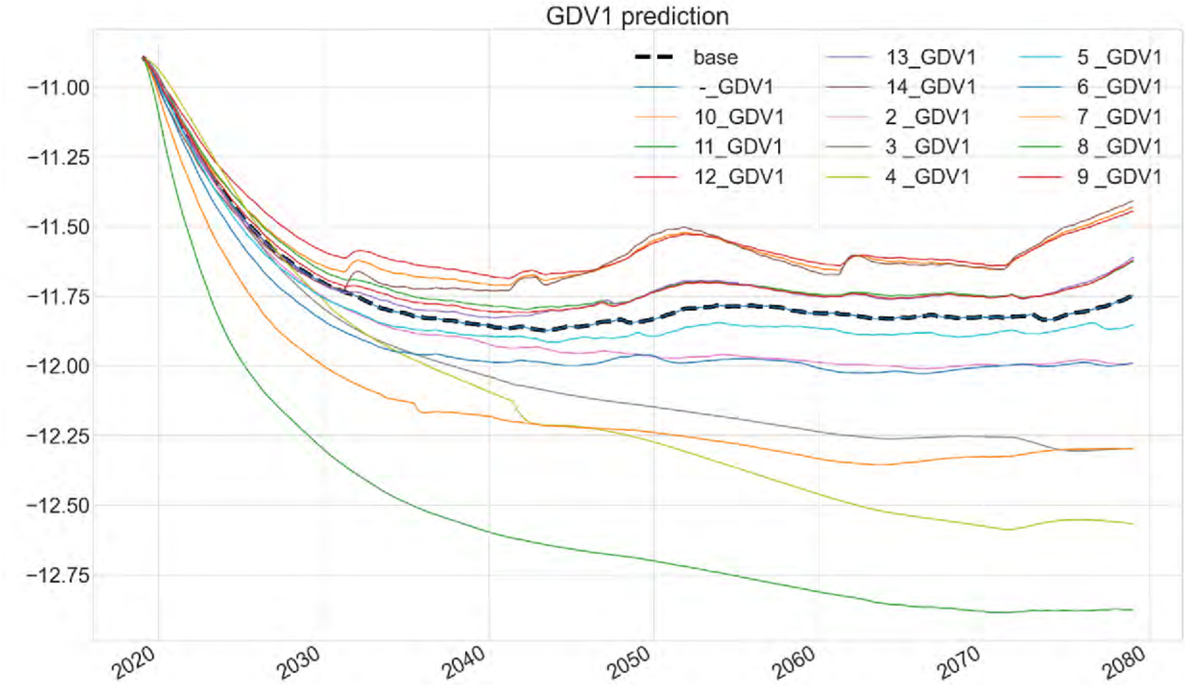

GDV6 prediction
−7
−8
−9
−10
−11
−12
−13
−14
−15
2020
2030
2040
2050
2060
2070
2080
base
-_GDV6
10_GDV6
11_GDV6
12_GDV6
13_GDV6
14_GDV6
2 _GDV6
3 _GDV6
4 _GDV6
5 _GDV6
6 _GDV6
7 _GDV6
8 _GDV6
9 _GDV6


GDV5 prediction
−12.0
−12.5
−13.0
−13.5
2020
2030
2040
2050
2060
2070
2080
base
-_GDV5
10_GDV5
11_GDV5
12_GDV5
13_GDV5
14_GDV5
2 _GDV5
3 _GDV5
4 _GDV5
5 _GDV5
6 _GDV5
7 _GDV5
8 _GDV5
9 _GDV5

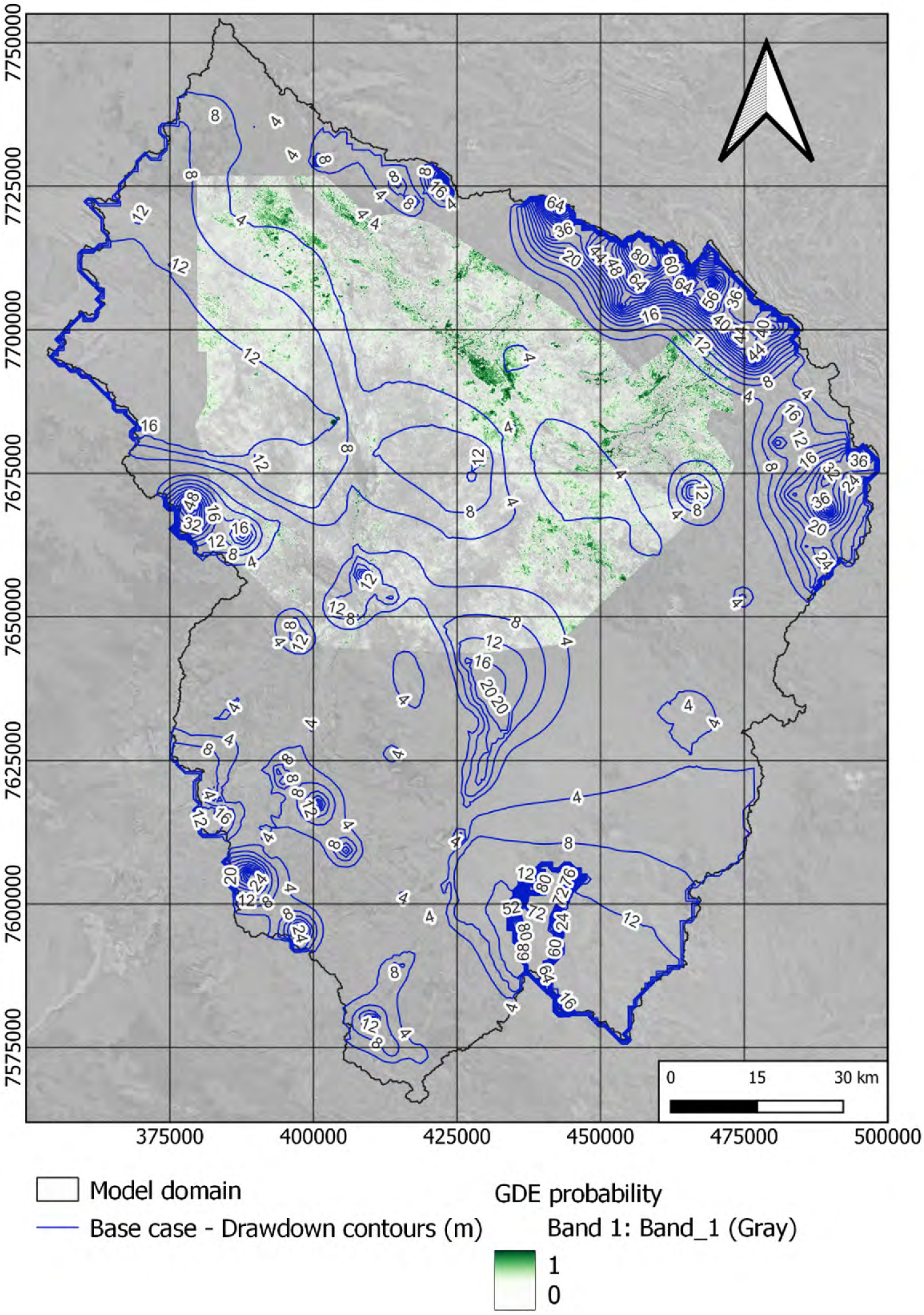

GDV4 prediction
−12.75
−13.00
−13.25
−13.50
−13.75
−14.00
−14.25
−14.50
2020
2030
2040
2050
2060
2070
2080
base
-_GDV4
10_GDV4
11_GDV4
12_GDV4
13_GDV4
14_GDV4
2 _GDV4
3 _GDV4
4 _GDV4
5 _GDV4
6 _GDV4
7 _GDV4
8 _GDV4
9 _GDV4

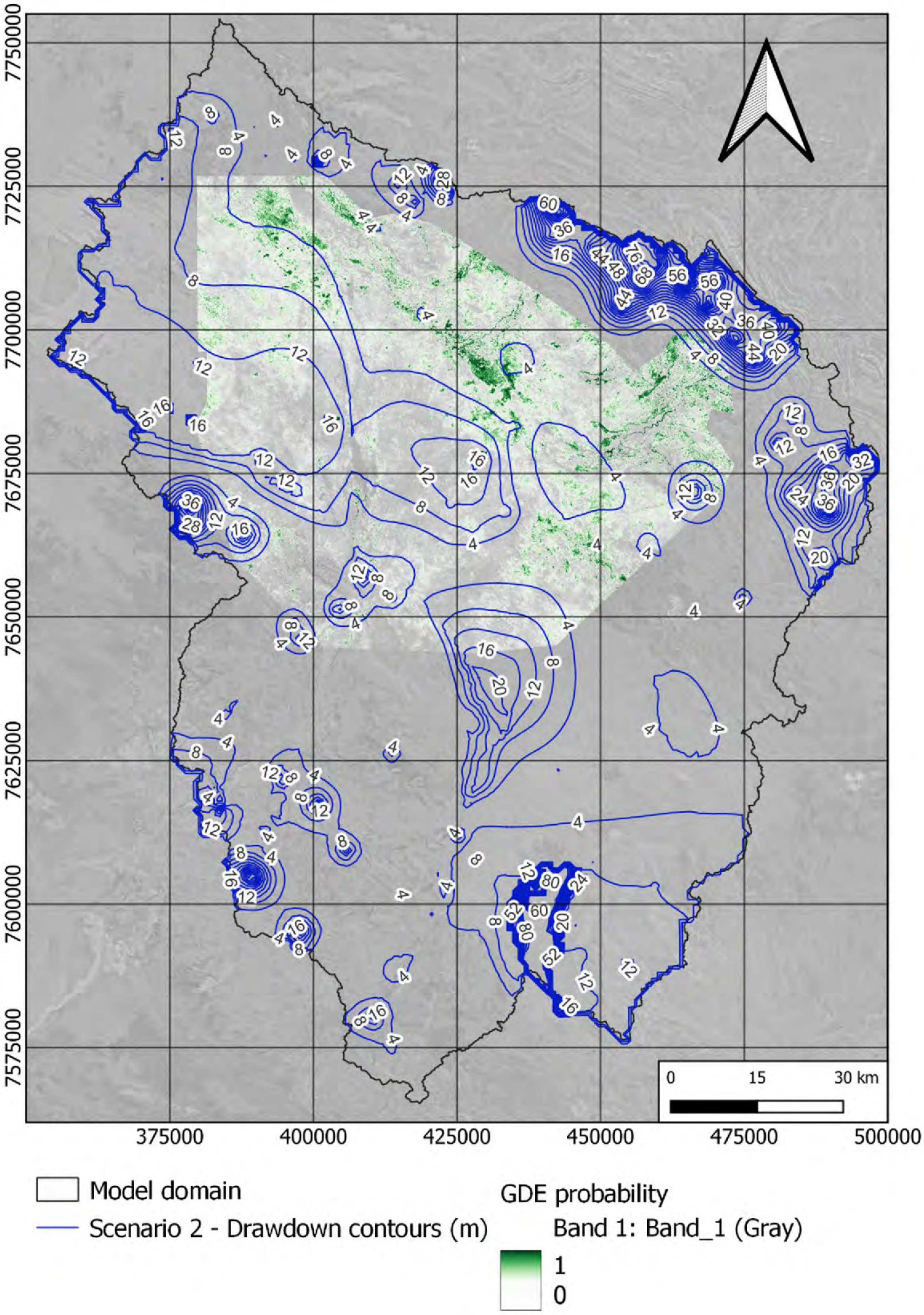

GDV3 prediction
-7.5
-8.0
-8.5
-9.0
-9.5
2020
2030
2040
2050
2060
2070
2080
base
-_GDV3
10_GDV3
11_GDV3
12_GDV3
13_GDV3
14_GDV3
2 _GDV3
3 _GDV3
4 _GDV3
5 _GDV3
6 _GDV3
7 _GDV3
8 _GDV3
9 _GDV3

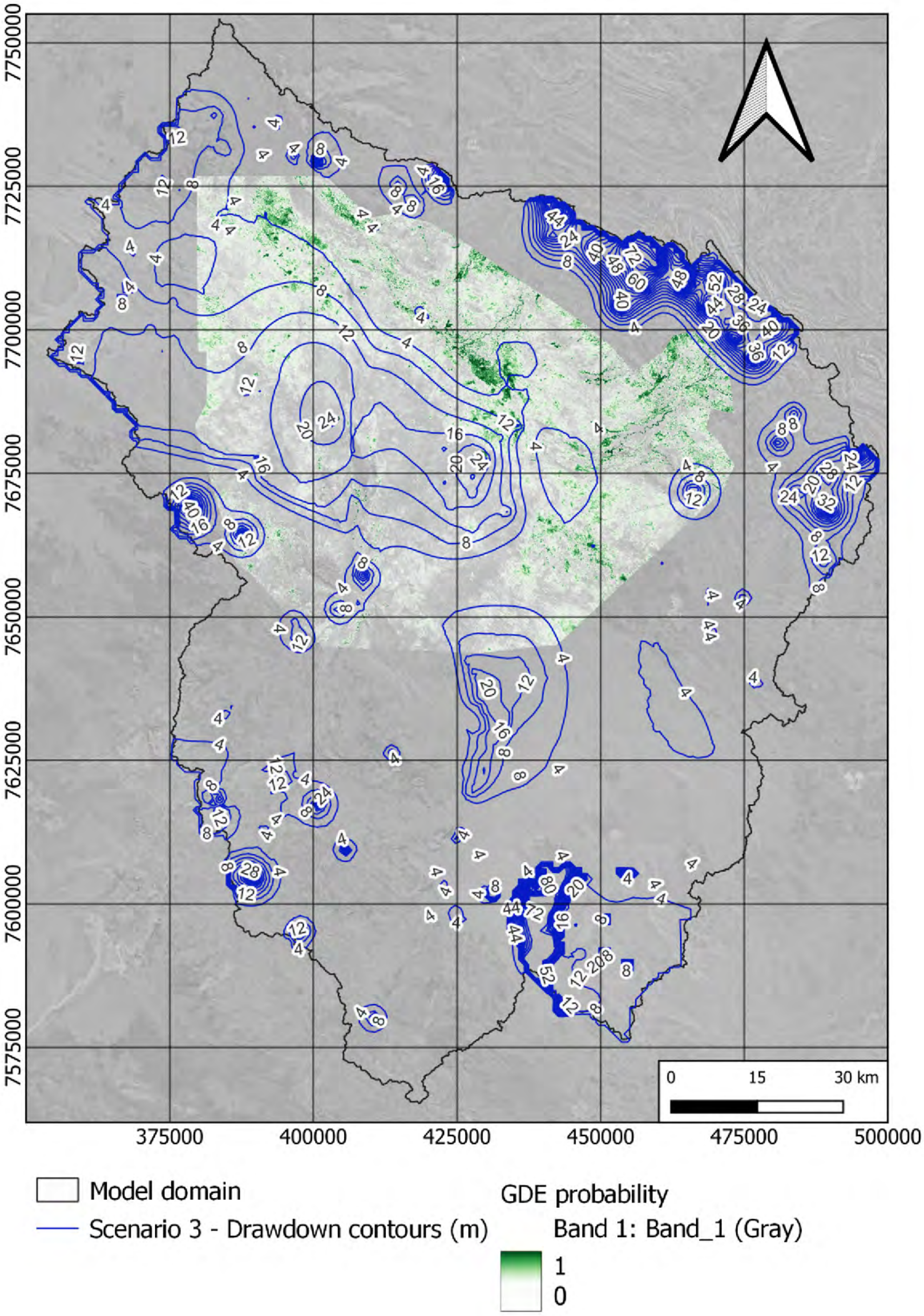

GDV2 prediction
0
-1
-2
-3
-4
-5
-6
2020
2030
2040
2050
2060
2070
2080
base
-_GDV2
10_GDV2
11_GDV2
12_GDV2
13_GDV2
14_GDV2
2 _GDV2
3 _GDV2
4 _GDV2
5 _GDV2
6 _GDV2
7 _GDV2
8 _GDV2
9 _GDV2


GDV1 prediction
base
-_GDV1
10_GDV1
11_GDV1
12_GDV1
13_GDV1
14_GDV1
2 _GDV1
3 _GDV1
4 _GDV1
5 _GDV1
6 _GDV1
7 _GDV1
8 _GDV1
9 _GDV1
−11.00
−11.25
−11.50
−11.75
−12.00
−12.25
−12.50
−12.75
2020
2030
2040
2050
2060
2070
2080

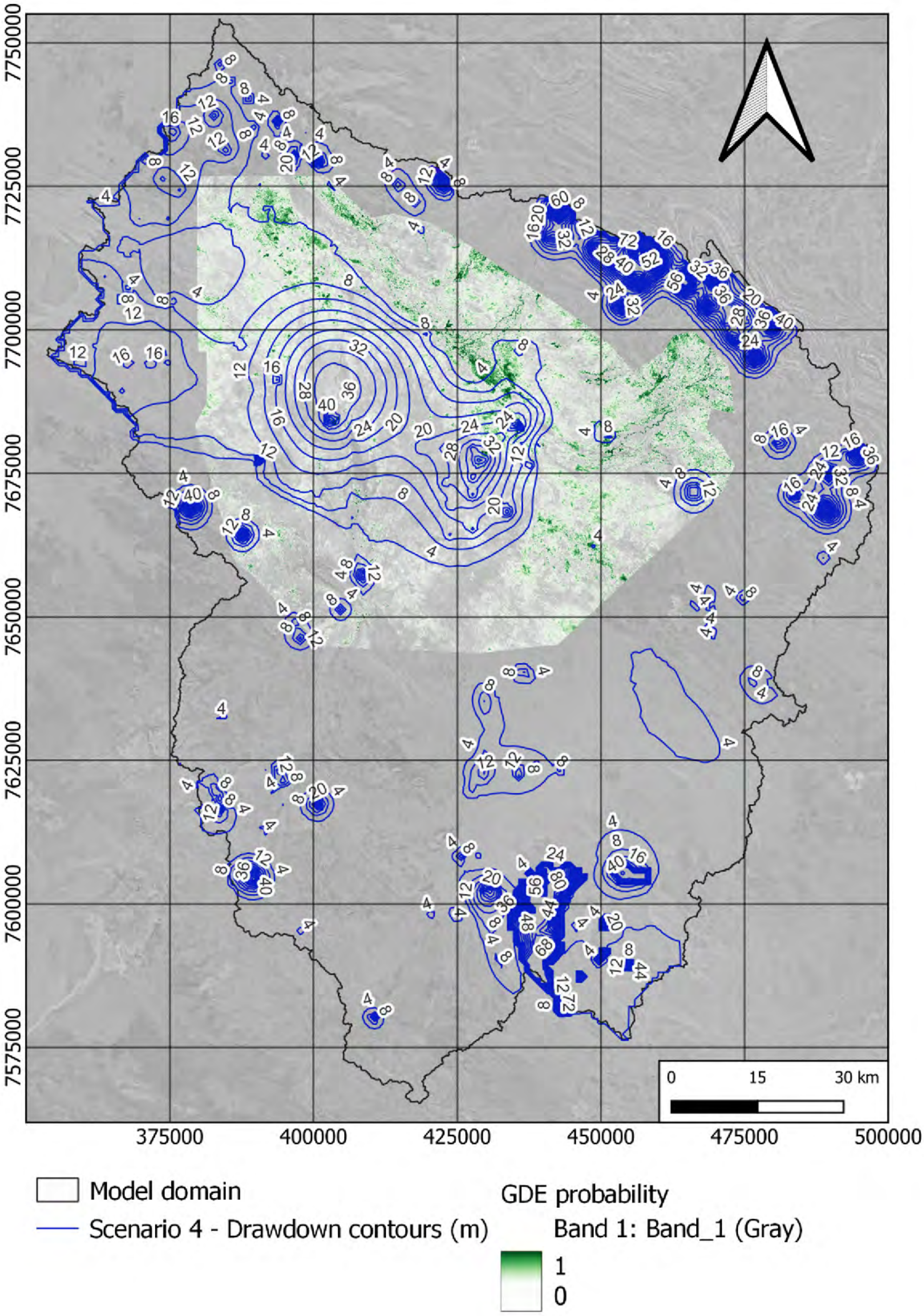
Appendix 3 - PREDICTIVE DRAWDOWN CONTOURS at 2080



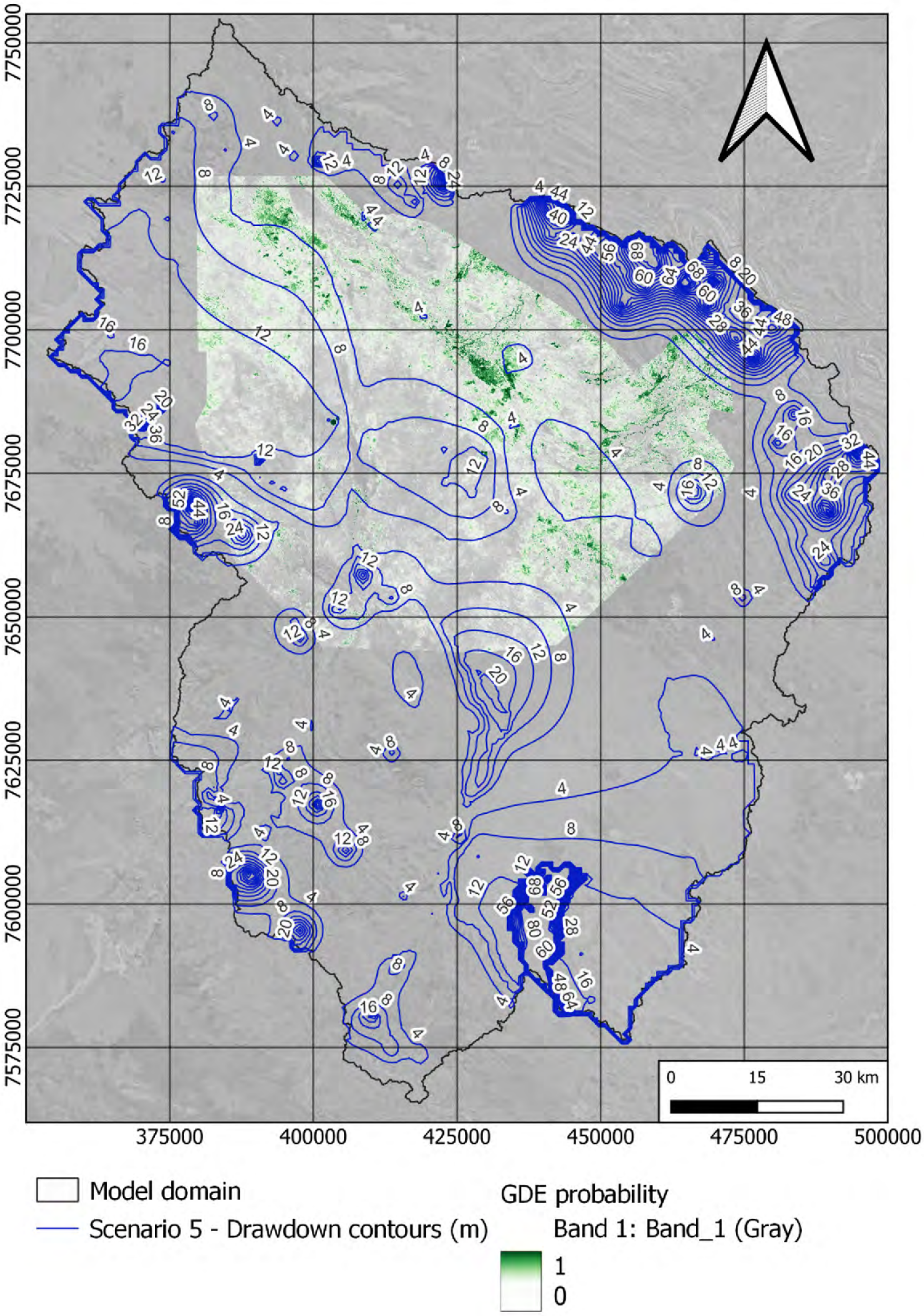

7750000
7725000
7700000
7675000
7650000
7625000
7600000
7575000
375000
400000
425000
450000
475000
500000
0
15
30 km
Model domain
Scenario 2 - Drawdown contours (m)
GDE probability
Band 1: Band_1 (Gray)
1
0

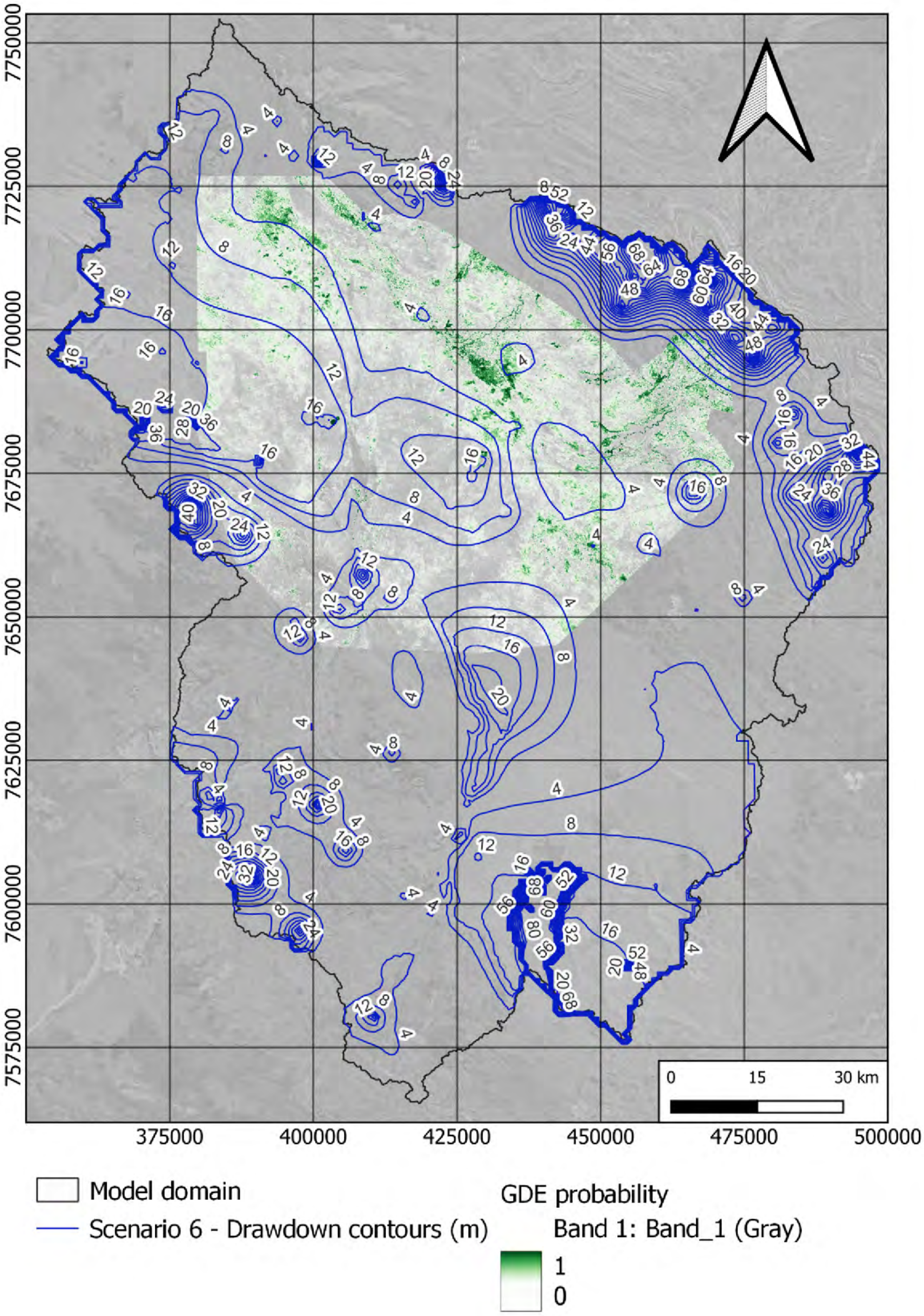


7750000
7725000
7700000
7675000
7650000
7625000
7600000
7575000
375000
400000
425000
450000
475000
500000
0
15
30 km
Model domain
Scenario 3 - Drawdown contours (m)
GDE probability
Band 1: Band_1 (Gray)
1
0

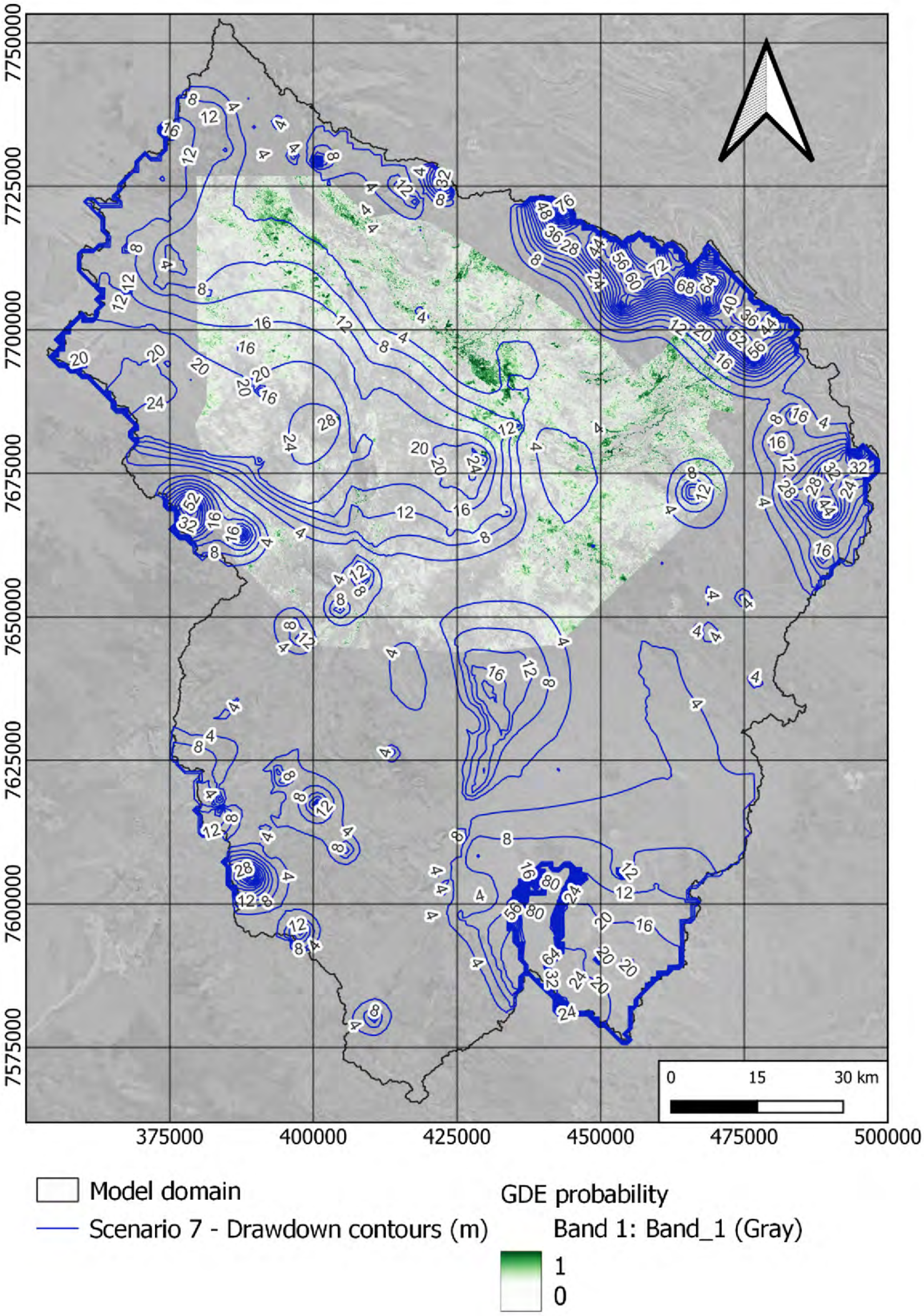


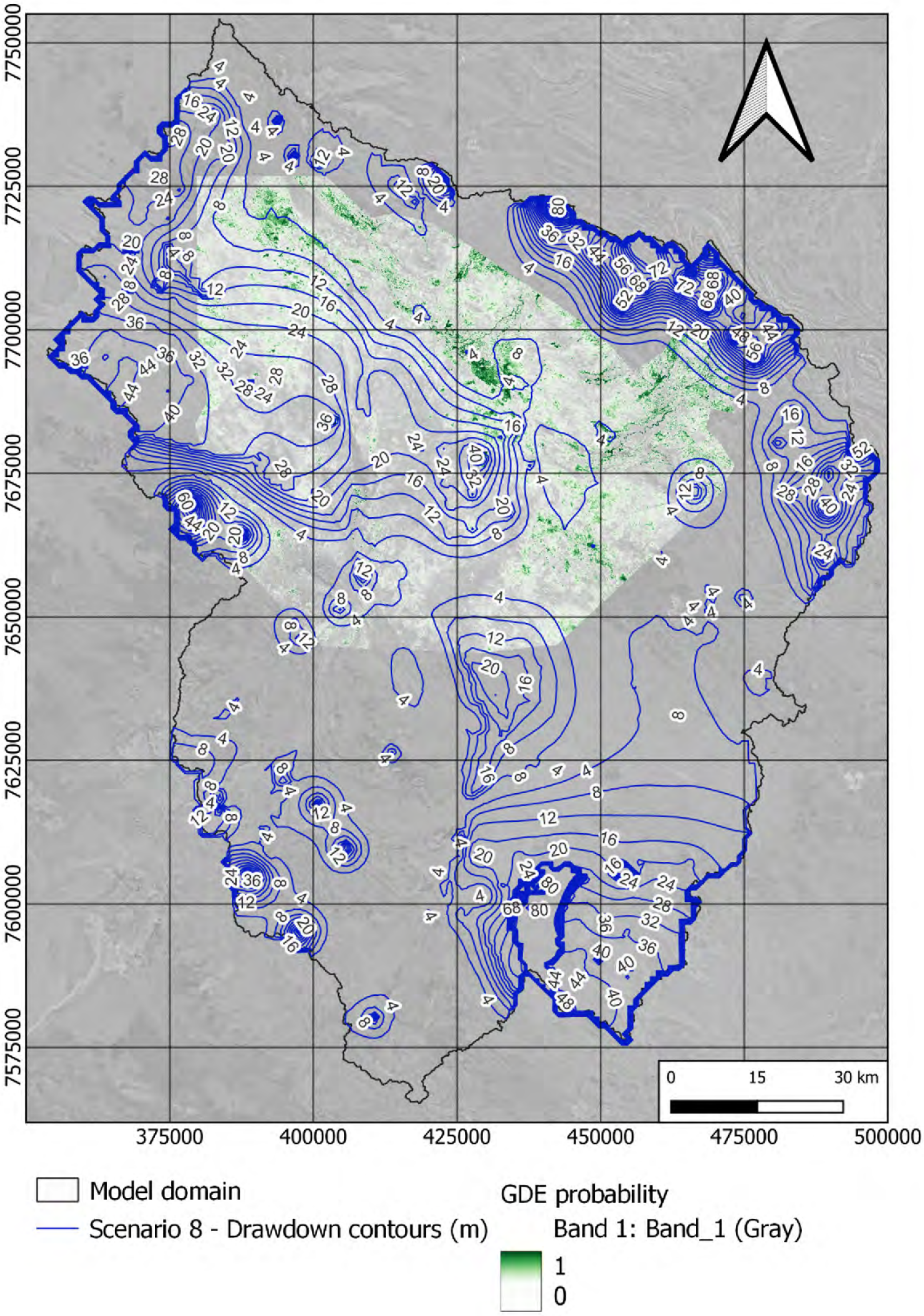
7750000
7725000
7700000
7675000
7650000
7625000
7600000
7575000
375000
400000
425000
450000
475000
500000
0
15
30 km
Model domain
Scenario 4 - Drawdown contours (m)
GDE probability
Band 1: Band_1 (Gray)
1
0

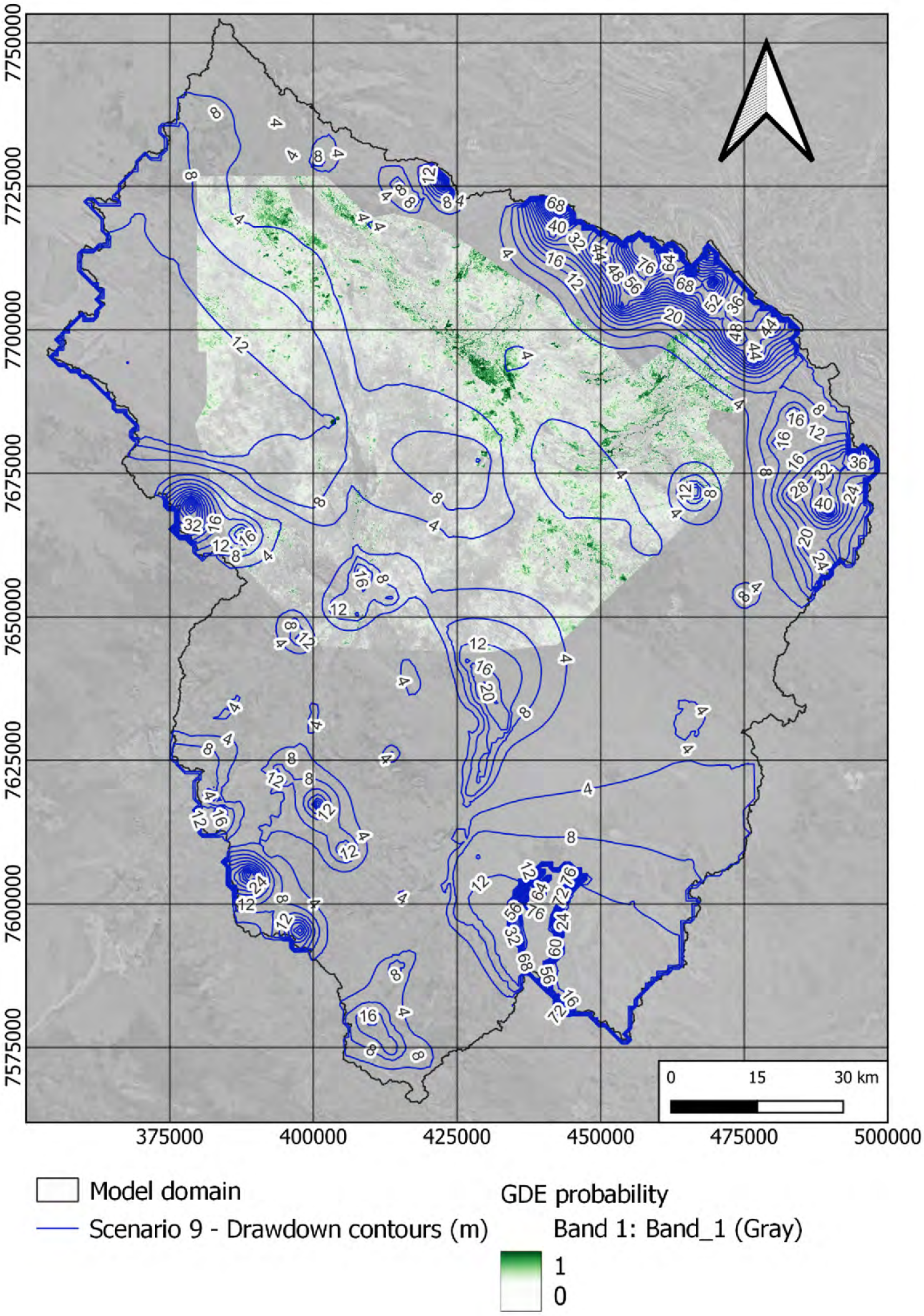

7750000
7725000
7700000
7675000
7650000
7625000
7600000
7575000
375000
400000
425000
450000
475000
500000
0
15
30 km
Model domain
Scenario 5 - Drawdown contours (m)
GDE probability
Band 1: Band_1 (Gray)
1
0

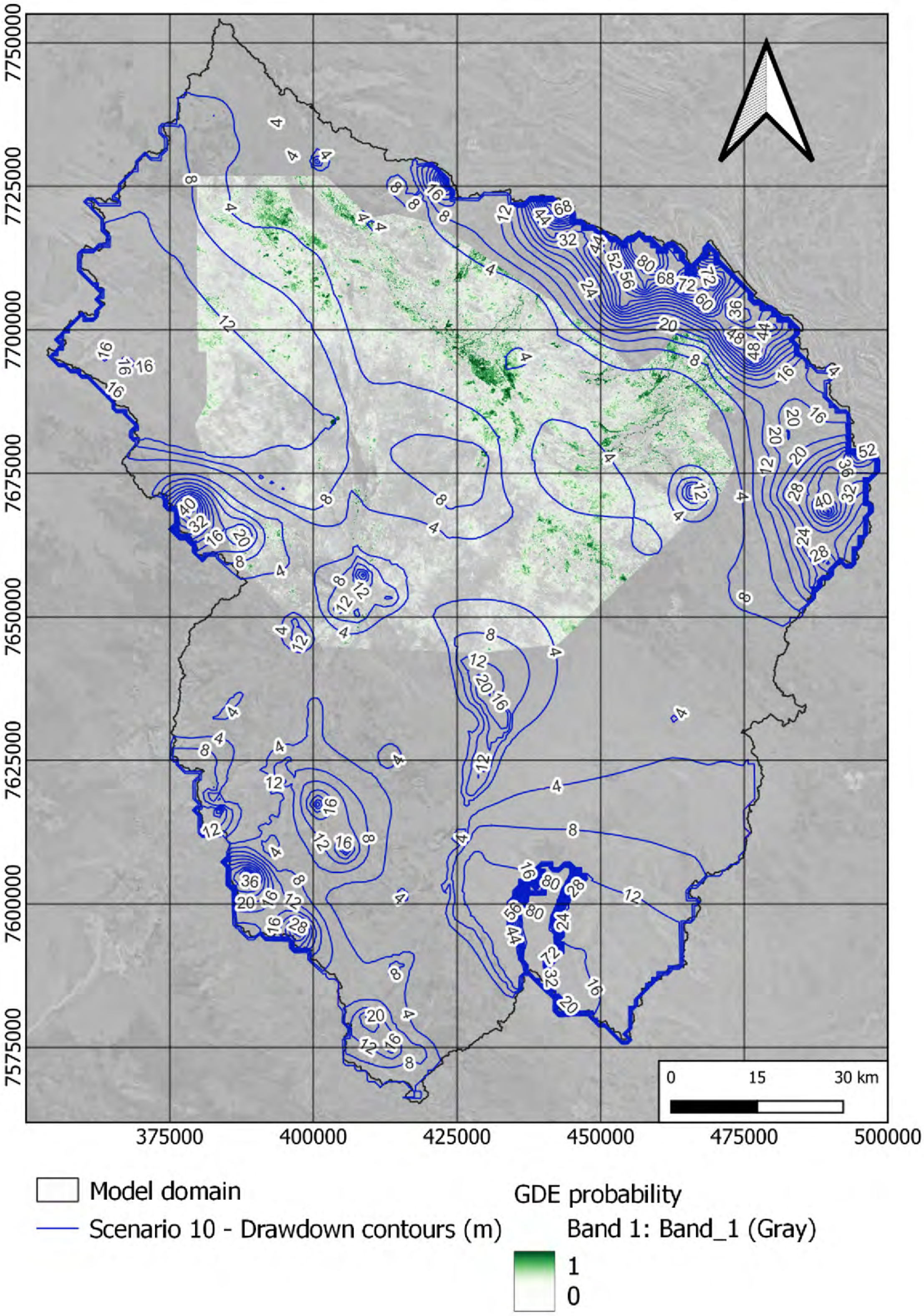


7750000
7725000
7700000
7675000
7650000
7625000
7600000
7575000
375000
400000
425000
450000
475000
500000
0
15
30 km
Model domain
Scenario 6 - Drawdown contours (m)
GDE probability
Band 1: Band_1 (Gray)
1
0


7750000
7725000
7700000
7675000
7650000
7625000
7600000
7575000
375000
400000
425000
450000
475000
500000
0
15
30 km
Model domain
Scenario 7 - Drawdown contours (m)
GDE probability
Band 1: Band_1 (Gray)
1
0


7750000
7725000
7700000
7675000
7650000
7625000
7600000
7575000
375000
400000
425000
450000
475000
500000
0
15
30 km
Model domain
Scenario 8 - Drawdown contours (m)
GDE probability
Band 1: Band_1 (Gray)
1
0


7750000
7725000
7700000
7675000
7650000
7625000
7600000
7575000
375000
400000
425000
450000
475000
500000
0
15
30 km
Model domain
Scenario 9 - Drawdown contours (m)
GDE probability
Band 1: Band_1 (Gray)
1
0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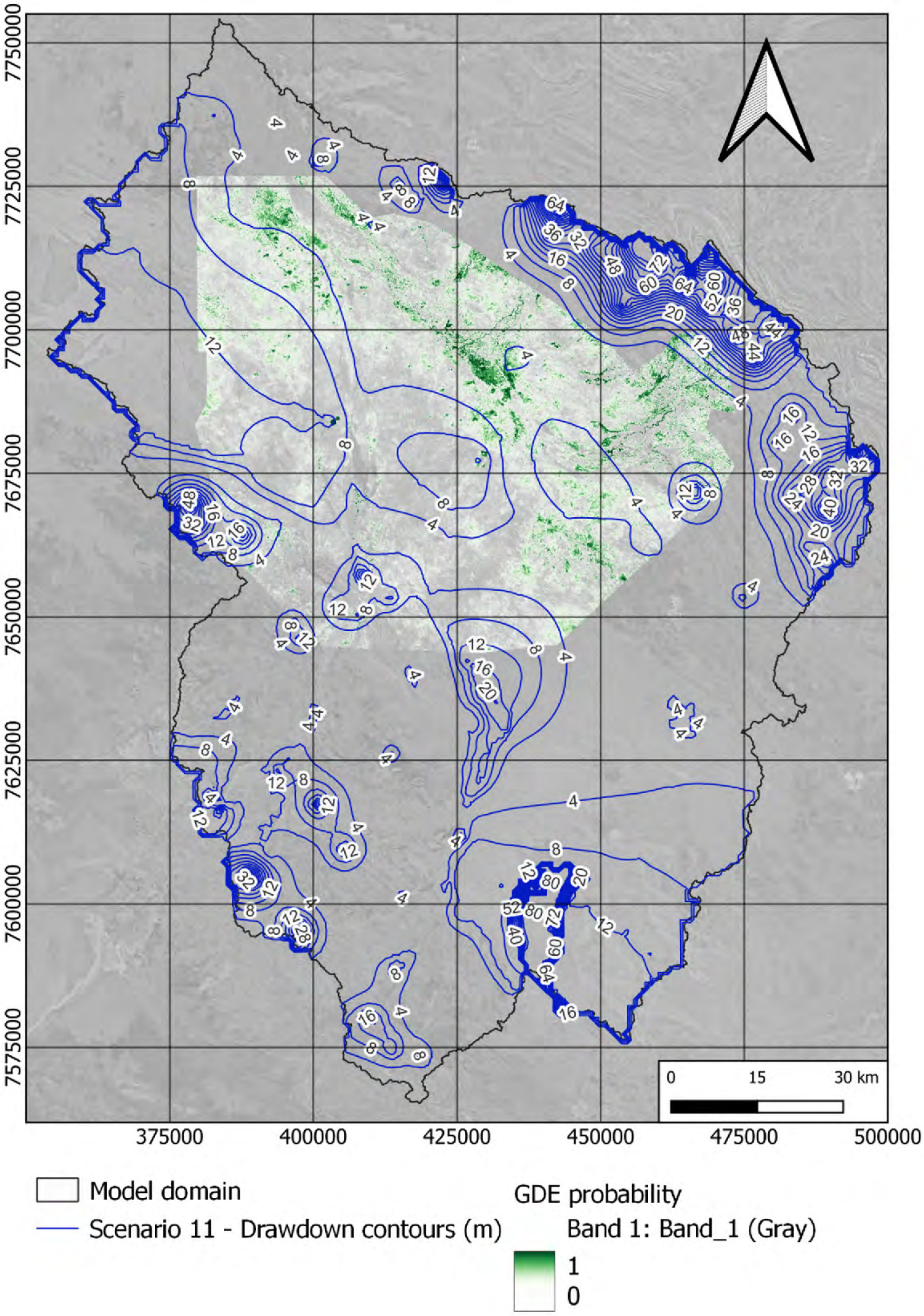
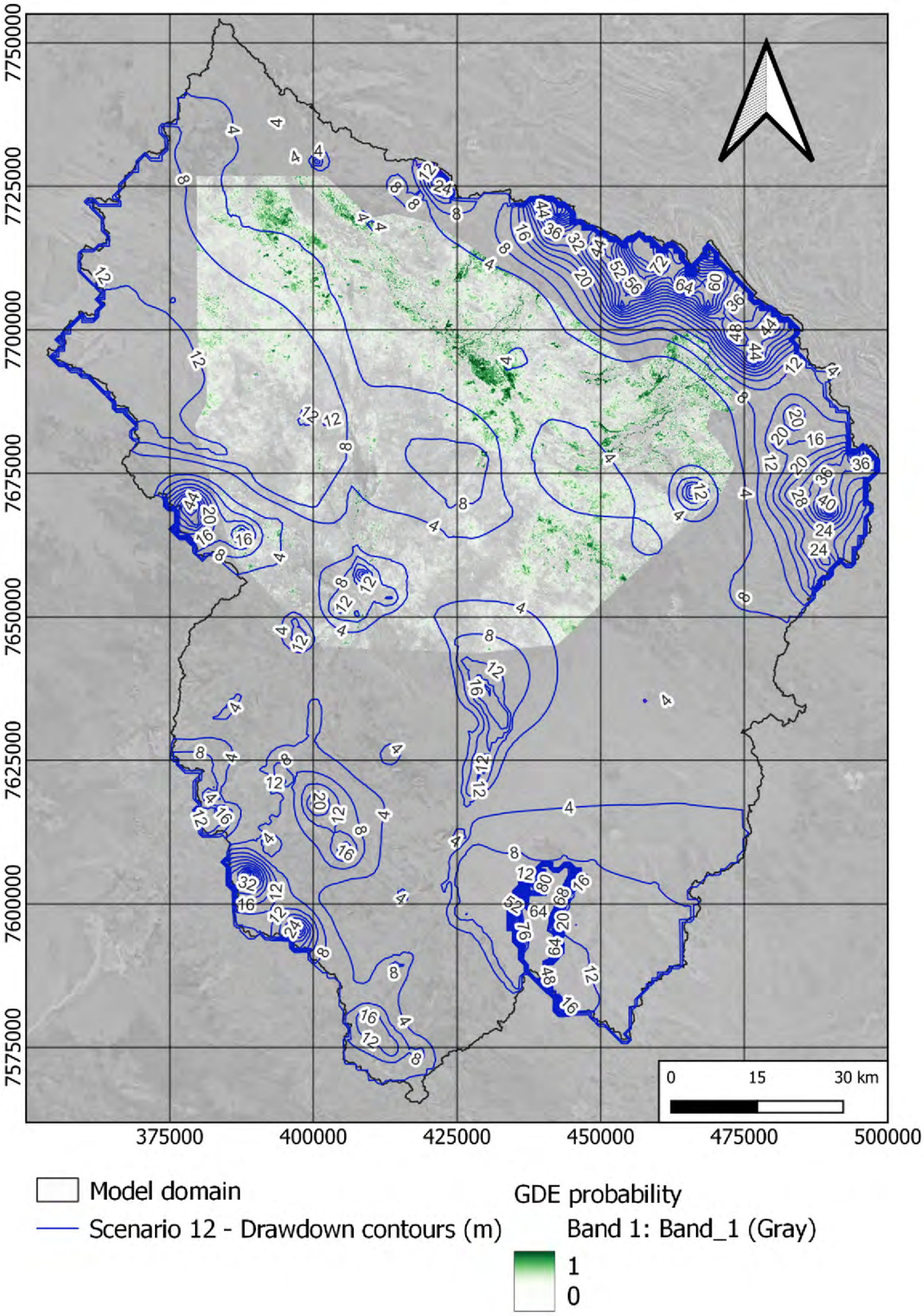
7725000
7700000
7675000
7650000
7625000
7600000
7575000
375000
400000
425000
450000
475000
500000
0
15
30 km
Model domain
Scenario 10 - Drawdown contours (m)
GDE probability
Band 1: Band_1 (Gray)
1
0



7750000
7725000
7700000
7675000
7650000
7625000
7600000
7575000
375000
400000
425000
450000
475000
500000
0
15
30 km
Model domain
Scenario 11 - Drawdown contours (m)
GDE probability
Band 1: Band_1 (Gray)
1
0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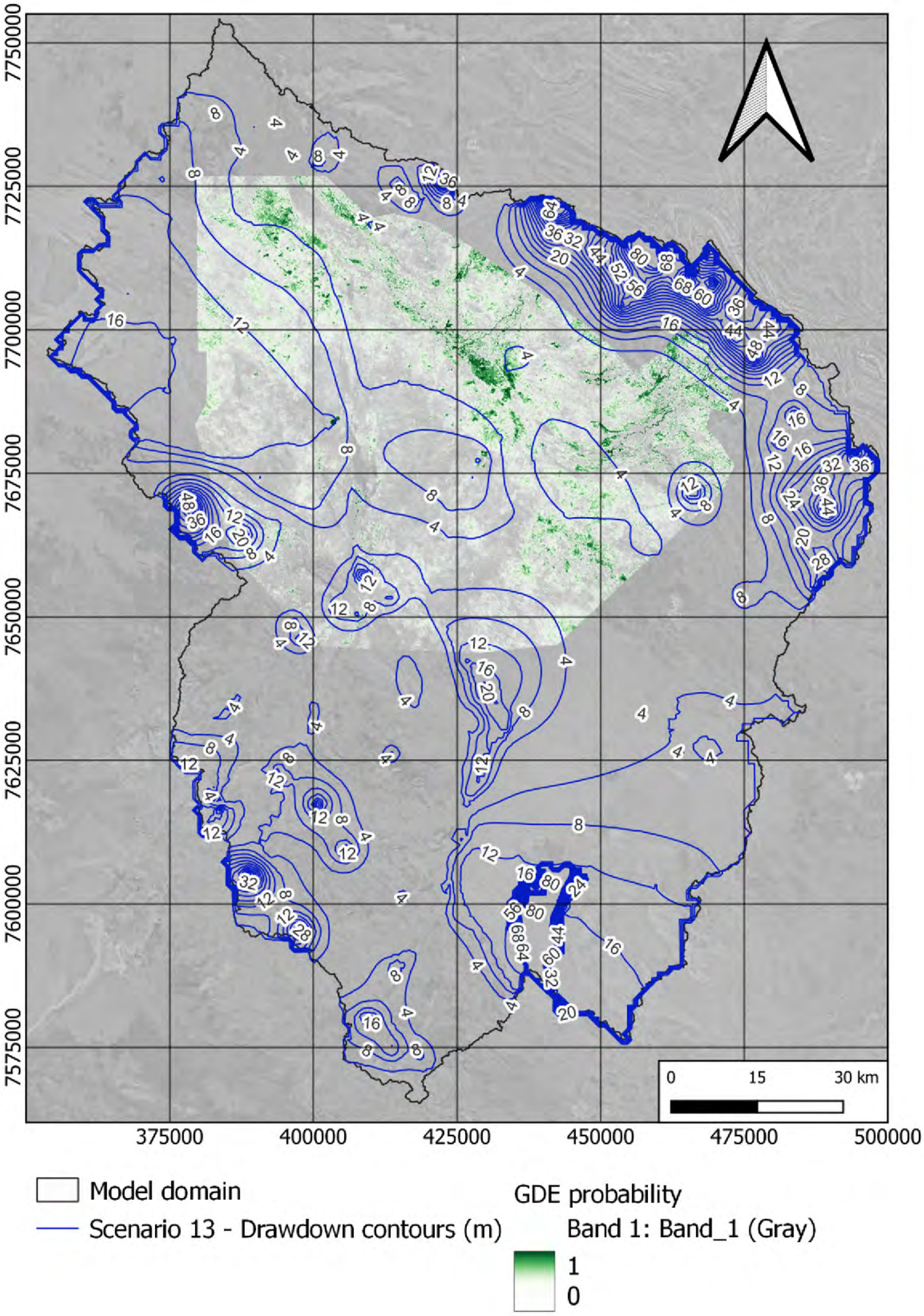
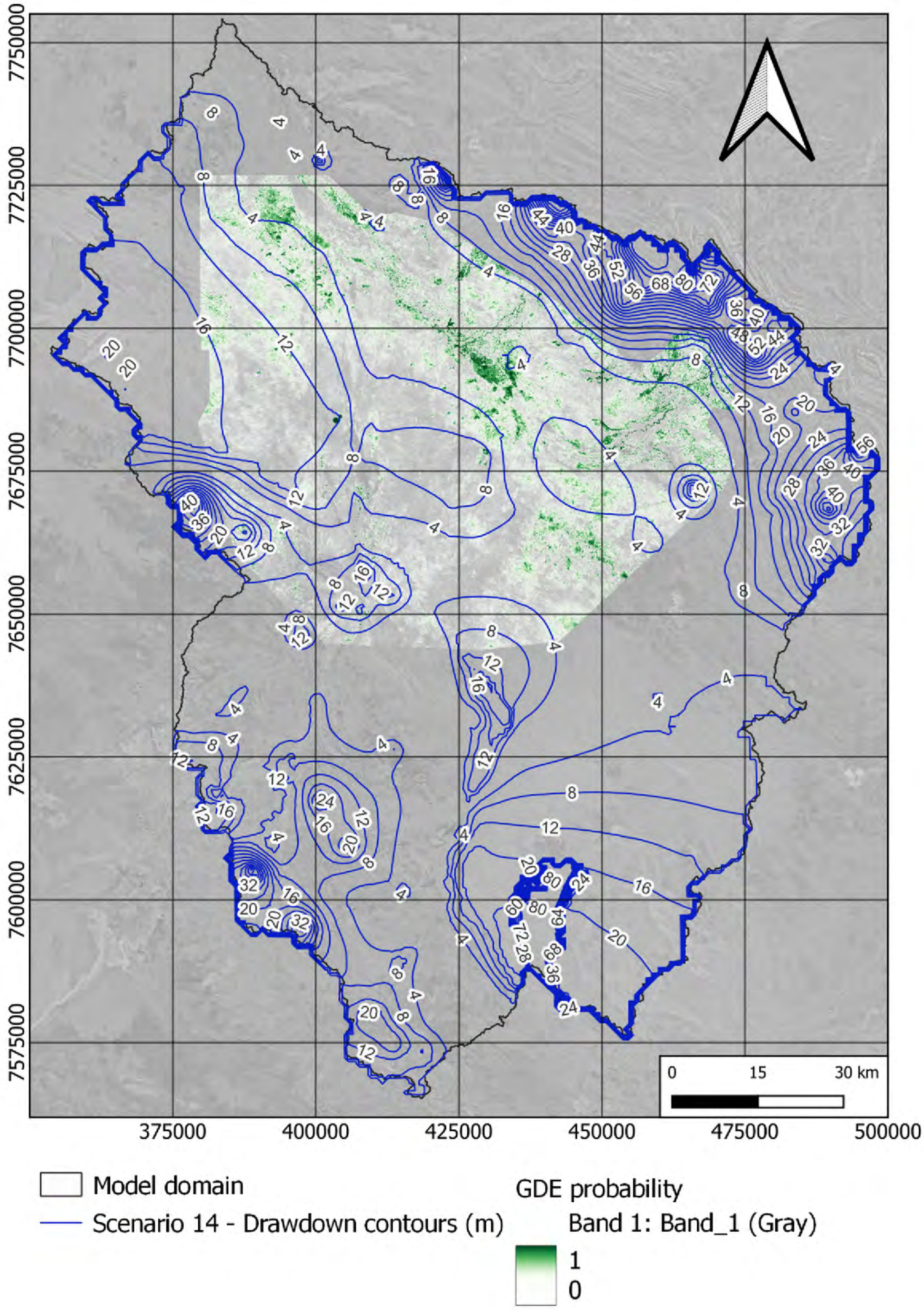
7725000
7700000
7675000
7650000
7625000
7600000
7575000
375000
400000
425000
450000
475000
500000
0
15
30 km
Model domain
Scenario 12 - Drawdown contours (m)
GDE probability
Band 1: Band_1 (Gray)
1
0

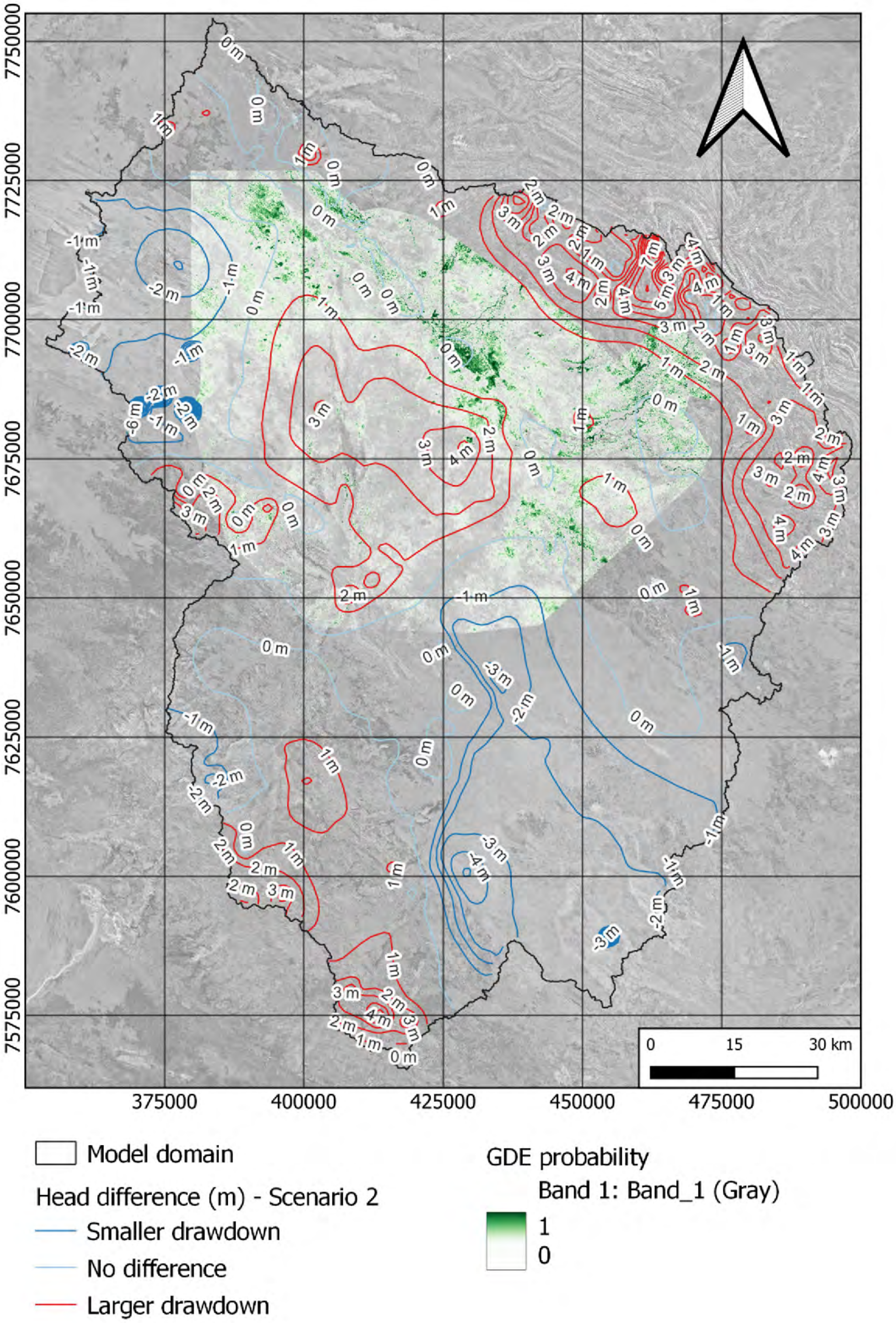


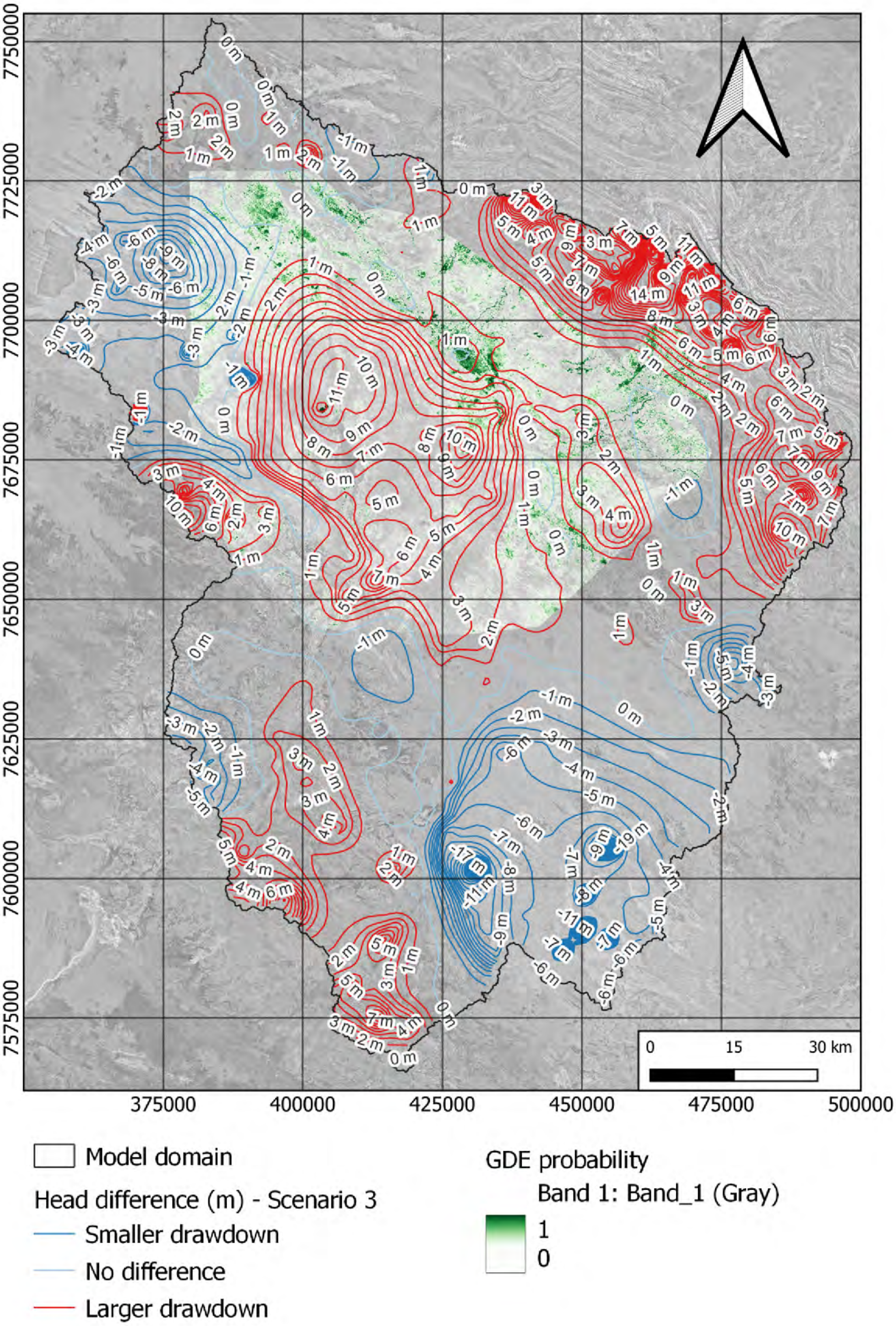
7750000
7725000
7700000
7675000
7650000
7625000
7600000
7575000
375000
400000
425000
450000
475000
500000
0
15
30 km
Model domain
Scenario 13 - Drawdown contours (m)
GDE probability
Band 1: Band_1 (Gray)
1
0



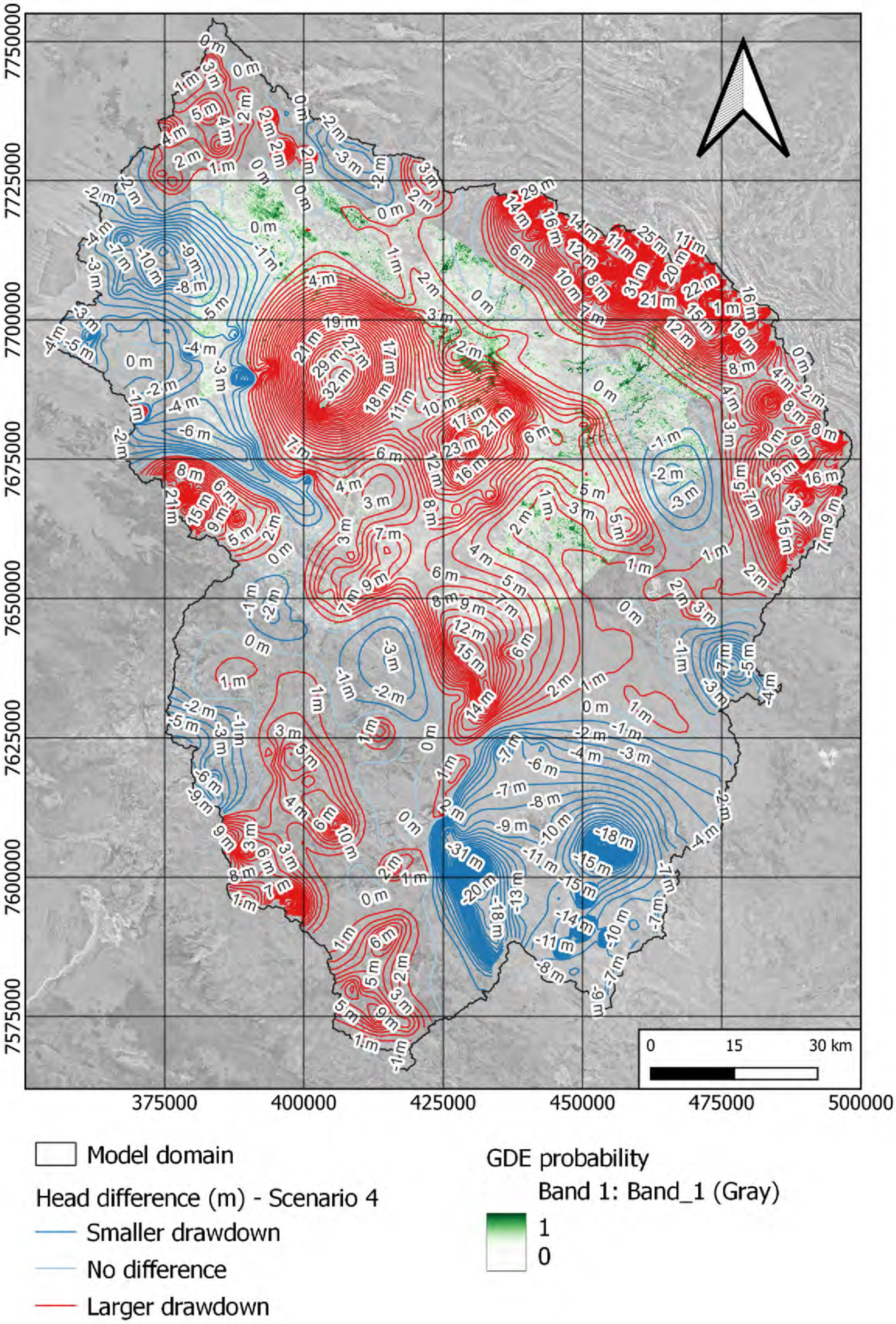
7750000
7725000
7700000
7675000
7650000
7625000
7600000
7575000
375000
400000
425000
450000
475000
500000
0
15
30 km
Model domain
Scenario 14 - Drawdown contours (m)
GDE probability
Band 1: Band_1 (Gray)
1
0

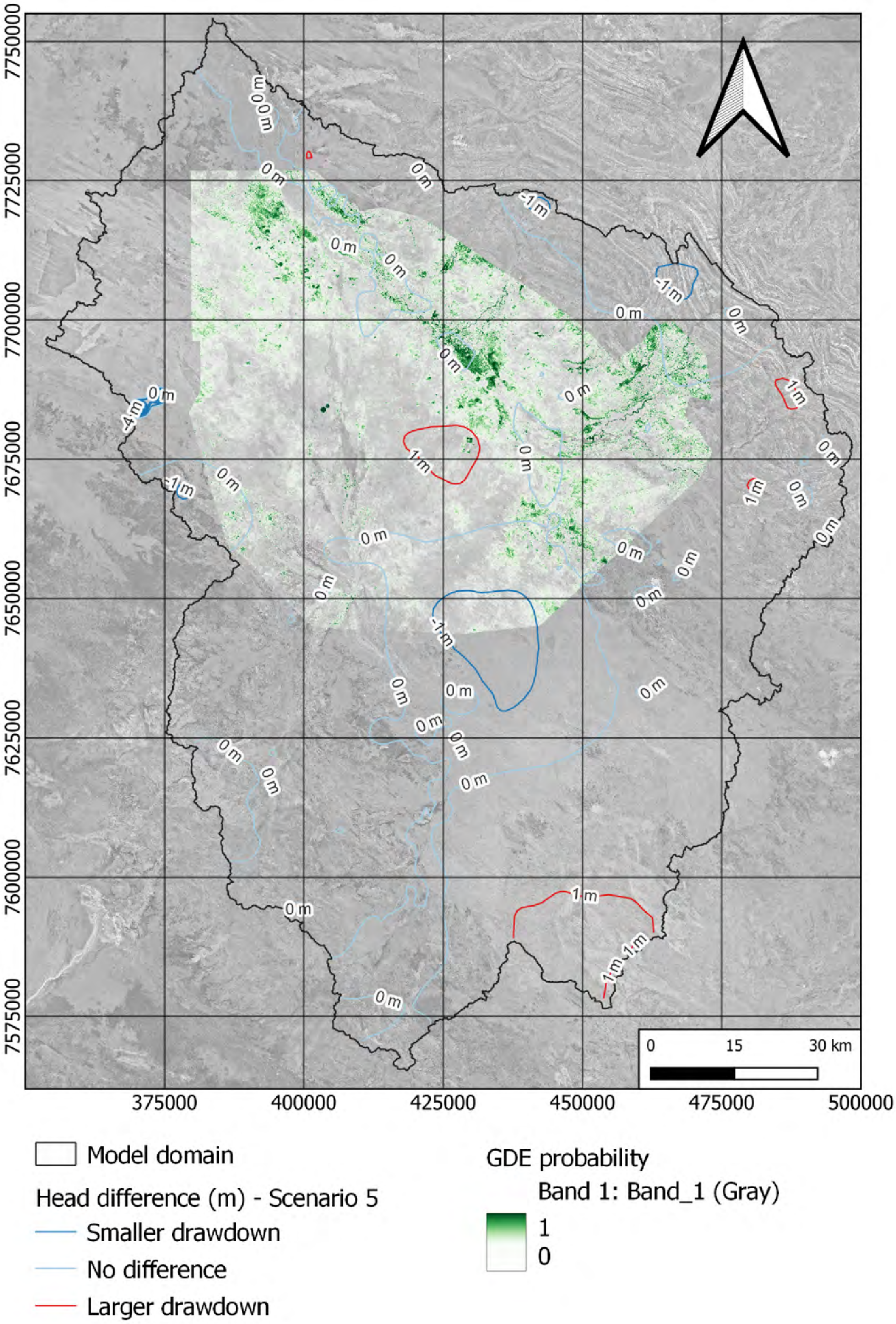
Appendix 4 - HEAD DIFFERENCES IN RELATION TO BASE CASE MODEL at 2080



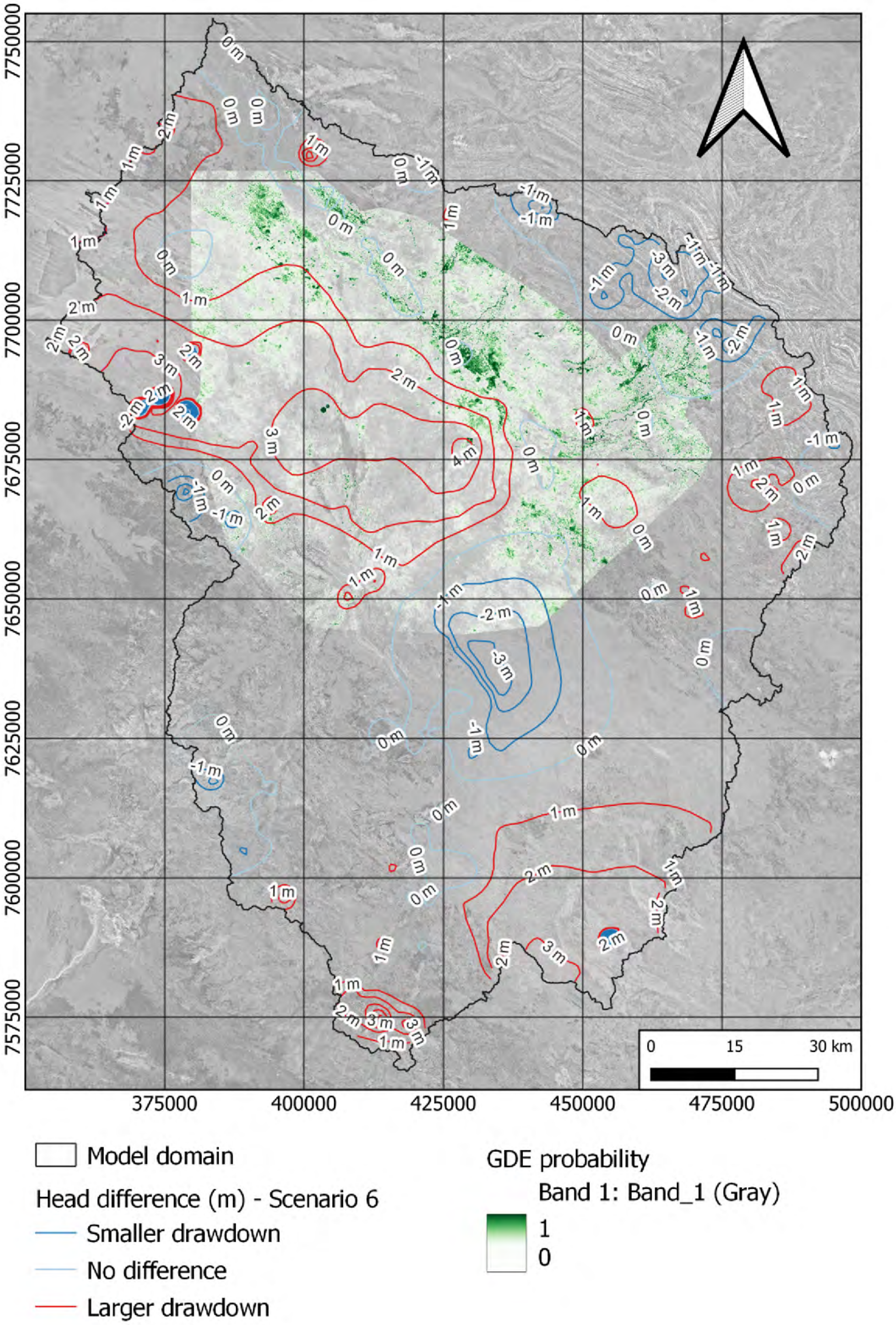


Model domain
Head difference (m) - Scenario 3
Smaller drawdown
No difference
Larger drawdown
GDE probability
Band 1: Band_1 (Gray)
1
0
0
15
30 km
375000
400000
425000
450000
475000
500000
7750000
7725000
7700000
7675000
7650000
7625000
7600000
7575000


7750000
7725000
7700000
7675000
7650000
7625000
7600000
7575000
375000
400000
425000
450000
475000
500000
0
15
30 km
Model domain
Head difference (m) - Scenario 4
Smaller drawdown
No difference
Larger drawdown
GDE probability
Band 1: Band_1 (Gray)
1
0



7750000
7725000
7700000
7675000
7650000
7625000
7600000
7575000
375000
400000
425000
450000
475000
500000
0
15
30 km
Model domain
Head difference (m) - Scenario 5
Smaller drawdown
No difference
Larger drawdown
GDE probability
Band 1: Band_1 (Gray)
1
0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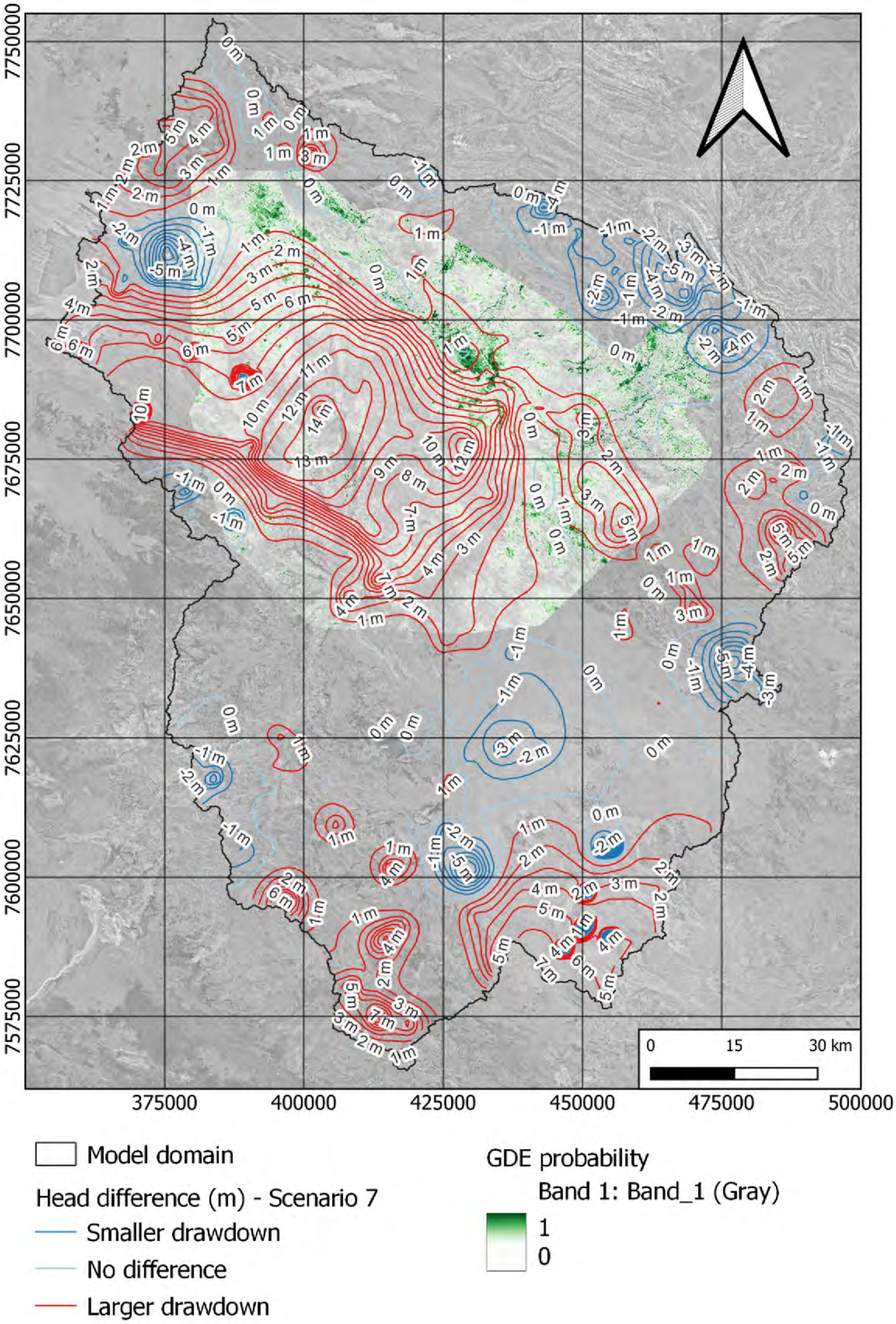

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Head difference (m) - Scenario 7
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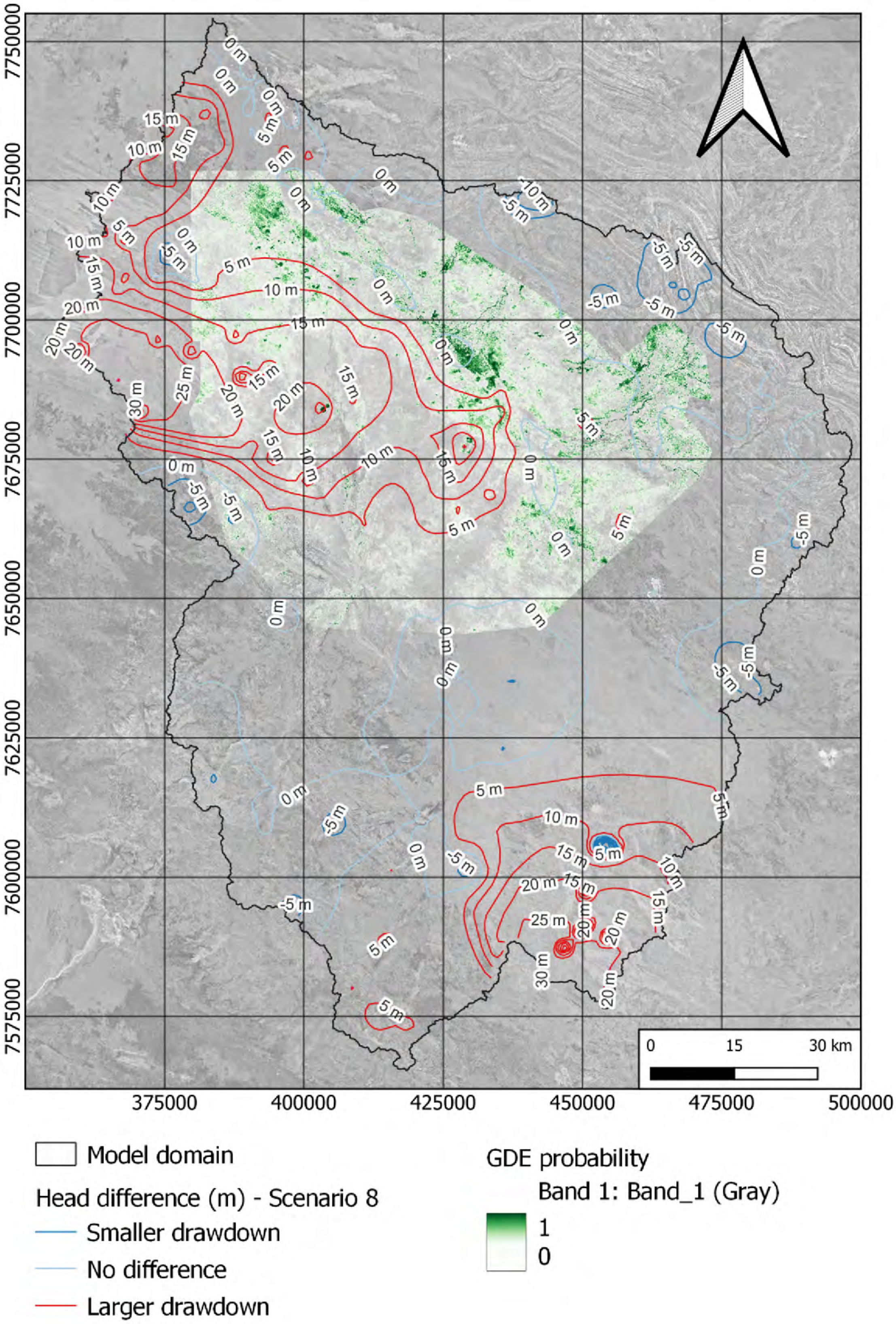
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Model domain
Head difference (m) - Scenario 8
Smaller drawdown
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Larger drawdown
GDE probability
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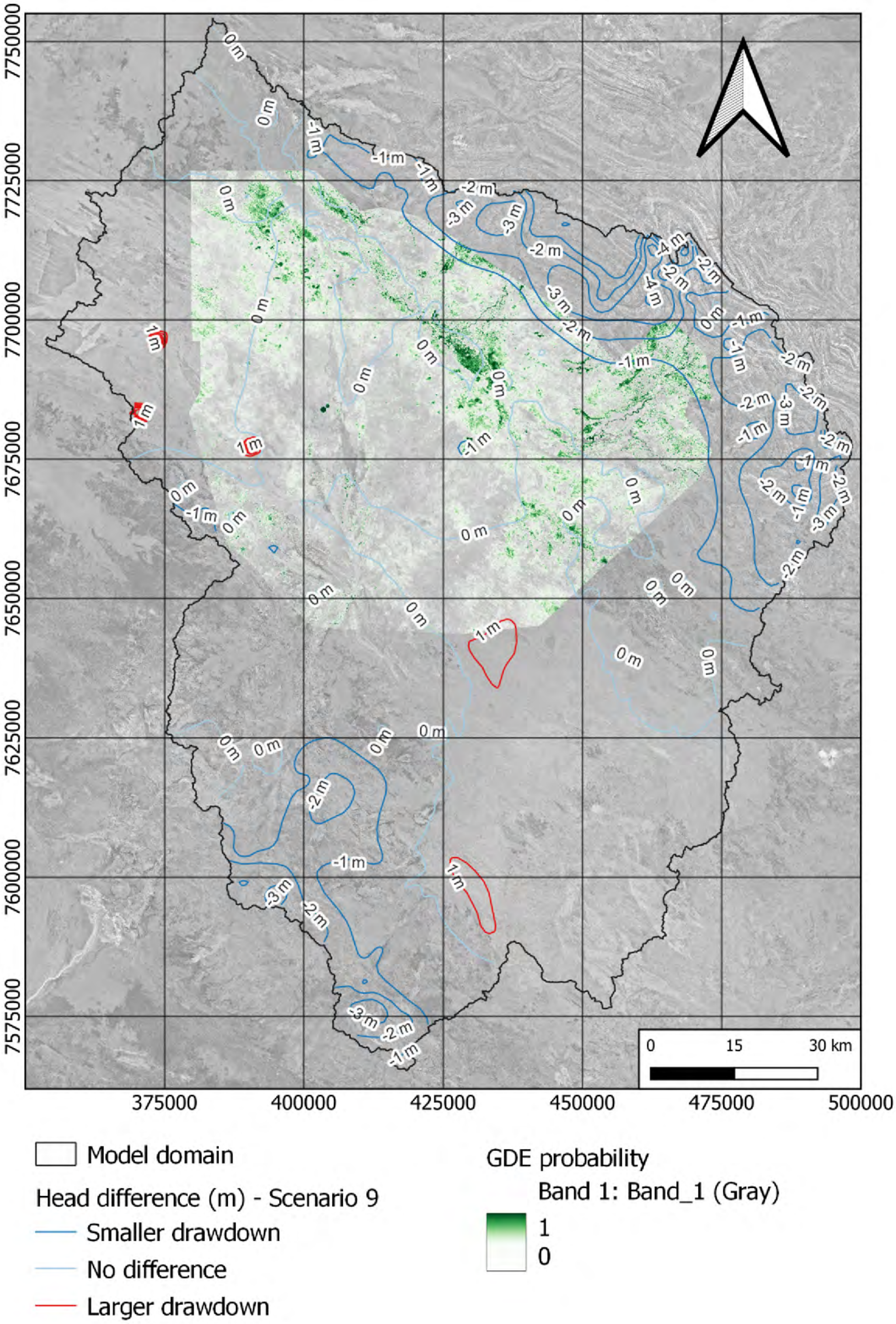
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Smaller drawdown
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Larger drawdown
GDE probability
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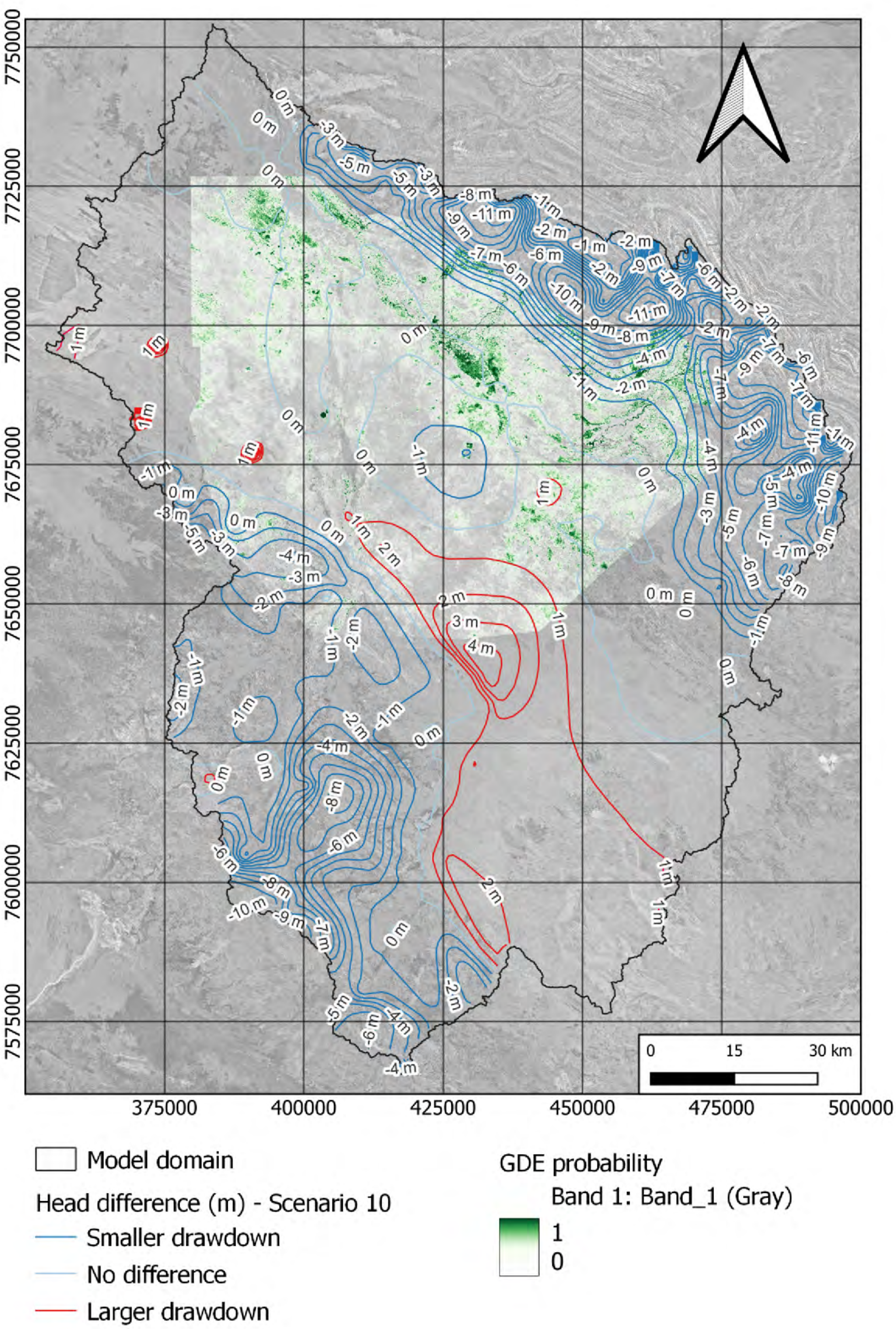

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Head difference (m) - Scenario 10
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GDE probability
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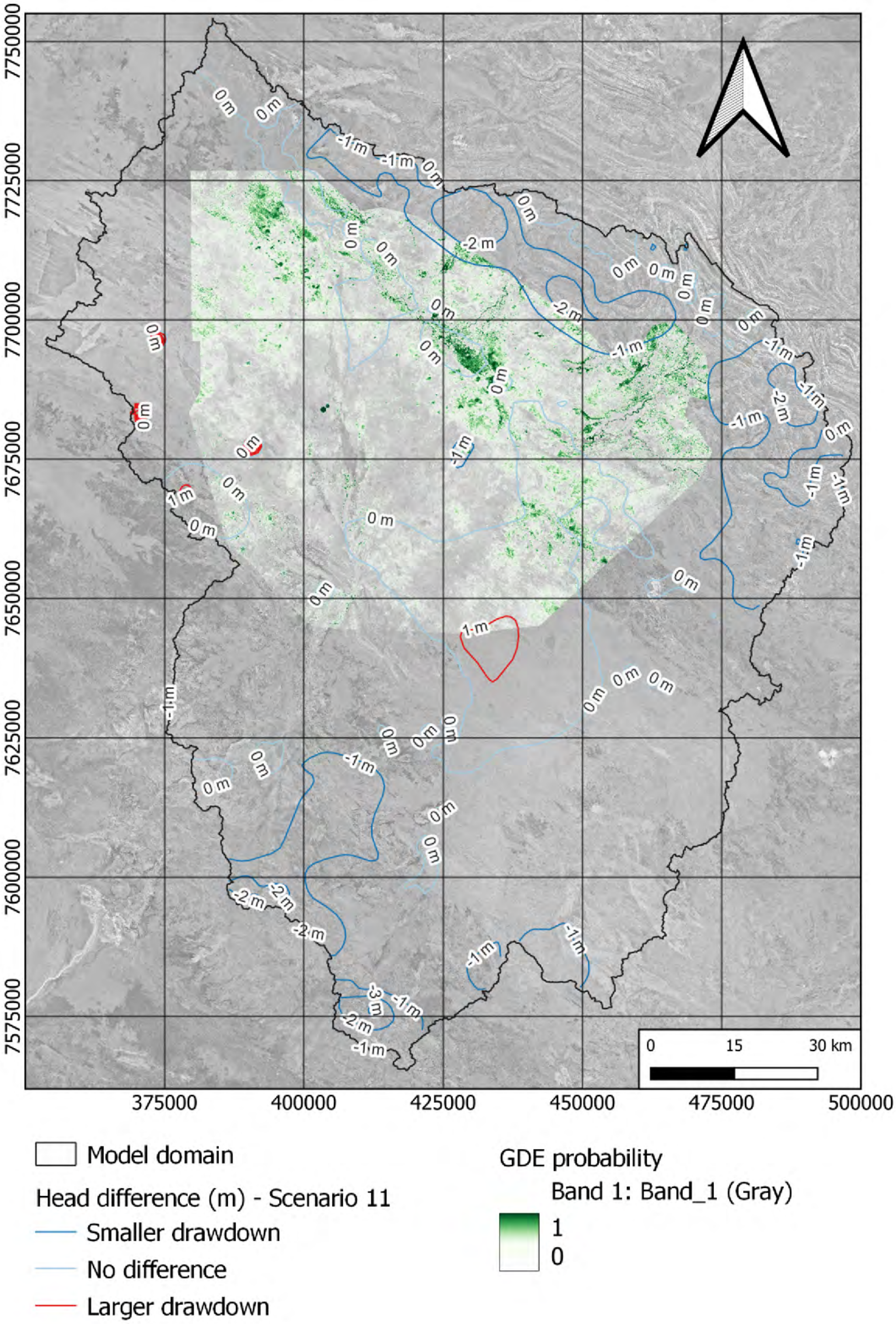
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Model domain
Head difference (m) - Scenario 11
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GDE probability
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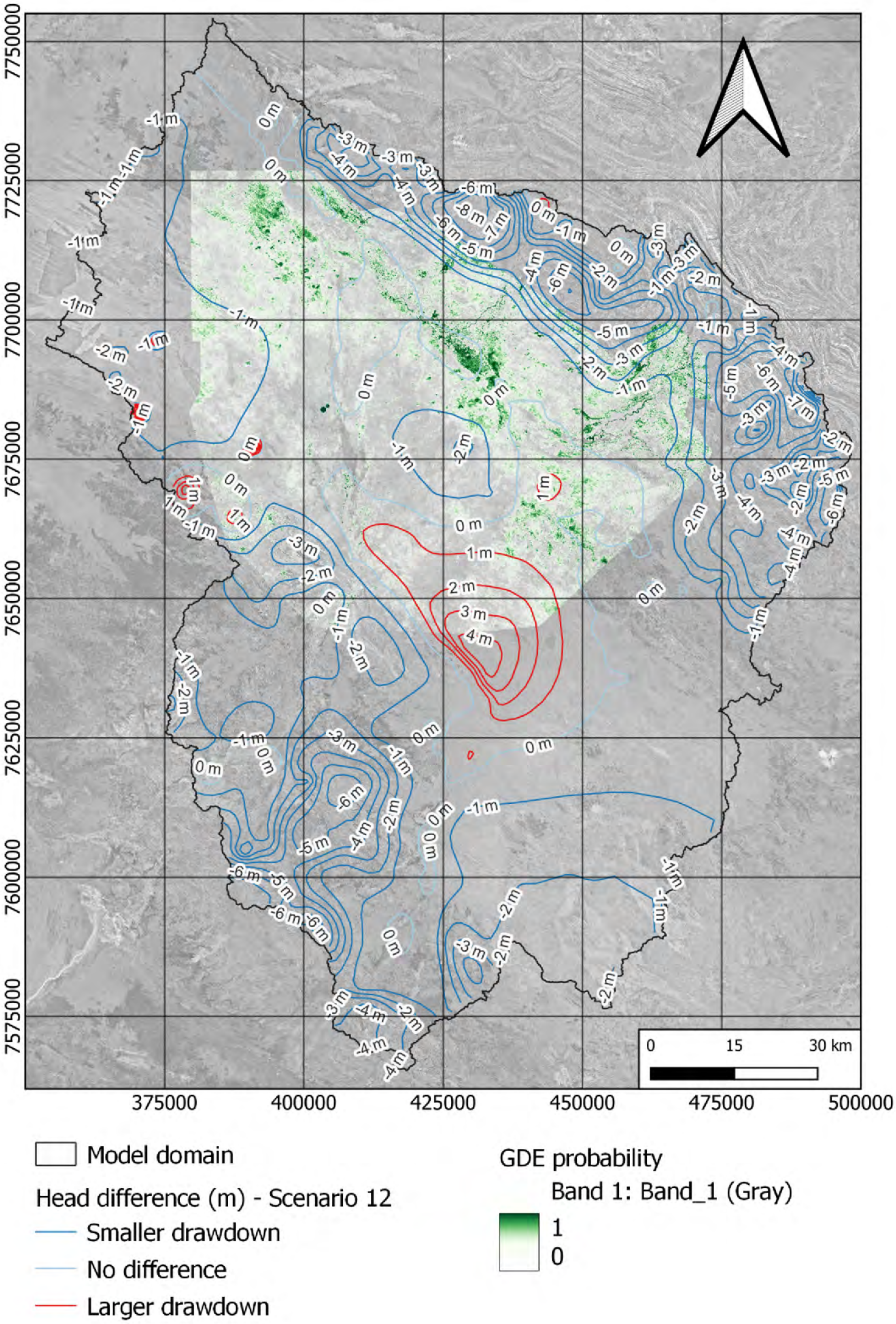

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Model domain
Head difference (m) - Scenario 12
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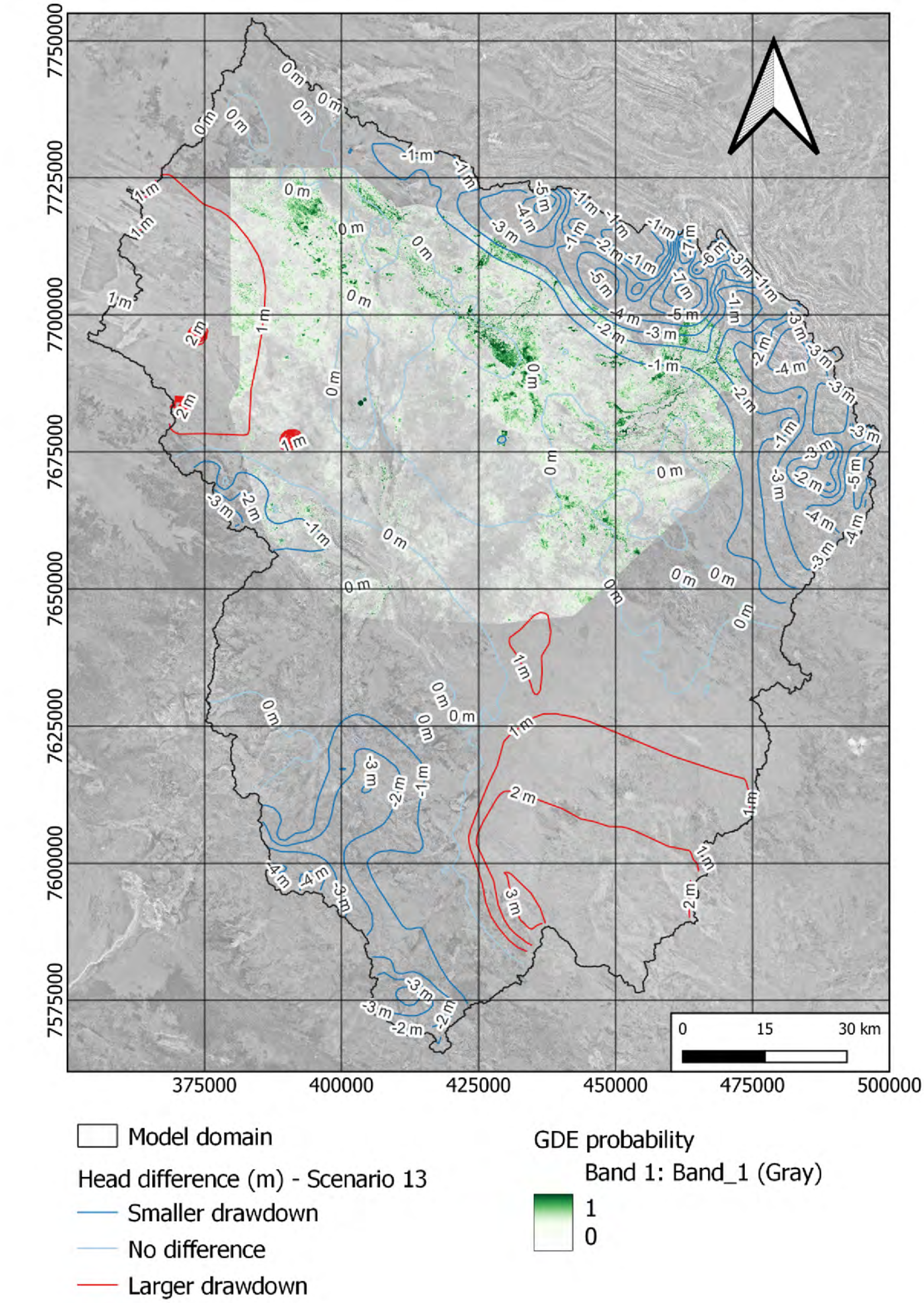

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Model domain
Head difference (m) - Scenario 13
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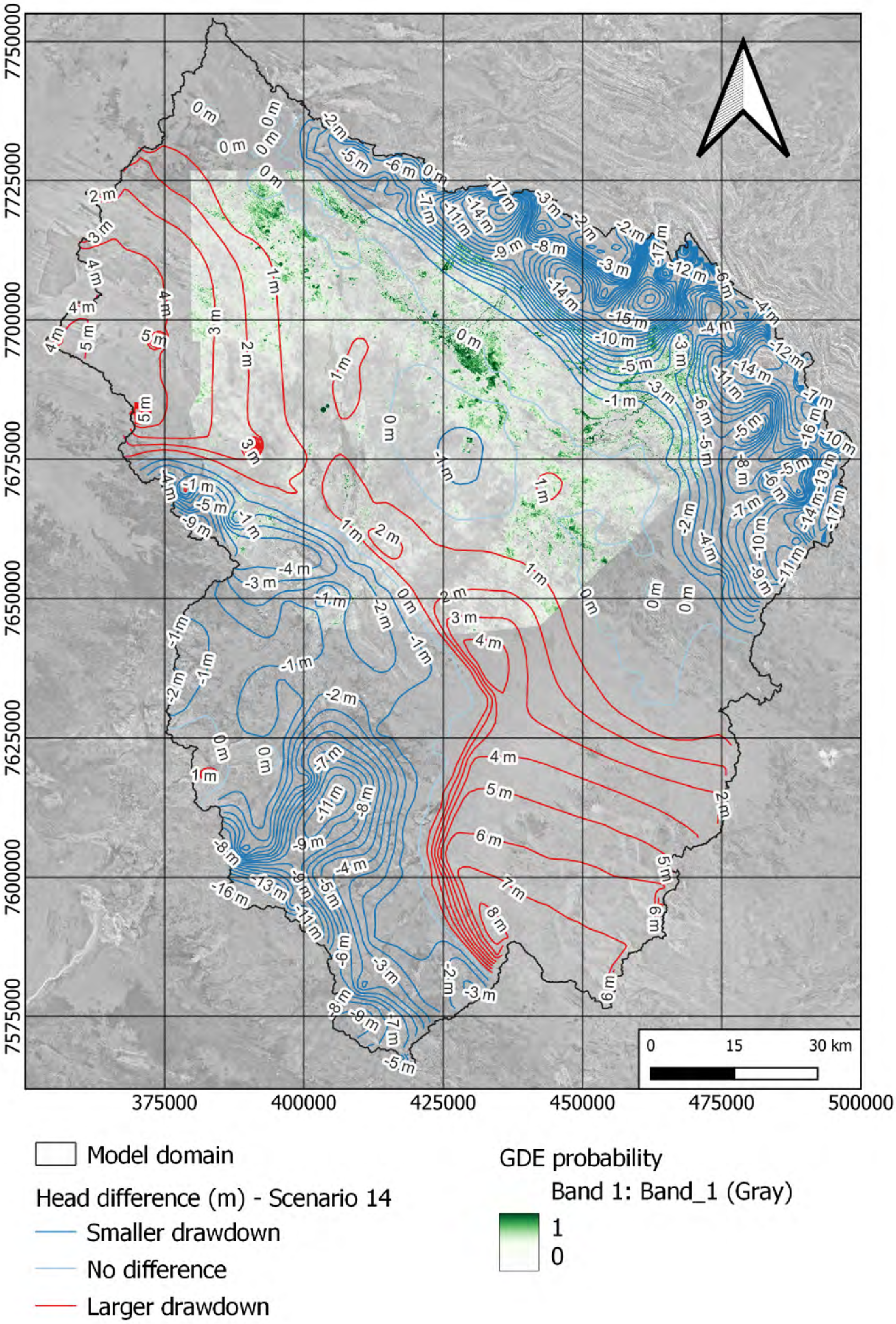
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Model domain
Head difference (m) - Scenario 14
Smaller drawdown
No difference
Larger drawdown
GDE probability
Band 1: Band_1 (Gray)
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Appendix 5 – Curriculum Vitaes

CURRICULUM VITAE

Dr. RYAN I.J. VOGWILL

ABOUT

Ryan's more than 20 years of technical expertise encompass groundwater modelling, water resource planning and recovery of hydrologically impacted ecosystems, with a focus on applying research to sustainable groundwater management and environmental impact/risk assessment

QUALIFICATIONS

BSc (Applied Geology) - Curtin University

First Class Hons (Applied Geology) - Curtin University

Doctor of Philosophy (Applied Geology) - Curtin University

Member Australian Institute of Geoscientists

EXPERIENCE

Ryan has been an influential Hydrogeologist in Western Australia for more than 20 years. He has undertaken project work and provided advice regarding the management of groundwater resources and environmental impacts across most business areas and across all regions of WA, but also with national and international based projects. He played a significant role in establishing and the initial application of the Perth Regional Aquifer System Model, a platform for more responsible and informed management of groundwater resources in the Perth region. He also established, coordinated and was the primary lecturer for the Hydrogeology MSc course at UWA. He has worked in consultancy intermittently throughout his career, but this is now full time as of September 2016.

KEY SKIILS & EXPERTISE

Technical and editorial review

Regional and local scale water allocation planning including drought contingency planning

Water quality and ecology (i.e. effluent discharge and algal blooms)

Sedimentological and geochemical assessment

Land use re-evaluation

Environmental risk assessment

Groundwater Dependent Ecosystems (GDEs) and Environmental Water Requirements (EWRs)

Dryland salinity

Groundwater training and education

Groundwater modelling generally but with a focus on MODFLOW

Surface water/groundwater interaction modelling including water and solute balances

Project and staff supervision

AWARDS

Ocean Seas Ocean Hero Award.

Hydrology and Earth Systems Science - Jim Dooge Award 2020

KEY PROJECT EXPERIENCE

PRAMS development and application - a $5M groundwater model of the Perth (Moora to Mandurah) Region

South West Yarragadee groundwater and impact assessment modelling (SWAMS and local area models) review for the Department of Conservation and Land Management

A member of the modelling technical reference groups for Ord Stage 2 - Weaber Plains and the southern river/Murray River MikeSHE modelling projects by CSIRO

Salt Lake Potash - Water supply and production impact assessment and licensing.

Millennium Minerals Limited - Multiple mine dewatering requirements and GDE impact risk assessment

Supervising Hydrologist for the Natural Diversity Recovery Catchment Program

KEY CAREER HISTORY

Director, Principal Hydrogeologist, Hydro Geo Enviro Pty Ltd, Feb 2018 to date

Principal Hydrogeologist (Sole Trader) September 2016 to Feb 2018

Associate Professor Hydrogeology, The University of Western Australia, December 2011 – September 2016

Supervising Hydrogeologist, Nature Conservation Division, Department of Environment, and Conservation, February 2006 – April 2011

Hydrogeologist, Department of Water, Groundwater Hydrology Section, February 2003 – February 2006

CONTACT

E: ryanv@hydrogeoenviro.com.au
www.hydrogeoenviro.com.au
m: 0427 427 269

DR RYAN I.J. VOGWILL

PRINCIPAL HYDROGEOLOGIST

Continued…

PROFESSIONAL EXPERIENCE

DIRECTOR AND PRINCIPAL HYDROGEOLOGIST

HYDRO GEO ENVIRO AND SOLE TRADER SEPTEMBER 2016 – ONGOING

Key clients and project during this time include:

- Salt Lake Potash - water supply and production impact assessment/licensing.
- Millennium Minerals Limited - Multiple mine dewatering requirements, surface water management, GDE mapping and impact risk assessment
- City of Kalamunda - Acid sulphate soil management
- Adelaide Brighton Cement - Inorganic contamination conceptual modelling and remediation
- City of Rockingham - Lake Richmond microbialites, hydrology, chemical risk and weed management
- Rottnest Island Authority - Microbialite monitoring plan and impact criteria

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ASSOCIATE PROFESSOR OF HYDROGEOLOGY

THE UNIVERSITY OF WESTERN AUSTRALIA, DECEMBER 2013 – SEPTEMBER 2016

JOINT ASSOCIATE PROFESSOR OF HYDROGEOLOGY

THE UNIVERSITY OF WESTERN AUSTRALIA/CURTIN UNIVERSITY, APRIL 2011 – DECEMBER 2013

SUPERVISING HYDROLOGIST, NATURE CONSERVATION DIVISION

DEPARTMENT OF ENVIRONMENT, AND CONSERVATION, FEBRUARY 2006 – APRIL 2011

Ryan was the key hydrogeologist employed by DEC, providing advice across all business areas. He continued working on GDEs of the Gnangara Mound, dryland salinity and all of the associated issues. Ryan has reviewed, critiqued and presented to the EPA on a number of subjects, including the sustainability of groundwater abstraction from the Gnangara Mound and Southwest Yarragadee project. He has also been heavily involved in many referrals from other government departments and sections of the DEC for many technical reviews of mining applications. Ryan continued to co-ordinate research and projects for the DEC, which involved the interaction of hydrology and biology in the Natural Diversity Recovery Catchments during the first 3 years of his time in academia until the Natural Diversity Recovery Catchment project was shut down.

HYDROGEOLOGIST

DEPARTMENT OF WATER, GROUNDWATER HYDROLOGY SECTION, FEBRUARY 2003 – FEBRUARY 2006

Preparation of modelling scenarios and the associated reporting; Section 46 modelling; Drought Contingency modelling; East Wanneroo Land Use Re-evaluation; graphic presentation of modelling data; database analysis and retrieval for various purposes; development of sampling programs; research proposals; and a large number of modelling/report critiques amongst other duties.

BOOKS AND PUBLISHED REPORTS

Vogwill R., 2017, Western Australia's Tight Gas Industry - A review of groundwater and environmental risks. Conservation Council of Western Australia. ISBN (13): 978-0-9750708-1-9.

Vogwill R. (ed), 2016, Solving the Groundwater Challenges of the 21st Century - IAH - Selected Papers on Hydrogeology. CRC Press, Taylor & Francis. ISBN 9781138027473. https://www.crcpress.com/Solving-the-Groundwater-Challenges-of-the-21st-Century/Vogwill/9781138027473.

Vogwill R., 2015, Water Resources of the Mardoowarra (Fitzroy River) Catchment. Published by The Wilderness Society. ISBN: 978-0-646-94928-4

BOOK CHAPTERS

Doherty J. and Vogwill R., 2016, Models, Decision-Making and Science. In Vogwill R. (ed), 2016, Solving the Groundwater Challenges of the 21st Century - IAH - Selected Papers on Hydrogeology. CRC Press, Taylor & Francis. ISBN 9781138027473. https://www.crcpress.com/Solving-the-Groundwater-Challenges-of-the-21st-Century/Vogwill/9781138027473 (in press).

Vogwill R., 2016, Solutions to the Groundwater Challenges of the 21st Century - Introduction IAH - Selected Papers on Hydrogeology. CRC Press, Taylor & Francis. ISBN 9781138027473. https://www.crcpress.com/Solving-the-Groundwater-Challenges-of-the-21st-Century/Vogwill/9781138027473.

Boulton, A., Brock, M., Robson, B., Ryder, D., Chambers, J., Davis, J., 2014, Australian Freshwater Ecology: processes and management, Wiley and sons. Note Vogwill contribution is a salinity case study on Lake Toolibin. Given this is a published text book, chapters are not attributed specifically but my input has been formally acknowledged in the publication.

THESES

Vogwill, R.I.J., 1996, Aspects of the Hydrogeology and Environmental Geochemistry of Lake Walyungup, Rockingham Western Australia Honours Thesis, Curtin University, Western Australia.

Vogwill, R.I.J, 2003, Hydrogeology and Aspects of the Environmental Geology of the Broome Area Western Australia, PhD Thesis, Curtin University, Western Australia.

JOURNAL PUBLICATIONS

Callow J.N, Hipsey M.R., and Vogwill R.I.J, 2020, Surface water as a cause of land degradation from dryland salinity. Hydrol. Earth Syst. Sci., 24, 717–734, 2020 https://doi.org/10.5194/hess-24-717-2020

Mendes Monteiro J., Vogwill R., Bischoff K. and Gleeson D.B., 2019, Comparative metagenomics of microbial mats from hypersaline lakes at Rottnest Island (WA, Australia), advancing our understanding of the effect of mat community and functional genes on microbialite accretion. Limnol. Oceanogr. 00, 2019, 1–17 doi: 10.1002/lno.11323

Davies C., Vogwill R. and Oldham C., 2017, Urban Subsurface Drainage as an Alternative Water Source in a Drying Climate. Australasian Journal of Water Resources. In Press. http://dx.doi.org/10.1080/13241583.2017.1351130

Coletti J.Z., Vogwill R., Hipsey M.R., 2017, Water management can reinforce plant competition in salt-affected semi-arid wetlands, Journal of Hydrology, doi: http://dx.doi.org/10.1016/j.jhydrol.2017.05.002.

Forbes M. and Vogwill R., 2016, Hydrological change at Lake Clifton, Western Australia – Evidence from hydrographic time series and isotopic data. Journal of the Royal Society of Western Australia, 99(2): 47–60.

Davies, C. Oldham, C. and Vogwill, R., 2016, *Urban Subsoil Drainage as an Alternative Water Source in a Drying Climate.* Peer reviewed paper for Stormwater Australia 2016 National Conference, September 2016, Gold Coast QLD.

Gunaratne GL, Vogwill R, and Hipsey M, 2016, Effect of seasonal flushing on nutrient export characteristics of an urbanising, remote, ungauged coastal catchment. *Hydrological Sciences Journal* http://dx.doi.org/10.1080/02626667.2016.1264585.

Smith, M. J., P. L. Drake, R. Vogwill, and C. A. McCormick. 2015. Managing natural resources for their human values. Ecosphere 6(8):140.

Viezzoli A, Rutherford J., Munday T and Vogwill R, 2013, Updated inversion of SkyTEM data using downhole a-priori for new conceptual model and GW management targets at Toolibin Lake ASEG Extended Abstracts 2013 (1) 1 – 4.

S. Clohessy , S. Appleyard , R. Vogwill, 2013, Groundwater acidification near the water table of the Superficial Aquifer, Gnangara Mound, Swan Coastal Plain, Western Australia. Applied Geochemistry, V 36, pp 14-152. doi:10.1016/j.apgeochem.2013.06.003.

Mitchell, N., Hipsey, M.R., Arnall, S.G., McGrath, G.S., Tareque, A., Kuchling, G., Vogwill, R.I., Sivapalan, M., Porter, W., Kearney, M. 2013, 'Linking eco-energetics and eco-hydrology to select sites for the assisted colonization of Australia's rarest reptile', Biology, 2, 1, pp. 1-25.

Coletti, J.Z., Hinz, C., Vogwill, R., Hipsey, M.R.,2013, Hydrological controls on carbon metabolism in wetlands, Ecological Modelling, 249, 3-18.

Drake P.L., Coleman B.F. and Vogwill R., 2012, The response of semi-arid ephemeral wetland plants to flooding: linking water use to hydrological processes. Ecohydrology 2012 online.

Forbes M.S., Vogwill, R., 2011. A geochemical investigation of hydrologically derived threats to rare biota: The Drummond Nature Reserve, Western Australia. Hydrogeology Journal Hydrogeology Journal (16 September 2011), pp. 1-17, doi:10.1007/s10040-011-0780-8 Key: citeulike:9818473

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Chow W., Vogwill R. and Forbes M, 2010, Floristic values and hydrological threats to freshwater claypans in Drummond Nature Reserve, Western Australia. Australasian Plant Conservation, Vol 18 No. 4.

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I.C. Lau, T.J. Cudahy, C.C.H. Ong, R.J.J. Vogwill, S. L. McHugh, R.D. Hewson and M.S. Caccetta, , 2006, Environmental monitoring of acid sulphate soils in the Swan Coastal Plain, using hyperspectral methods. ASEG Extended Abstracts Volume 2006 Number 1.

NOTABLE "GREY" LITERATURE PUBLICATIONS

Department of Parks and Wildlife (in review). Toolibin Lake Natural Diversity Recovery Catchment: Recovery Plan (2015 to 2035). Department of Parks and Wildlife, Perth, Australia.

Coletti, J.Z, Vogwill, R., Busch, B.D., Callow, N., Hipsey, M.R., (2014) A Decision Support Tool for the Ecohydrological Management of Lake Toolibin Recovery Catchment. Report prepared for the Department of Parks and Wildlife, Government of Western Australia, 127pp.

Coletti, J.Z, Gunaratne, G., Hipsey, M.R., Busch, B.D., Callow, N., Vogwill, R., (2012) BioRisk – Model assessment of wheat-belt biodiversity asset response to ecohydrological dynamics. Report prepared for the Department of Environment and Conservation, Government of Western Australia, 84pp.

Wallace, K., Connell, K., Vogwill, R., Edgely, M., Hearn, R., Huston, R., Lacey, P., Massenbauer, T., Mullan, G., and Nicholson, N., 2011, Natural Diversity Recovery Catchment Program: 2010 Review. Department of Environment and Conservation, Perth, Western Australia.

Vogwill, R.I.J, McHugh, S.L., O'Boy, C.A., and Yu, X., 2008. PRAMS scenario modelling for water management of the Gnangara Groundwater Mound, HG 21, Western Australia Department of Water.

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Vogwill, R. I. J., 2004, Section 46 Groundwater Modelling Results - Stage 1, Department of Environment, HR 223 Department of Environment, Government of Western Australia.

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McHugh, S.L., and Vogwill, R.I.J., 2005, Investigation of the Sustainability of Shallow Groundwater Systems on Gnangara and Jandakot Mounds, HR 240 Department of Environment, Government of Western Australia.

Buntine-Marchagee Natural Diversity Recovery Catchment, Recovery Plan 2007-2027, DEC, 2007. This report has been copy edited to international publication standards and represents a crucial step in developing a new method of recovery planning to reduce salinisation impacts in the wheatbelt. I was responsible for much of the hydrological content and a key input to planning process and research plan.

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Groundwater control and supply for developments on shallow water tables, Swan Coastal Plain, Western Australia - Preliminary results. Stormwater Industry Association of WA, Hydropolis 2015, Perth Western Australia, 22 April 2015 (oral)

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Gunaratne GL, Hipsey M and Vogwill R (2014) A mechanistic description of Lyngbya algal blooms for inter-tidal coastal embayments, Proceedings of Coast to coast Conference, Mandurah, Australia. 27-31October, 2014. (abstract)

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Drake P., Vogwill R., Coleman B and Tarplin R, 2012, Optimising conditions of the root zone to restore wetland vegetation. SERA Conference Perth. (abstract and oral) Vogwill R., Drake P., Coleman B, Tarplin R., Hinz C, Colletti J. and Hipsey M., 2012, Toolibin Lake 2012, catchment and asset scale ecohydrological modelling to explain the response of existing and potential management intervention. SERA Conference Perth. (abstract and oral)

Zanella Coletti, J., Hinz, C., Vogwill, R.I., Hipsey, M.R. 2011, 'A minimalistic model for carbon cycling in wetlands', 19th International Congress on Modelling and Simulation, Australia, 1, pp. 2219-2225. (oral and reviewed paper)

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Hanna J.P., Coletti J.Z., Hipsey M.R .and. Vogwill R, 2011, Identification of the Major Hydrological Threats for Two Clay Pan Wetlands in the South West of Australia MODSIM 2011 . (oral and reviewed paper).

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Forbes M.S., & Vogwill R.I.J., 2009. Hydrological assessment of the Drummond Nature Reserve. 10th Australasian Environmental Isotope Conference and 3rd Australasian Hydrogeology Research Conference. Perth, Western Australia. (Abstract and oral presentation).

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Noorduijn, S.L., Vogwill, R, Smettem, K.R.J., and Ghadouani, A., 2008, Water Balance Analysis of an Australian Alley Farming Trial, Toolibin Lake, European Geoscience Union, Vienna 13th -18th April 2008 (poster presentation)

Mudgway L., Lacey P. and Vogwill R, 2008, Know what you are measuring—a detailed review of groundwater monitoring at Toolibin Lake and Lake Bryde, 2nd International Salinity Forum, Adelaide 31st Mar – 3rd Apr 2008. (Paper)

Noorduijn, S.L., Vogwill, R. O'Sullivan, W., Ghadouani, A., and Smettem, K. R. J., 2008, Multi Frequency monitoring of water table response to Alley Farming, 2nd International Salinity Forum, Adelaide 31st Mar – 3rd Apr 2008 (poster presentation)

Vogwill R, Cook TF, Appleyard, SJ, Watkins R, 2007, Potential for Negative Ecological Impacts of Current Water and Landuse of Gnangara Mound GQ2007, the 6th International IAHS Groundwater Quality Conference, held in Fremantle, Western Australia, 2-7 December 2007. (abstract and oral presentation).

Noorduijn, S.L., Vogwill, R, Ghadouani, A, and Smettem, K. R. J., 2007, Assessing agroforestry as a tool for sustainable water resources management in western Australia, SSEE International Conference on Sustainable Engineering, 31st Oct-2nd Nov 2007 (oral presentation)

Cook TF, Watkins R, Appleyard, SJ, Vogwill R, 2006, Acidification of groundwater caused by a falling water table in a sandy aquifer in the Perth Region, Western Australia. Proceedings of the 18th World Congress of Soil Science, 9-15 July 2006, Philadelphia, USA. (abstract and oral presentation).

Vogwill R, 2004, Groundwater Resources of Western Australia, learning from the past and present with an eye to the future. 175th Anniversary conference. (abstract and oral presentation).

Eduardo De Sousa, PhD

Principal Groundwater Modeller/Business Area Manager

INTERA GEOSCIENCE & ENGINEERING SOLUTIONS

Years of Experience: 19

Education:

- PhD, 2021, Hydrogeology, University of Western Australia
- MSc, 2007, Hydrogeology, University of the Free State
- BSc, 2002, Geology, Universidade Federal do Rio Grande do Sul

Professional History:

2021 – Present	Principal Groundwater Modeller/Business Area Manager – INTERA Geosciences Pty Ltd, Perth, Australia
2019 – 2021	Principal Groundwater Modeller/Business Area Manager – DHI Water and Environment, Perth Australia
2012 – 2019	Principal Hydrogeologist – Pells Sullivan Meynink, Perth, Australia
2008 – 2012	Senior Groundwater Modeller – Schlumberger Water Services, Perth, Australia
2007 – 2008	Senior Hydrogeologist – URS Asia Pacific, Perth, Australia
2006 – 2007	Hydrogeologist – Golder Associates, Johannesburg, South Africa
2005 – 2006	Groundwater Modeller – Groundwater Consulting Services, Johannesburg, South Africa
2002 – 2005	Hydrogeologist – AmbiTerra/Essencis remediaco, Porto Alegre, Brazil

Software and Skills

- Proficient in C++, Qt, Python and FORTRAN. Experience in heavy customization of groundwater modelling codes either as external plugins or changes in the original source code.
- SQL Server, SQlite, MS Access. Developed 3Space, an open source database for groundwater and geotechnical data
- Proficient in ArcGIS, Quantum GIS and Global Mapper
- Proficient in Leapfrog Geo, Petrel and SURPAC packages.

Dr. Eduardo de Sousa is a Principal Groundwater Modeller at INTERA. He has nearly two decades of experience working in South America, Africa and Australasia delivering modelling solutions in hydrogeological systems of high complexity, including modelling of geothermal systems, reactive transport modelling, design of dewatering and depressurization systems, environmental impact assessments, ecohydrology and groundwater remediation. Dr. De Sousa's work has included the development of DHI's tool for MODFLOW6 to FEFLOW conversions, dewatering optimization workflows for consulting projects and software product, tools to emulate steam pressures in the unsaturated zones in geothermal sites, software infra structure to allow the use of PEST with FEFLOW models, and high-complexity 3D models in mining environments for operations (dewatering and depressurisation), environmental purposes and dynamic coupling of pit-lake and groundwater models in mine closure projects. His experience also encompasses civil engineering projects, including modelling for underground tunnels, basements, and slope stability purposes as well as experience in contaminated sites, including field activities, and remediation projects (pump and treat and phytoremediation). Additionally, Dr. De Sousa was also an invited keynote speaker for the FEFLOW user conference in Adelaide, 2013, where he presented the importance customization in numerical models of high complexity.

Project Experience – Mining

Liwa Managed Aquifer Recharge, ACC/POSCO E&C, Liwa, United Arab Emirates. 2019. *Principal Groundwater Modeller.* Responsible for calibration, sensitivity analysis and uncertainty quantification of a Managed Aquifer Recharge project.

Office of Groundwater Impact Assessment, Brisbane, Australia. 2020 – Present. *Principal Groundwater Modeller.* Responsible for signal processing works for over 700 boreholes distributed across Brisbane, with the objective to identify and separate influences from rainfall, coal seam gas abstraction and private water users in groundwater level hydrographs. Contributor to design and fault-geology model discretization for the next-gen OGIA model.

Hope Downs, Rio Tinto Iron Ore, Pilbara, Australia. 2020. *Principal Groundwater Modeller.* Conceptualisation and development of a three-dimensional groundwater model of an open pit mine for slope stability purposes. Uncertainty analysis using PESTPP-IES.

Marandoo, Rio Tinto Iron Ore, Pilbara, Australia. 2020. *Principal Groundwater Modeller.* Conceptualisation and development of a three-dimensional groundwater model of an open pit mine for slope stability purposes. Uncertainty analysis using PESTPP-IES.

Koodaideri Solitude, Rio Tinto Iron Ore, Pilbara, Australia. 2019 – 2020. *Principal Groundwater Modeller.* Development of a Goldsim tailings water balance model for estimation of pit seepage rates and environmental impacts on groundwater. Results from Goldsim were used as inputs to a FEFLOW solute transport model.

Solitude, BHP, Arizona, USA. 2020 – 2021. *Principal Groundwater Modeller.* Model review and uncertainty analysis for a tailings dam model, aimed at estimating pore pressures and potential for slope failure.

Antapaccay, Glencore, Yauri district, Peru. 2019 – 2020. *Principal Groundwater Modeller.* Dewatering optimization for an open pit mine, including heavy customization of FEFLOW to allow the use of gradient methods (PESTPP-GLM) in the constrained optimization.

Candelaria, Client, Lundin Mining, Chile. 2020. *Principal Groundwater Modeller.* Responsible for model calibration of a three-dimensional groundwater model of an open pit mine for environmental impact assessments.

Clermont, Glencore, Clermont, Australia. 2018. *Principal Groundwater Modeller.* Groundwater model setup and calibration of an open pit coal mine for slope-stability analysis, and simulation of pore pressure intervention measures including horizontal drains and dewatering wells.

West Canning Basin Model, Department of Water, Perth, Australia. 2017 – 2018. *Principal Groundwater Modeller.* Responsible for conceptualization and development of a three-dimensional groundwater variable-density flow and transport model to be used by the local regulatory agencies (DoW) as a tool for water allocation. Involved the use of highly-parallelised parameter inversion using PEST and cloud computing on Amazon EC2 platform.

Lihir Gold Mine, Newcrest mining, Lihir Island, Papua New Guinea. 2009 – 2018. *Principal Groundwater Modeller.* Responsible for the development of three-dimensional groundwater flow and heat transport model for the site. The model was used to provide pore pressure distributions for slope stability analysis, and estimates on pit floor temperature, inflow rates and dewatering designs.

Collie Basin, Griffin Coal, Collie, Australia. 2015 – 2018. *Principal Groundwater Modeller.* Responsible for the development of several groundwater models for environmental impact assessments and mine closure-studies, including explicit modeling of pit lakes and their interactions with surrounding aquifers.

Cerrejon mine, Glencore, La Guajira, Colombia. 2016. *Principal Groundwater Modeller.* Responsible for the development of cross-section pore pressure models of open-pit mine for slope-stability purposes

Prominent Hill, OzMinerals, Coober Pedy, Australia. 2014 – 2015. *Principal Groundwater Modeller.* Responsible for the hydrogeological conceptualisation and numerical modelling of pore pressures of an open pit and its interaction with the adjacent tailings storage facility.

Pani Gold project, One Asia Resources, Hulawa, Indonesia. 2013. *Associate Groundwater Modeller.* Hydrogeological field investigation, including drilling supervision, packer testing and installation of Vibrating Wire Piezometers. Pore pressure groundwater modelling for slope stability purposes.

Stuart Oil Shale Project, Queensland Energy Resources, Yarwun, Australia. 2013. *Associate Groundwater Modeller.* Hydrogeological review and depressurization assessment for the Stuart oil shale deposit.

Arrow Energy, Brisbane, Australia. 2010. *Senior Groundwater Modeller.* Geological modelling and groundwater flow modelling for the environmental impact assessment of Coal Seam Gas activities.

QGC Energy, Brisbane, Australia. 2010. *Senior Groundwater Modeller.* Geological modelling and groundwater flow modelling for impact assessment of Coal Seam Gas activities.

BHPBIO, Various Locations, Australia. 2009 – 2011. *Senior Groundwater Modeller.* Pore pressure groundwater modelling for slope stability analysis for several sites across the Pilbara region.

Bluewater Ash Co-disposal, Bluewaters, Collie, Australia. 2008. *Senior Groundwater Modeller.* Developed a groundwater flow and transport modelling for the environmental impact assessment of pit backfilling with coal ash materials.

Wesfarmers Premier Coal, Wesfarmers, Collie, Australia. 2008. *Senior Groundwater Modeller.* Dewatering designs and mine water balance with the development of a groundwater flow model.

Bootu Creek Manganese Project, OM Holdings, Tennant Creek, Australia. 2008. *Senior Groundwater Modeller.* Groundwater flow modelling using MODFLOW developed for dewatering designs.

Nooitgedacht Groundwater Impact Assessment, Glencore, Nooitgedacht, South Africa. 2007. *Hydrogeologist.* Developed a groundwater flow model using FEFLOW with the objective of assess drawdown impacts caused by open pit coal mines.

Grootegeluk Groundwater Impact Assessment, Exxaro, Limpopo province, South Africa. 2007. *Hydrogeologist.* Developed a groundwater flow and transport model (MODFLOW-MT3DMS) to assess the impacts of ash co disposal in a coal pit. The model was integrated with geochemical models (PHREEQC) and unsaturated flow models to the define source term water quality and seepage rates.

Capanga Aquifer Characterization, Vale, Moatize, Mozambique. 2006 – 2007. *Hydrogeologist.* Worked in the field program and groundwater modelling activities for the aquifer characterization and impact assessment from river abstraction and open pit mining. Undertaken drilling supervision, groundwater and river level monitoring, groundwater sampling and aquifer tests.

ESKOM UCG Phase 2 Hydrogeological Investigation, ESKOM, Majuba, South Africa. 2006 – 2007. *Groundwater Modeller.* Undertaken field investigations and numerical modelling using FEFLOW for assessing impacts from underground coal gasification in the groundwater environment.

Kalgold Mine, Harmony, Mahikeng, South Africa. 2006. *Groundwater Modeller.* Developed a groundwater model using MODFLOW to assess groundwater impacts in terms of drawdown and baseflow reduction along streams. Undertaken site visit and groundwater monitoring.

Kayelekera Uranium Mine, Paladin, Karonga, Malawi. 2006. *Groundwater Modeller.* Geological modelling and hydrogeology conceptualization for an environmental impact assessment.

Ambatovy Tailings Storage Facility, Knight Piezold, Ambatovy, Madagascar. 2005 – 2006. *Groundwater Modeler.* Conducted field investigations and developed a groundwater flow and transport model using MODFLOW and MT3DMS. Field investigations included drilling supervision, aquifer testing and groundwater monitoring. Undertaken tailings seepage modelling and salt-load calculations in to local streams.

Ambatovy Mine Site Hydrogeological Study, Knight Piezold, Ambatovy, Madagascar. 2005 – 2006. *Groundwater Modeler.* Conducted field investigations and developed a groundwater flow and transport model using MODFLOW and MT3DMS. The model was used to assess groundwater drawdowns, estimate pit inflows and provide salt load estimates along local streams.

Project Experience – Water Resources

M4East Tunnel, Leighton/Samsung C&T/John Holland, Sydney, Australia. 2015 – 2016. *Principal Groundwater Modeler.* responsible for the development of groundwater models for excavation of underground tunnels, aiming at providing predictive estimates of drawdowns, tunnel inflows and pore pressures along the tunnel crown.

Melbourne Metro, CPB, Melbourne, Australia. 2016. *Principal Groundwater Modeler.* responsible for the development of groundwater models aiming at the impact assessment of different excavation methods in terms of drawdown and groundwater inflows.

North West Rail Link, Thiess/John Holland, Sydney, Australia. 2013 – 2014. *Principal Groundwater Modeller.* responsible for the groundwater modelling of the railway tunnel structures, aimed at the simulation of pore pressures above the tunnel crown and inflow estimates.

Lake Muir-Unicup, Department of Parks and Wildlife, City, Australia. 2013 – 2020. *Principal Groundwater Modeler.* Developed integrated surface water-groundwater and ecosystems model couplings using FEFLOW and the University of Western Australia suit of codes to simulate interactions and feedback loops between wetlands, groundwater and vegetation assemblages in semi-arid wetlands of Western Australia.

Phytoremediation site, Undisclosed client, Sao Paulo, Brazil. 2003 – 2007. *Groundwater Modeler.* Developed a groundwater flow model for estimation of evapotranspiration rates and effectiveness of a phytoremediation system. Also conducted field activities, including slug testing, groundwater monitoring and sampling.

Publications, Presentations, and Reports

SOUSA, Eduardo Reckziegel de; Fast Assessment of pore pressures and inflows in open pits using smart models. In: Modflow and More 2017, Proceedings, Golden, United States.

SOUSA, Eduardo Reckziegel de; Simulating open pit transient inflows and pore pressure distributions with variable data availability using FEFLOW and customized plugins: IFMOpenPits and IFMLinearPits. In: Modflow and More, 2015, Proceedings, Golden, United States.

SOUSA, Eduardo Reckziegel de, FOWLER, Mark, SWARBIRCK, Gareth; Importance of monitoring temperature in the improvement of groundwater models – an example from an open pit in Papua New Guinea. In: 9^{th} Symposium of Field Measurements in Geomechanics, Proceedings, Perth, Australia.

SOUSA, Eduardo Reckziegel de; Three-dimensional pore pressure prediction in dual phase conditions for slope stability assessment. In: International Symposium on Slope Stability in Open Pit Mining and Civil Engineering, 2013, Proceedings, Brisbane, Australia.

SOUSA, Eduardo Reckziegel de; When cross section modelling is not enough – Improving pore pressure modelling with use of full 3D models. In: 40th IAH International Congress, 2013, Proceedings, Perth, Australia.

SOUSA, Eduardo Reckziegel de; Improving open pit boundary conditions in FEFLOW with IfmOpenPits. In: 40th IAH International Congress, 2013, Proceedings, Perth, Australia.

SOUSA, Eduardo Reckziegel de; When layering is not enough – Converting geology block models into groundwater models. In: Modflow and More, 2013, Proceedings, Golden, United States.

SOUSA, Eduardo Reckziegel de; Improving recharge representation in FEFLOW with IFMMoveableRecharge. In: Modflow and More, 2013, Proceedings, Golden, United States.

SOUSA, Eduardo Reckziegel de; Myths on spatial discretization, quantification of errors related to geometry and layering misrepresentations. In: Modflow and More, 2013, Proceedings, Golden, United States.

SOUSA, Eduardo Reckziegel de; IFMPHREEQC - Multicomponent reactive transport model coupling Feflow and Phreeqc-2 - Preliminary benchmarking and implementation challenges. In: Modflow and More, 2011, Golden, United States.

SOUSA, Eduardo Reckziegel de; USHER, B; BERNARDES JR., C. Evaluation of the hydraulic effectiveness of a phytoremediation system from southeastern Brazil.In: GSSA Groundwater Conference, 2007, Bloemfontein – South Africa.

SOUSA, Eduardo Reckziegel de. Use of groundwater models to evaluate the effectiveness of Phytoremediation systems: an example from southeastern Brazil. In: IAH Congress – Groundwater and Ecossystems. 2007. Lisbon – Portugal.

SOUSA, Eduardo Reckziegel de; ROSA, A A S; CHEMALE JR, Farid; MAGRO, Francisco Henrique Simões; SCHERER, Claiton Marlon dos Santos. Estudo gravimétrico e magnetométrico da Bacia do Itajaí - SC - Análise preliminar. In: VIII SIMPÓSIO NACIONAL DE ESTUDOS TECTÔNICOS, 2001, Recife. 2001. p. 385-386.

SOUSA, Eduardo Reckziegel de. Avaliação preliminar dos recursos hídricos subterrâneos da região de Lajeado - RS. In: XII CONGRESSO BRASILEIRO DE ÁGUAS SUBTERRÂNEAS, 2002, Florianópolis. Boletim de Resumos. 2002. p. 87-87.

OLIVEIRA, A S; SILVA, M M A; WILD, Felipe; MALLMANN, Guilherme; PRADO, Maurício; SOUSA, Eduardo Reckziegel de. Caracterização Estrutural do Complexo Metamórfico Brusque na região de Camboriú e Tijucas, SC. In: VIII SIMPÓSIO NACIONAL DE ESTUDOS TECTÔNICOS, 2001, Recife. 2001. p. 99-102.

SOUSA, Eduardo Reckziegel de; LISBOA, Nelson Luis Amoretti. Caracterização hidrogeológica da região do Alto Taquari - RS. In: XIII SALÃO DE INICIAÇÃO CIENTÍFICA, 2001, Porto Alegre. Livro de resumos. Porto Alegre: Editora da Unversidade, 2001.

PHILLIP, Ruy Paulo; MALLMANN, Guilherme; PRADO, Maurício; SILVA, M M A; SOUSA, Eduardo Reckziegel de; WILD, Felipe; AREND, Silvana T; LIZ, Joaquim Daniel de; DUARTE, L C. Caracterização litológica e condições metamórficas do Complexo Metamórfico Brusque na região de Camboriú-Tijucas, SC. In: VIII SIMPÓSIO NACIONAL DE ESTUDOS TECTÔNICOS, 2001, Recife. Anais. 2001. p. 93-96.

MALLMANN, Guilherme; SOUSA, Eduardo Reckziegel de; PHILLIP, Ruy Paulo. Correlação entre os padrões de lineamentos mesoscópicos do Complexo Camboriú, Complexo Metamórfico Brusque e granitóides intrusivos na região de Camboriú. In: VIII SIMPÓSIO NACIONAL DE ESTUDOS TECTÔNICOS, 2001, Recife. Anais. 2001. p. 77-80.

WILDNER, Wilson; SOUSA, Eduardo Reckziegel de; NARDI, Lauro Valentim Stoll; LIMA, Evandro Fernandes de; SOMMER, Carlos Augusto. Ancient volcanic successions of Taquarembo Plateau - Brazil - Rio Grande do Sul State. In: IAVCEI GENERAL ASSEMBLY, 2000, Bali. Abstracts. 2000. p. 95-95.

SOUSA, Eduardo Reckziegel de; MORALES, Luiz Fernado Grafulha; PHILLIP, Ruy Paulo. Evolução estrutural e metamórfica do Complexo Metamórfico Brusque na Folha Camboriú (SG-22-2-D-II-2/III-1). In: XIII SALÃO DE INICIAÇÃO CIENTÍFICA, 2000, Porto Alegre. Livro de Resumos. Porto Alegre: Editora da Universidade, 2000.

SOMMER, Carlos Augusto; LIMA, Evandro Fernandes de; NARDI, Lauro Valentim Stoll; SOUSA,Eduardo Reckziegel de. Gênese e Evolução Geoquímica do magmatismo da Sequência Vulcânica Ácida - Dom Pedrito - RS. In: SIMPÓSIO SOBRE VULCANISMO E AMBIENTES ASSOCIADOS, 1999, Gramado. Livro de Resumos. Porto Alegre: Editora da Universidade, 1999. p. 29-29.

WILDNER, Wilson; LIMA, Evandro Fernandes de; SOUSA, Eduardo Reckziegel de. Interpretação de texturas vulcânicas Cambrianas preservadas no Platô do Taquarembó - RS. In: SIMPÓSIO SOBRE VULCANISMO E AMBIENTES ASSOCIADOS, 1999, Gramado. Boletim de resumos. 1999. p. 42.

SOUSA, Eduardo Reckziegel de; WILDNER, Wilson; LIMA, Evandro Fernandes de. Química mineral das lavas comendiíticas do Platô do Taquarembó - Dom Pedrito - RS. In: XI SALÃO DE INICIAÇÃO CIENTÍFICA, 1999, Porto Alegre. Livro de Resumos. Porto Alegre: Editora da Universidade, 1999.

SOUSA, Eduardo Reckziegel de; LIMA, Evandro Fernandes de. O vulcanismo ácido neoproterozóico do Escudo-Sul-Rio-Grandense: Estratigrafia, Ambientação Geotectônica e Evolução Petrogenética. In: X SALÃO DE INICIAÇÃO CIENTÍFICA, 1998, Porto Alegre. Livro de Resumos. Porto Alegre: Editora da Universidade, 1998. p. 73-73.

<u>ATTACHMENT D:</u>

SINGLETON STATION HORTICULTURE PROJECT – EIS AND APPENDICES, FOCUSSED REVIEW

Prepared by Dr Ryan Vogwill of Hydro Geo Enviro Pty Ltd

6 February 2023

SINGLETON STATION HORTICULTURE PROJECT - EIS AND APPENDICES, FOCUSSED REVIEW

PREPARED FOR | Central Land Council - Northern Territory

PREPARED BY | Hydro Geo Enviro Pty Ltd

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Proprietary Information Statement

Document Information

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Contents

Overall Summary of Review

There is very little new hard data or analysis (if any) presented in my areas (hydrogeology, hydrology, impact assessment modelling and GDE impacts). The salinity assessment is definitely an improvement but is not based much site-specific data. The surface water assessment and management plan are suitable and fit for purpose. The risk of surface water derived impacts is low.

The EIS contains reference to aquatic GDEs but the proponent and their consultants have just applied the terrestrial GDE criteria with no justification of their suitability to an aquatic ecosystem. Aquatic GDEs typically need more stringent criteria than terrestrial vegetation in my experience.

Monitoring and adaptive management plans are generic and have very little actual detail about what will be done when and where. These documents are effectively "a plan to make a plan" after the project is approved, many of the studies proposed to be undertaken after approval should be undertaken before approval to give regulators and stakeholders more confidence in the suitability of the monitoring and adaptive management frameworks.

The existing issues from my previous reviews have not been addressed and in many ways this referral and associated documents contain less information than some of the previous reports. Without good data and analyses underpinning them, the risk assessment presented in the EIS (likelihood verses consequences style) is qualitative and subjective. They have assigned risk ratings but others might assign very different risk rating both before and after proposed management actions. The project team and consultants should not be developing these risk ratings in isolation, they need to include a wider stakeholder group to give these risk ratings any substance.

I would encourage the NT EPA to apply a Tier 3 assessment and require that the proponent addresses these issues prior to approval.

Introduction

The Environmental Impact Statement (EIS) for the NT EPA referral (including some of the appendices) for the Singleton Horticulture Project have been reviewed by HydroGeoEnviro at the request of Central Land Council (CLC). The aim of this review was to assess, at a high level, what new material has been presented and if any conclusions from my previous reviews of the hydrogeology, groundwater modelling and GDE impact potential would change due to the material presented in the EIS. My scientific opinion on the level of assessment was also requested. Points of interest or note resulting from review of the individual document are presented by document below. Where page numbers are referred to, they represent the PDF page number (not the page number in the document headers/footers) to prevent confusion. Given the focus of this review was to assess what additional information is available compared to previous documents produced by the proponent and their consultants, a review of each document is not included however overall comments for some documents are included where I've considered it appropriate.

Individual Document Review Points

Main Referral Document - nt-epa-referral-singleton-horticulture-project.pdf

Page 6 - The Minister declared the Western Davenport Water Allocation Plan (WAP) 2018 - 2021 in December 2018, hence FAFM's application for a Water Extraction Licence was in the context of the declared WAP 2018-2021 (Department of Environment, Parks and Water Security 2021).

> Comment - New WAP is forthcoming and the cited WAP should be referred to as out of date.

Page 8 - 1. Water Extraction Licence (WEL) to access 40,000 ML groundwater per year (Granted)

> Comment - Only stage 1 (12,788ML) has been granted, they have conditions that need to be fulfilled to access more the license entitlement. This should be stated here to not give a false impression of full license approval.

Page 8 - The environmental risk assessment identified 38 risk events in total, and of these no risks were assessed to have a residual risk higher than medium, of which there were 10.

> Comment - Table states 9 not 10 and I would likely disagree with the rankings in Table 1-1. This disagrees with a table later in the document and I counted 13 medium residual risks in Section 6, this should be confirmed. Maybe Table 1-1 didn't include the climate change (CCRA Summary in Table 7-20 which has 3 medium residual risks) but I would think it should?

Page 9 and 10 - Inland water quality Groundwater

> Comment - No mention of herbicides, pesticides and nutrients which all have potential to cause impacts. Mentioned later but should be here also.

Page 10 - Aquatic ecosystems

> Comment - Good that this is finally included but they don't appear to have much data still on this (will confirm later in the review - confirmed just using terrestrial criteria). Wetlands that could be impacted are more diverse than just waterway pools, springs and soaks. This is a very limited definition of aquatic ecosystems and systems other than these can have groundwater dependence. The WAP GDE criteria have not been altered, just expanded to include aquatic GDEs with no additional protection (criteria) for aquatic ecosystems. This

shows a lack of acknowledgement of the heightened sensitivity of aquatic ecosystems to drawdown.

Page 17 - Negative impacts to over 30% of all sandplain **and** alluvial GDEs modelled to occur within Singleton Station and/or the whole Western Davenport Water Control District.

Comment - I think it is 30% impact to either not both combined if I remember the WAP correctly. The **and** should be or. How would the % of GDEs impacted change under a reasonable range of model uncertainty? This is a significant issue in the impact assessment and baseline data collecting processes as previously discussed.

Page 33 - The Review Panel provided its report to the Minister on 15 October 2021. On the 15 November 21, the Minister made the decision to replace the water extraction licence with a new licence that included additional (2) conditions precedent and amended conditions precedent (1).

Comment - Important to note that the minister did not follow the review panel's recommendations on WEL staging volumes (5,000ML/stage?).

Page 39 and 40 - 3.1.1.2 Western Davenport Water Allocation Plan.

The WAP estimates sustainable yield for groundwater for the Western Davenport Water Control District as a whole as 168,405 ML/year, of which 138,405 ML/year is available for extraction for beneficial uses other than environmental and cultural.

Comment - Nothing new here and the sustainable yield is based on 80% depletion of aquifers which are poorly understood. Sustainable yield should be sustainable and not mining 80% groundwater by definition. How does the license compare to annual average recharge as would be used in other jurisdictions to determine sustainable yield? Looking at the WAP (except below) 40,000ML/year is a very high proportion of recharge (40,000/57,000 = 70.1% of average annual recharge). However, they state in the WAP that "Recharge is the portion of rainfall that passes through the unsaturated zone into the saturated zone, less the evapotranspiration loss. This is the volume of water that enters the groundwater system." how much of this is deducted from the recharge? If it is half of it (12,500 ML) then 57,000-12,500 = 44,500 ML per year so 40,000/44,500 = 90%.

WDWAP Management zone	Natural Evapotranspiration	Modelled Recharge
Davenport Ranges	4,000	11,000
Central Plains	25,000	57,000
Southern Ranges	1,000	36,000
TOTAL	**30,000**	**104,000**

Page 51 - Figure 3-4

> Comment - The western bore field is located within the crop plots, but the eastern bore field isn't. If the eastern bore field was located in the cropping area it would reduce clearing substantially. Not sure how this "minimises land clearing required"?
>
> This is their statement on page 62 "Careful micro-siting of bore fields to minimise both initial clearing …" and on page 75 "Co-locate the cropping areas and the bores as far as practical." it is not clear why the eastern bore field couldn't be inside the eastern crop area or better if the proposed eastern cropping area was located on the eastern bore field (i.e. further away from Thring Swamp). Likely to do with soils/land units and flooding but the logic should be briefly stated at this point. Moving the eastern bore field into the eastern plots will move them 1-2 kilometres closer to Thring Swamp (higher impact risk) but will reduce land clearing. This is a difficult trade off given the high uncertainty of impact prediction modelling.

Page 62 - Crops that have a higher water demand located further from identified GDE areas than those with less water demand, thus reducing the GDE impact

> Comment - This makes little sense as the water demand for the crops isn't relevant to impacts to GDEs, the location of the supply bores is. More relevant in terms of contamination (salinity, nutrients etc) but this section is about "configuration of supply".

Page 62 - Pumping tests will be carried out at a more detailed stage of design to confirm the sustainable yield of boreholes on site.

> Comment - This is not directly relevant for sustainable yield it's about calculating hydraulic parameters, and bore efficiency (well loss etc). This would need to be done prior to license approval in many other jurisdictions. More bores will be required if they cannot get their 1ML/day per bore so more clearing etc. This is an example of why the basic investigation work should be done prior to approval.

Page 67 - In addition to the reduction in nutrient and chemical use

> Comment - First mention of "chemical use" in an environmental impact context which I presume would include the herbicides, pesticides etc as previously commented on.

Page 97 - The ephemeral pools that remain are important from a local perspective and provide a surficial water resource (albeit scarce and inconsistent) that is critical to the biodiversity and cultural values of the area (Burgess et al. 2016). They are also an important grazing resource for local pastoralists (Burgess et al. 2016).

> Comment - I'm surprised and concerned that these biodiversity and culturally significant sites are not fenced to exclude stock. Increased weeds and nutrients, physical disturbance of seedlings and small plants in these sensitive wetlands will all be consequences of this. Noit relevant to the review but of concern.

Page 107 - Surface aquatic GDEs within Singleton Station are distributed through alluvial country along the sandy channels of the major creek systems including Wycliffe Creek, Hurst Creek and Skinner Creek

> Comment - As above only mentioned but with not assessment of their sensitivity to drawdown compared to terrestrial.

Page 114 - Figure 5.13 GDE sacred sites within the Singleton Water Licence Area (Donaldson, 2021).

> Comment - First time I've seen this and its very interesting how closely the Dreaming Tracks follow drainages and all converge on Thring Swamp. This is intuitive and further highlights the cultural values and how they are connected to the landscape.

Page 121 - Table 6-5 Environmental risk analysis summary

> Comment - note numbers are slightly different to the summary as peviosuly noted but I'd disagree on their risk ratings. Highly qualitative and subjective.

Page 129 - It is likely that many species have higher vigour and biomass when able to access groundwater but can persist in the environment with moisture obtained during rainfall events.

> Comment - Possibly but if groundwater is removed from the root zone during high water stress periods it may cause species specific vegetation death, particularly for larger trees (which are often the most culturally important) that have greater inherent water requirements hence why they are occurring in areas where groundwater is available in the root zone. Root elongation rates need more consideration in the context of drawdown also.

Page 129 - There will be an adaptive management plan including monitoring and management of GDEs

> Comment - But what about areas currently not inferred to be GDEs due inaccuracies in the GDE mapping and water table elevation maps? If they aren't being identified and monitored it will be not possible to adaptively manage the impacts.

Page 129 - Details for this management plan will be developed and implemented prior to commencement of the Proposal.

> Comment - Should be completed prior to approval as how can the regulators and stakeholders know this plan is suitable?

Page 129 and 130 - The results of the MCAP (multicriteria analysis to determine the likelihood of occurrence of Stygofauna) were limited by the available data, Due to the lack of registered bores with data available close to the proposed bore field, it is difficult to ascertain stygofauna presence closest to the modelled area of intense drawdown.

and

Though the species and community assemblages of stygofauna found within the aquifer will inevitably dictate the extent of the impact on the stygofauna community

> Comment - Stygofauna assessment is desktop only and highly subjective. The extent of impacts also relates to drawdown and the type of aquifer as well as the ability of the species present to move with the water table as it declines. For example, if you have alluvial sediments underlain by low permeability fractured rocks the stygofauna may only be able to migrate as far as the base of the alluvial sediments which would then present a hard criterion for drawdown (i.e. drawdown to the base of the alluvial sediments). In WA stygofauna are often managed by applying a 50% drawdown criterion. This means that drawdown impacts can at most dewater half of their habitat so this would be half the thickness of saturated alluvial sediment in the example I've used.

Page 133 - Climate change - Terrestrial Ecosystems

However, the extent to which is difficult to predict, given the uncertainties around what constitutes negative impacts to GDEs in terms of biological condition.

> Comment - This is why the proponent needs to have pre development monitoring (less than 5 years data will not be sufficient, preferable 10 years or more) to determine an appropriate baseline of vegetation condition relative to rainfall and groundwater levels. There are quantitative measures (sapflow and dendrometry for example) that could be used. Also, no aquatic ecosystem assessment in the Climate Change section. The existing model, as uncertain as it is, could have been used to look at some climate change impacts with and without the project.

Page 141 - and where the features are hydraulically connected to the production aquifer

> Comment - This is simplistic. To be impacted aquatic GDE features do not need to be directly connected to the target aquifer. They could be connected to the alluvial groundwater (not the groundwater in the target aquifer) but if the target aquifer declines underlying the alluvial aquifer this may in turn impact alluvial groundwater levels.

Page 143 - The residual risks associated with the Proposal in relation to aquatic ecosystems do not exceed a residual rating of 'low'.

> Comment - as previously stated I would disagree with this subject and qualitative assessment.

Page 143 - The Salinity Impact Assessment (GHD 2022e) provides a solute transport model based on irrigation drainage in an average climate scenario and presents crop demand estimates (ML/ha/year) for a wet (90th percentile), dry (10th percentile) and average rainfall year (50^{th} percentile).

> Comment - So they can assess the climate variability/uncertainty on the salinity modelling but not in the other areas such as the groundwater model? Salinity present only minor risks compared to drawdown.

Page 143 - The potential to impact offsite receptors during and after completion of the Proposal will be assessed by further modelling after the completion of further onsite investigations.

> Comment - This should be done before approval in my opinion.

Appendix-e-groundwater-extraction-allocation-licence-no-wdcp10358.pdf

Comment - Dated 15/11/2021, no new information.

Appendix-g-singleton-horticulture-project-monitoring-program-and-adaptive-management-plan.pdf

Page 13 - Protection of the aquifer integrity, e.g. avoidance of aquifer compaction

> Comment - This seems like an odd objective for the GMP, possibly they mean aquifer depressurisation and subsidence but it's unclear.

Page 17 - Using the above criteria and the existing groundwater model, FAFM has designed a bore field that is predicted to negatively impact an overall maximum of 10.5% of GDEs on Singleton during the 30 year life of the project. In the 30 years following shutdown of the bores, the impact reaches a maximum of 15.6% (12.7% and 25.3% respectively on the alluvial landform). These are well within the allowable limits (30%).

> Comment - But how do these percentages of GDE's impacted vary under a reasonable range of parameters in the groundwater model? Same issue and question as is previous impact assessments without even beginning to look at conceptual uncertainty.

Page 17 - There are recognised uncertainties with numerical groundwater modelling, however, these are addressed as part of the adaptive management strategy.

> Comment - And what happens if after collecting monitoring and recalibrating the model it predicts that more than 30% of GDEs will be impacted in a particular landform? Active adaptive management necessitates uncertainty analysis prior to approval.

Page 18 - Table 6 Sensitive receptors and their relationship to the FAFM borefield

> Comment - This table could be much more complete based on existing data, for example the location of Neutral Junction is known and post Susan Donaldson's work we know the location of sacred sites, e.g. specific trees, soaks and water holes.

Page 20 - Far from the borefield to establish background conditions. In some cases these would be established in GDE locations which may not be effected for 10 years to 20 years after the commencement of pumping. This is required to obtain background information pre-groundwater disturbance, but also to understand potential variations caused by longer term influences, e.g. climate change

> Comment - What if the potentially impacted GDE's change as the baseline data is collected and the model is updated? How will baseline data be collected for sites that haven't currently been acknowledged as potentially impacted but are then predicted to be impacted in future iterations of the groundwater modelling? This is one of the reasons why the assessment level needs to be higher before commencement of the project and the GDE impact area needs to incorporate the uncertainty in impacts as currently predicted by the groundwater model.

Page 21 - Verification of predictive modelling

> Comment - The modelling is at stage where this is not really a verification (which has a particular meaning in groundwater modelling) it is attaining a minimum sufficient transient calibration which does not currently exist.

Page 22 - This is a common, unavoidable issue with many developments. However, with the staging of the entitlements, and implementation of an adaptive management plan, a long time series of baseline information can be obtained to support the assessment of conditions associated with sensitive receptors.

and

At the time of preparation of this GMP, FAFM have no monitoring or production bores established at the SHP.

> Comment - It is clearly avoidable as they have had ample opportunity (time) to collect the data to have a better assessment now. In many jurisdictions this would be required before approval.

Page 23 - The current NGM predicts that the groundwater drawdown will not reach these areas until after 15 years of pumping. Under these circumstances FAFM will obtain at least 15 years of monitoring information at these sensitive receptors prior to any water level disturbance predicted to be imposed by FAFM.

> Comment - What if the drawdown propagates much quicker than anticipated or in areas that were unanticipated (i.e. drawdown propagates at depth rapidly along preferential flow paths with monitoring focused on the near project/shallow water able? You need to understand the hydraulics of the aquifer before you can predict where impacts will occur, but here there is still significant conceptual uncertainty let alone everything else.

Page 24 - The location of the existing NT network bores is shown in Figure 3, and their construction and formation monitored summarised in Appendix A.

> Comment - Figure 3 has been censored in the document, not very helpful to assess suitability. Likewise, on page 25 Figure 6 has been censored. I know the rough distribution the network from other reports. Why haven't these been monitored for the last 5+ years and the data used to calibrate the groundwater model?

Page 25 - Extensive NGM has been undertaken to determine the staging of the borefield development

> Comment - Extensive is not the term I'd use. Regardless The "extensive NGM" but has little data for model conditioning and calibration. I would argue that the modelling is not extensive and is preliminary, targeted on operational issues not off-site impacts. They have lots of modelling focussed on borefield design.

Page 25 - Bores are installed well before the predicted radius of influence is reached, to provide a minimum of 2 years, and for some sensitive receptors, over 15 years, baseline data prior to water level disturbance.

> Comment - Which receptors are getting 2 years and which are getting 15 years of baseline data? This is important to stakeholders.

Page 29 - Additional monitoring bores will be installed if the measured drawdown in bores outside the borefield exceeds those triggers specified in this plan (refer section 8.4), e.g. water levels in monitoring bores are greater than 20% different from that predicted by the most up to date numerical groundwater model. Monitoring bores will be installed a minimum 2 years in advance of the predicted model extents, so that background water level and water quality can be obtained within the 24 months prior to 'predicted' change.

> Comment - 20% is a strange criterion to use as this works very differently with water levels in mAHD verses meters below ground level (mBGL). What will the 20% be based on? I think an absolute level in meters should be specified. 2 years will likely not be enough to specify a suitable baseline at GDEs and TO sites. Will biological data be collected at GDE sites at the same time and place? In my experience this is critical.

Page 30 - All sites will be assessed at the beginning of the project and then on a five yearly basis.

Comment - 5 years is infrequent, should be sub annual at the start and scale back once (if) they understand how the aquifer actually works and where it is connected to GDEs.

Page 33 - 6.3.3 Soil quality and 6.3.3.1 Method

> Comment - Simplistic monitoring for soil quality, they should consider using tensiometers and other installed soil/unsaturated monitoring equipment rather than repeatedly doing test pits/auger sampling. Nearby sites (extracted samples taken from the same location) may have slightly different soils and structure so may not be directly comparable.

Page 34 - 6.3.4 GDE Health 6.3.4.1 Method

> Comment - This section is vague and generic, more detail required. What does the "formal condition assessment" entail? Quarterly is a good frequency and 5 years is minimum however on page 29 they said 2 years for water monitoring? Biological and hydrogeological monitoring must be undertaken together at the same frequency in the same places.

Page 34 - The predominant sacred sites in the vicinity of SHP are trees, water holes and soaks.

and

However, FAFM plans to consult with the Traditional Owners of this land in order to seek their input to identifying sites that they wish to be monitored and to include these in the monitoring program

> Comment - As I've previously stated this as a limited subset of cultural (wetland) assets. Thring Swamp? Dreaming lines? I think at this late stage the TO consultation needs to be much more complete.

Page 36 - 7. Risk register

> Comment - This should be much more completely developed at this stage. They could have completed most of this but have done almost none.

Page 36 - FAFM propose to undertake a number of site investigations, including exploratory drilling and pumping test investigations, to a) assess the development potential of the aquifer and b) install the monitoring network.

> Comment - By now they should know this for their own security as well as environmental/cultural values.

Page 39 - A <u>comprehensive</u> groundwater model that is used to predict the rate and extent of groundwater drawdown, and subsequently <u>used to predict the impact</u> on GDEs.

Comment - This an overreach of their assessment (modelling and GDEs) to say the least. On page 43 they state "The groundwater model is based on assumptions around aquifer properties that are based on relatively limited data." for example. Contradictory. With this model you should not predict "the" impact you should predict a range of possible impact, i.e. predictive uncertainty.

Page 43 - No site-specific investigations of soaks have been undertaken. The initial hydrogeological conceptualisation of these soaks are that they are fed by water that is less than 2 m depth.

Page 44 - Initial hydrogeological conceptualisations suggest that there may be perched water present which is accessible for GDEs.

> Comment for 43 and 44 - So this is based on basically nothing? Perched water is unlikely to be the case for all of them, this is relatively rare.

Page 49 - Table 15 and Artificial watering of GDEs - If a specific GDE location cannot be protected through this means, re-adjust the pumping regime elsewhere on the project to 'save' others which were 'planned' to be impacted, i.e. an offset process.

> Comment - This is not likely to be successful to protect TO sacred sites (which cannot be "swapped" for another site). Given their lack of understanding, by their own admission, this table is highly speculative. In my experience artificial maintenance (watering) is typically not successful in stopping GDE impacts, I can give some examples. Also you need to know relative value of these cultural assets to be able to offset impacts.

Page 53 - Indigenous Rangers

> Comment - Is there any actual agreement between FABM and CLC?

Page 57 - Recalibration (if required): if large differences between obseCommented and predicted groundwater levels are identified, then a recalibration of the NGM may be necessary.

> Comment - Recalibration will be required as no transient calibration exists for most of the model domain. No model ever matches reality (particularly when the model is so highly uncertain) so this statement is misleading in that it gives a non-specialist in modelling the impression that the model is near perfect when it is in fact highly uncertain and preliminary.

Page 57 - Provide a critical review of uncertainty of the science and technology presented and the conclusions reached

> Comment - This should be done by now not at some unspecified time in the future.

Appendix-l-singleton-horticulture-project-salinity-impact-assessment.pdf

Overall - There is insufficient time to review this in detail but I have completed a high-level review. The assessment looks reasonable. The method is generally suitable and the assumptions over model parameters etc are reasonable. However, there are again issues with a lack of site-specific data as in all of their assessments. They have made the assumption that as the increased salinity water is flushed to the aquifer this does not change the irrigation water's salinity, this feedback could cause moderately worse salinity impacts than currently predicted although this will be predominately an issue for FABM operationally.

Page 14 - Given site-specific information is limited, GHD has assumed values based upon the broader Davenport region, or from correlations with other areas. A sensitivity analysis was completed to address uncertainty attached with the quantification of salt movement within the unsaturated and saturated zone (section 5.4.2). The modelling should be revisited when site specific information becomes available (as proposed by planned additional field investigations described herein).

> Comment - So this is not a site-specific assessment more of a generic/desktop type assessment.

Page 27 - Key to this impact assessment was the identification of additional information required to fully characterise the existing environment, noting that FAFM has scheduled additional field investigations to be undertaken in the second quarter of the 2022-2023 financial year.

> Comment - This time has passed so has this investigation occurred? Again, this assessment is not based on site specific, measured data.

Page 34 - The proposal is at least 5 km east from the Thring Swamp Site of Botanical Significance (SoBs) and is within the area likely to experience drawdown as a result of groundwater extraction.

> Comment - At least they have acknowledged the existence of Thring Swamp and identified that it will experience drawdown. Why is this not noted more in other impact assessments and studies? My understanding is that it is a key cultural asset that is an aquatic GDE surrounded by some areas of terrestrial GDE.

Page 61 - leaching fraction has been used for modelling based on an assumed groundwater salinity of 900 mg/L. If groundwater salinity is significantly lower or higher as verified through intrusive drilling and groundwater sampling, the leaching fraction may require amendment.

Comment - Given there is no site-specific data this (the leaching fraction may require amendment) will likely need to happen, implications of higher salinity water will be significant on this threatening process. Climate obviously important in this also. This will be mostly an operational issue for them to manage and off-site impacts are unlikely, however there will be on site project impacts from this that may impact the on-site GDEs etc.

Appendix-m-gdv-model-validation-figures-extracted.pdf

Overall - highlights the inaccuracy of the GDV model technique but at least they are doing field studies in some areas. This should be coupled with a groundwater assessment as they are using model derived depth to groundwater estimates. Is the inaccuracy in the estimate of GDVs due to the inaccuracy of the NDVI technique or the groundwater modelling/water table elevation mapping? I think a useful additional validation (and one that is independent) would be to look at MODIS derived transpiration estimates which are available (I have checked). Even noting all this yes, the false negatives are few but exist and these represent sites that are GDEs but the model didn't identify them as such. What if the sites assumed to not be GDV have high cultural or biodiversity value? What other GDE sites are being missed?

Page 4 - Most of the areas that were thought to be incorrectly identified as GDV by the NDVI model on alluvial landform were patches of mulga (Acacia sp.), usually with scattered, small Eucalyptus victrix, on sites receiving run-on from the adjacent plain. Typically, these densely vegetated areas occur either at the fringes of the alluvial plain, or fringing localised depressions within the floodplain.

and

These dense areas of persistent woody vegetation were wrongly identified as likely GDV by the model.

> Comment - Just because these receive run-on doesn't mean they aren't groundwater dependant. Measured depth to groundwater or plant ecophysiology are the only conclusive discriminators.

Page 42 - Sandy channels of the major creek systems originating in the Davenport Ranges, such as Sutherland Creek, Wycliffe Creek, and the upper section of Hurst Creek are all high probability GDV in the NDVI model, despite sections of the latter two occurring at DTGW >15 m. These coarse sandy channels are characteristically lined with river red gums (Eucalyptus camaldulensis)(Figure 21), which are likely tapping into a perched aquifer rather than the regional water table as has been obseCommented in the Ti-Tree Basin (Villeneuve et al. 2015). Because of this, suCommentey sites were not included in this vegetation type.

> Comment - Model derived DTGW estimate are not categorical in terms of defining GDV. Just because there are "perched aquifers" in the Ti Tree area doesn't mean they occur here. This needs to be proven not inferred. Not sufficient data to exclude this important vegetation type.

Page 52 - GHD has now conducted an extensive GDV field study to ground-truth the NDVI model and the desktop landform mapping and has found that in most cases the model was reasonably successful in identifying areas of GDV.

> Comment - Is it extensive? I'd say preliminary. It's definitely an improvement. The most important ground truthing is measured depth to groundwater which still hasn't occurred.

Appendix-r-singleton-horticulture-project-gde-mapping.pdf

Overall - Not reviewed as is essentially the same as earlier documents just with a different bore field scenario.

Appendix-s-singleton-horticulture-project-station-baseline-flood-assessment.pdf

Overall - This report is completed to industry standards and is fit for purpose given the low flooding risk at the site. Their validation and reasons why the validation doesn't match the output of their modelling make sense.

Page 6 - Due to the relatively short design life of the project, the flood modelling has not considered long term changes in rainfall, such as climate change.

> Comment - 30 years isn't that short and I would think that some assessment would be prudent as significant climatic changes are predicted by 2050. This is more of an operational issue than an impact issue however.

Appendix-t-singleton-station-horticultural-operation-surface-water-management-plan.pdf

Overall - Reasonable plan and monitoring locations. Low risk to CLC with the exception of impacts to the actual site (including on site natural drainages). These areas are likely to be impacted regardless.

Appendix-w-singleton-horticulture-project-climate-change-risk-assessment.pdf

Overall - good summary of likely (and the range in) climate change impacts but is focussed on operational issues. No investigation of the impact of climate change on groundwater, surface water or the environment. Generic desktop-based risk assessment but a good summary of climate change .

Appendix-y-groundwater-modeling-cloud-gms.pdf

Overall - Very little of note, salinity data map (not FABM - NT government) has significant uncertainty in it as they just contoured up all data regardless of depth. This is not good practise and makes the map of little use.

ATTACHMENT E:

DEVELOPING ADAPTIVE MANAGEMENT GUIDANCE FOR GROUNDWATER PLANNING AND DEVELOPMENT

Thomann, J.A., Werner A. and Irvine D.

Journal of Environmental Management, 322 (2022) 116052

SINGLETON STATION HORTICULTURE PROJECT - ADAPTIVE MANAGEMENT PLAN ASSESSMENT AGAINST THOMANN ADAPTIVE MANAGEMENT REVIEW PAPER

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Contents

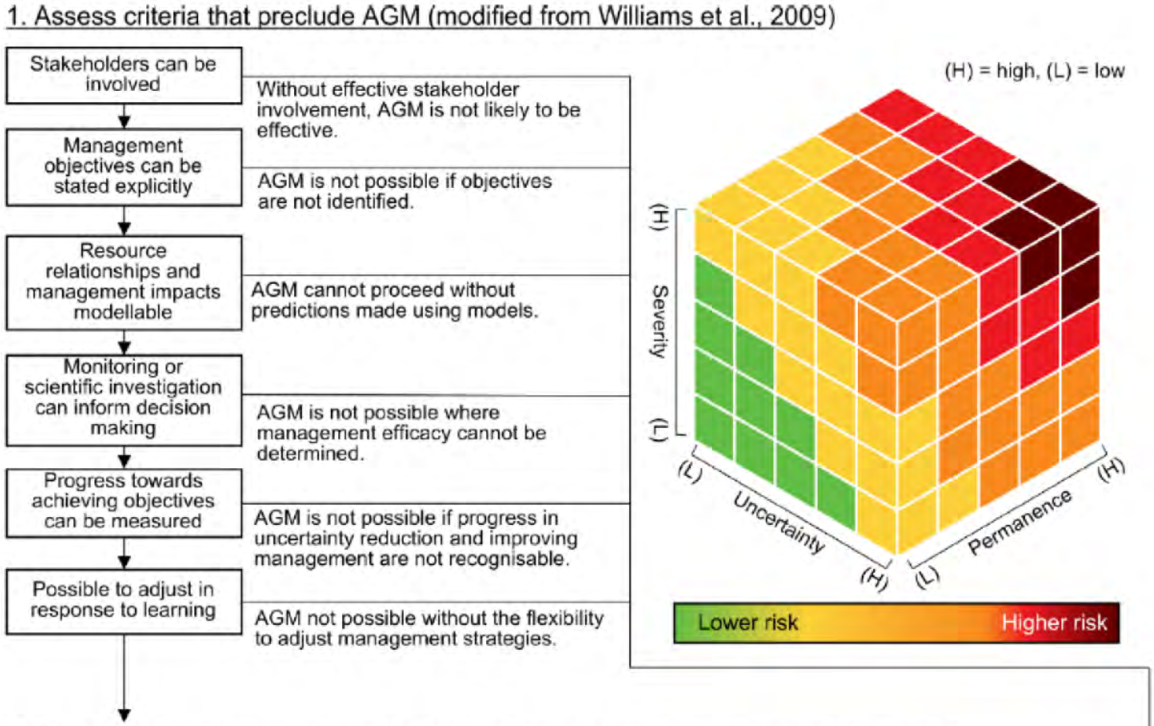
Introduction

This report is a review of the adaptive management plan (AMP) for the Fortune Agribusiness Funds Management Pty Ltd (FAFM) at the Singleton Horticulture Project (SHP) (appendix-g-singleton-horticulture-project-monitoring-program-and-adaptive-management-plan.pdf). It is based on the Thomann et al. (2022) paper titled - Developing adaptive management guidance for groundwater planning and development.

As an initial comment I found the Thomann et al. (2022) paper to be well-researched, well-considered and a useful framework by which to evaluate the level of adaptative management required for a project (i.e. active, passive or trial and error) and is current (published in 2022). The authors are well respected and experienced from high quality academic institutions with experience in groundwater and adaptive management.

The reader is directed to this paper for a full description of the figures and tables contained herein but some excerpts have been included (Table S2 and Figure S3) to assist the reader and the full paper reference is included immediately below.

> *Thomann, J.A., Werner, A.D. and Irvine, D.J., 2022. Developing adaptive management guidance for groundwater planning and development. Journal of Environmental Management, 322, p.116052.*



2. Evaluate severity, permanence and uncertainty to inform management approach

Factor combination	Influence on management strategy	Groundwater example	Approach
High severity, high permanence, high uncertainty.	Use of AGM may result in failed objectives and long-lasting, severe consequences. Assess stakeholder priorities and risk/reward tolerance to determine if the project should proceed	A greenfield mining project with a nearby environmentally and/or culturally significant GDE	AGM not advised
High severity, high permanence, low uncertainty.	AGM not appropriate due to inability to adapt to permanent impacts. "Make good agreements" may be investigated to offset impacts if the project is approved.	Project where destruction of a significant asset is required.	
High severity, low permanence, high uncertainty.	An investigation plan targeting key uncertainties related to severe impacts should be developed. This plan should be linked to stakeholder re-involvement in a structured way.	Project that may cause temporary loss of access to critical groundwater resources for other users.	Active AGM
Low severity, high permanence, high uncertainty.	An investigation plan should be developed to reduce uncertainty relating to permanent impacts.	An excavation or construction that intersects the water table to a shallow depth.	
Low severity, low permanence, high uncertainty.	Attainment of hydrogeological data for reduction of key uncertainties is recommended due to limited understanding of the site.	Greenfield irrigation site with renewable groundwater and no sensitive assets nearby.	Passive AGM
High severity, low permanence, low uncertainty.	Additional structure in management planning and development may be required due to the potential for severe impacts.	High rate groundwater extraction site, with spatially concentrated wells.	
Low severity, high permanence, low uncertainty.	Ad hoc management may be acceptable due to high confidence in predictions of impact combined with the lack of significant assets.	A mine with no nearby sensitive assets (e.g. GDE and/or other water users).	Trial-and-error
Low severity, low permanence, low uncertainty.	A long history of data collection and hydrogeological investigations combined with the lack sensitive assets, and reversible impacts means ad hoc management may be acceptable.	A brownfield irrigation site with no nearby sensitive assets of significance.	

Figure S3. Influence of severity, permanence and uncertainty on AGM.

Table S2 - Translation of AM elements to AGM elements. Active AGM is taken to include criteria under both active and passive columns. Italicised 28 text in the Passive column denotes where the DOI framework has been translated or extended to apply to groundwater problems. The Active 29 column represents additional management planning and development content required to meet the standard of active AGM.

Element	Passive	Active
Investigation	1. *At the project outset, collect baseline data to determine the prior status of the water resource.* 2. *Identify key knowledge gaps in the understanding of the relevant processes in the hydrogeological system.* 3. *Ensure sufficient data are available to inform/define plausible conceptual hydrogeological models.*	4. *Reduction in hydrological and ecological uncertainty through the targeted collection of data and analyses is demonstrated.*
Stakeholder involvement	1. Stakeholders must be identified and encouraged to participate [1]. 2. A process must be implemented that solicits stakeholder input in the design of the *AGM* project and the identification of management objectives and potential management actions [1]. 3. Stakeholders must commit to an agreed-upon process of reducing uncertainties and/or disagreements about the effects of management [1]. 4. Stakeholder organisations must be encouraged to commit time and energy to adaptively manage the *groundwater system* over the agreed-upon timeframe [1]. 5. *Information that underpins management decision-making should be easily accessible to stakeholders and conveyed in a way that enables an understanding of predicted risks and uncertainty associated with these predictions.*	6. *Hydrogeological investigations and the AGM approach should be independently peer-reviewed, and the findings of peer review should be made available to stakeholders and the broader scientific community.* 7. *Stakeholders are re-engaged at agreed-upon timeframes, allowing for revisiting and revision of stakeholder values and concerns in the context of revised uncertainty estimates arising from project progress.*
Objectives	Objectives should [1]: 1. Be unambiguous, with specific *hydrogeological variables (e.g. groundwater levels, flow rates, solute concentrations, groundwater-dependent ecosystem health indicators)* and specific target conditions. 2. Contain *hydrological and ecological* elements that can be readily measured, to promote the evaluation of management actions and recognise their contributions to successful management. 3. Be achievable based on the capacities of the *groundwater system* being managed and the political or social system within which management occurs. 4. *Define endpoints for the groundwater system in terms of metrics for quantifying groundwater system health.* 5. Indicate the timeframe for achievement, including where durations exceed that of the project.	6. *Contain measures, timing and target levels of uncertainty reduction.*
Management alternatives	1. Adaptive decision making involves selecting a management action at each decision point, on the basis of the *condition of the groundwater system* at the time [3]. 2. Management alternatives in adaptive *groundwater* management often focus on a potential change in *groundwater system* status or the alteration of process rates *(e.g. groundwater abstraction, groundwater recharge/discharge fluxes)* [1]. 3. Alternatives should be explicitly documented *and quantitatively assessed* [1].	As per passive AGM

Predictive modelling	1. The models used in adaptive *groundwater* management generally share *the following* certain attributes [1]. a. The *groundwater system* is described as changing through time, to allow learning to occur and management to adapt to learning. b. The hydrological system is characterised by key components of interest *(e.g. groundwater level, solute concentration, ecological health indicators)* that are the focus of management and the targets of monitoring. c. Changes often are described in terms of processes *(e.g. drawdown propagation, seawater intrusion, baseflow and/or spring flow)* that are thought to be directly influenced by management. d. Fluctuating environmental conditions *(e.g. seasonal variability in rainfall)* are incorporated as needed to characterise resource dynamics. e. Management impacts are described in terms of costs, benefits, and influences on components *of the groundwater system* or processes that are highlighted in the model. f. Models are calibrated with available data and knowledge, to ensure compatibility with current understanding about resource structures and functions. 2. The suite of models should capture key uncertainties (or disagreements) about resource processes (e.g. source aquifer of GDE water) and management effects [1].	3. *Quantitative modelling should be performed for the range of actions proposed during the "management alternatives" stage under each system conceptualisation.* 4. *Quantitative uncertainty analysis with respect to predictions of interest should be performed. This uncertainty assessment should be repeated over the lifespan of a project to quantify uncertainty reduction achieved through project activities.*
Monitoring and analysis protocols	In general, monitoring *and analysis* provide data for four key purposes [1]: 1. To evaluate progress toward achieving objectives. 2. To determine the *state of key indicators of the groundwater system*, in order to identify appropriate management actions. 3. To increase understanding of *groundwater system* dynamics via the comparison of predictions against survey data. 4. To enhance and develop models of *groundwater system* dynamics as needed and appropriate.	5. *To provide additional data required for uncertainty analysis.*
Project approval and regulatory conditions	*Where uncertainty in the functioning of the hydrogeological system is high, AGM may include:* 1. *Approval conditions set (or revised) based on demonstration of uncertainty reduction in hydrogeological system functioning and project impact.* 2. *A range of actions that modify core project activities that are linked to uncertainty reduction outcomes, such that project operations are contingent on the achievement of uncertainty objectives.* 3. *Knowledge gains are assessed against uncertainty reduction objectives to determine the extent of allowable core project activities*	4. *The recommendations for project approval and regulatory conditions listed under passive AGM are a requirement of active AGM.*
Decision-making	1. At each decision point in the timeframe of an adaptive *groundwater* management project, an action is chosen from the set of available management alternatives [1]. 2. Management is adjusted in response to both changing *groundwater system conditions* and learning [3].	3. *Analyses are selected based on the condition of the groundwater system and the level of uncertainty reduction that has been achieved.*
Follow-up monitoring and analysis	1. Monitoring is used in adaptive *groundwater* management to track system behaviour, and in particular to track the responses to management through time. 2. In the context of adaptive *groundwater* management, monitoring is seen as an ongoing activity, producing data after each management intervention *(e.g. extraction reduction)* to evaluate the intervention, update the measures of model confidence, and prioritise management options in the next time period [1].	3. *Analyses are undertaken that target the reduction of key uncertainties.*
Assessment	1. Assessment/analysis includes parameter estimation, comparative assessments, and prioritisation of management alternatives [1]. 2. Comparison of predicted and actual responses is used to update understanding of management impacts [1]. 3. Comparison and ranking of projected outcomes for management alternatives is used in selection of management actions [1]. 4. *Assessment is supported by the results of hydrogeological analyses and investigations.*	5. *Reductions in the uncertainty of key groundwater system attributes are assessed.*

DOI framework: (1) Williams et al. (2009); (2) Williams (2011); (3) Williams and Brown (2012); (4) Williams and Brown (2014); (5) Williams and Brown 2016); (6) Williams and Brown (2018).

Methodology

This review will have a 3-stage methodology.

Stage 1 - Initially Figure S3 from Thomann et al. (2022) supporting information document will be used to define the level of adaptive groundwater management (AGM) that is indicated according to their framework based on an assessment of permanence, uncertainty and severity of impacts. Note that this review is focused on GDE impacts, including impacts to dependant cultural values.

Stage 2 - Following on from Stage 1 the current SHP adaptive management plan (AMP) will be evaluated against Table S2 as a checklist, addressing the topics presented in from Thomann et al. (2022) supporting information document.

Stage 3 - Finally, a comparison will be made between key statements from Thomann et al. (2022) and the current SHP AM plan. This section should be read in the context of previous reviews.

Results

Stage 1 - Comparison with Figure S3 from Thomann et al. (2022) supporting information document.

Level of Adaptive Management Recommended.

Part 1 - Assess criteria that preclude AGM

Stakeholders can be involved - Yes but the involvement of some, like the Central Land Council (CLC) has been limited.

Management Objectives can be stated explicitly - Yes but the use of "30% of GDE's in a particular landform can be impacted" is a very loose management objective. The GDE mapping validation report (appendix-m-gdv-model-validation-figures-extracted.pdf) showed that some sites that are GDEs were missed in the remote sensing assessment used to identify them. Also, the depth to groundwater is primarily based on water table elevations from a highly uncertain numerical modelling with no uncertainty presented. There is no data for most (if not all) of the GDE sites so how do stakeholders know that their sites of interest are currently accurately assessed as GDEs? Also, the relative value of sites is important, the current assessment assumes all GDEs are equal in their value. What are the highest value biodiversity and cultural sites? Do any of these need to have a "no impact" criteria? There are also still issues relating to application of the terrestrial GDE criteria to aquatic GDEs as noted in my other reviews.

Resource relationships and management impacts modellable - Yes but with the current model the level of uncertainty in predictions of interest has not been presented and this won't be improved until 5 years into the project, if the right data is being collected FAFM undertakes predictive uncertainty analysis. There is minimal commitment in SHP AMP in terms of what actual data will be collected where and when and no commitment to predictive uncertainty analysis.

Monitoring or scientific investigation can inform decision making - Yes but the proposed scientific investigations are not detailed in the AMP, the AMP has more of a generic commitment to collect data. In this context how do stakeholders know their interests are being taken into account if no firm plan is presented?

Progress towards achieving objectives can be measured - Yes but similar to comments for assessment criteria above. If there is no pre approval monitoring at important GDE sites how can they be identified and protected?

Possible to adjust in response to learning - Yes but there is a significant risk of sites that are GDEs with high cultural value not currently being identified as such and that existing criteria are not suitable to provide protection.

Summary - Although none of these criteria are “no” by my assessment, hence according to Thomann et al. (2022) AGM can occur, there are some that are currently difficult to assess as a definitive yes due to high uncertainty and a lack of basic information of groundwater levels, relative value of GDEs (including cultural assets) and an impact assessment with a groundwater model that has high uncertainty and no uncertainty presented for key predictions.

Part 2 - Severity, permanence and uncertainty to inform management approach

Given these are ranked on a 3-axis diagram on a scale with 5 categories these will be labelled low (1), low-medium (2), medium (3), medium-high (4) and high (5).

Severity of impacts - **High**. GDEs (including cultural values) will be impacted it’s only a case of how many, how badly and their value.

Permanence of impacts - **High** but at best **medium-high**. Given the low recharge in the area and the assumption that 80% of aquifer storage can be abstraction in the Water Allocation Plans drawdown impacts will persist for a very long time and recovery of water levels may never fully occur. Impacts to GDEs (including cultural values) may also be permanent if the GDE collapses from lack of groundwater, an individual tree dies or in the case of an aquatic ecosystem the water body disappears and species present cannot recolonise. Even if groundwater drawdown fully recovers these losses may be permanent.

Uncertainty - **High.** Given the lack of baseline data on GDE groundwater levels, lack of drilling, lack of aquifer testing, concerns around GDE impact criteria (particularly aquatic GDEs), the lack of a transient model calibration for most of the model domain and a lack of predictive uncertainty analysis I would rank this as high.

In summary, for this part of the assessment, this interpretation results in a classification of the project as the highest factor combination with Thomann et al. (2022) advising “Use of AGM may result in failed objectives and long-lasting severe consequences. Assess stakeholder priorities and risk/reward tolerance to determine if the project should proceed”. Hence their recommendation would be, based on my assessment, that AGM is not advised.

Protecting the CLC’s interests necessitate that this particular stakeholder has a low appetite for risk, however other stakeholders may not ascribe the same level of risk to some of these factors. Even if for another stakeholder, two out of the three risk factors were ranked as medium, this would still place the factor combination in the second highest category where the recommendation of Thomann et al. (2022) that “AGM not appropriate due to inability to adapt to permanent impacts. “Make good agreements” may be investigated to offset impacts if the project is approved.” Their further recommendation would be based on this assessment would be that AGM is not advised. As a final point with regard to tradition owner values it is unclear how FAFM could make an offset if an irreplaceable cultural site was impacted by GDE collapse/mortality.

Stage 2 - Evaluation of current FAFM AM against Table S2

The recommendation from Stage 1 that AGM is not applied, however if it is to be applied then it should be approached in an active AGM according to Thomann et al. (2022). Table S2 is shown below and has been modified by adding two extra columns with comments from this review and Y/N response for each individual criterion.

Table S2 - Modified form Thomann et al. (2022) with my assessment against these elements and criteria. Note that the active AGM criteria are in grey shaded rows and AGM needs to also included the passive criteria (non-shaded rows). Question marks will be used when the reviewer is unclear if a particular criterion has been met.

Element	Passive/Active Criteria	Comments	Y/N
Investigation	1. At the project outset, collect baseline data to determine the prior status of the water resource.	Lacking, only pre-existing groundwater data has been used.	N
	2. Identify key knowledge gaps in the understanding of the relevant processes in the hydrogeological system.	Knowledge gaps have been acknowledged although they could be more fully considered and should have been addressed prior to approval.	Y
	3. Ensure sufficient data are available to inform/define plausible conceptual hydrogeological models.	Significant gaps exist, many processes not quantified or are poorly understood.	N
	4. Reduction in hydrological and ecological uncertainty through the targeted collection of data and analyses is demonstrated	Only minor amounts of data collected, some verification of GDE status has been undertaken on ground. No collection of groundwater data.	N
Stakeholder involvement	1. Stakeholders must be identified and encouraged to participate	Unclear as I've not been fully involved, I would suspect that CLC would conclude that they have not been as involved as they would have preferred, particularly with GDE/cultural assets identification and management issues.	?
	2. A process must be implemented that solicits stakeholder input in the design of the AGM project and the identification of management objectives and potential management actions	No formal process initiated, some consultation has occurred but it is unclear if CLC issues have been include in AMP management objectives and management actions. FAFM committed to further "further consultation" but this should have happened prior to approval according to Thomann et al. (2022)	N?
	3. Stakeholders must commit to an agreed-upon process of reducing uncertainties and/or disagreements about the effects of management	No process agreed with stakeholders regarding any of these issues.	N
	4. Stakeholder organisations must be encouraged to commit time and energy to adaptively manage the groundwater system over the agreed-upon timeframe	FAFM has stated they are committed to employ TOs in the monitoring program. But no formal agreement reached.	?

	5. Information that underpins management decision-making should be easily accessible to stakeholders and conveyed in a way that enables an understanding of predicted risks and uncertainty associated with these predictions.	Some of the work completed has not been made available to the CLC, it appears as though most has. No measure of predictive uncertainty has been presented although it appears as though some elements of this have been undertaken by FAFM. CLC had to commission their own assessment of model's sensitivity as a proxy for uncertainty. Predictive uncertainty analysis could have been completed if the model was developed in a more amenable modelling platform (MODFLOW) than the chosen platform (MIKESHE).	N
	6. Hydrogeological investigations and the AGM approach should be independently peer-reviewed, and the findings of peer review should be made available to stakeholders and the broader scientific community.	No investigations undertaken yet. Very little formal peer review.	N
	7. Stakeholders are re-engaged at agreed-upon timeframes, allowing for revisiting and revision of stakeholder values and concerns in the context of revised uncertainty estimates arising from project progress.	This hasn't occurred but should have according to Thomann et al. (2022)	N
Objectives	1. Be unambiguous, with specific hydrogeological variables (e.g. groundwater levels, flow rates, solute concentrations, groundwater-dependent ecosystem health indicators) and specific target conditions.	GDE impact criteria as provided by the NT Government are being used. These criteria have issues in my opinion (particularly with aquatic ecosystems) but this is not a FAFMs issue. Ecosystem targets (30% of GDEs in a particular landform can be impacted) are based on a simplistic assumption that all GDEs are of equal biological and cultural value. Again, these criteria are not a FAFM issue.	Y

	2. Contain hydrological and ecological elements that can be readily measured, to promote the evaluation of management actions and recognise their contributions to successful management.	Can be measured but have not been pre-approval, depth to groundwater is inferred from uncertain groundwater modelling of sparse often old data. Ecosystem health indicators (both biological and hydrogeological) at and individual GDE scale have been proposed but will not be fully developed until post approval. For example "10% reduction in GDE condition (health, diversity) based upon mapping" has not been presented on any scientific basis that this is sufficient. By the time impacts are apparent it may be too late to save a particular GDE as there may not be sufficient recharge to cause groundwater level/GDE recovery. Artificial maintenance is very difficult without a very high level of quantitative understanding about plant water sources. Operational triggers have been developed but are focussed on purely groundwater production not impacts.	?N
	3. Be achievable based on the capacities of the groundwater system being managed and the political or social system within which management occurs.	Achievable if sufficient resources are made available. I have concerns that if the aquifer does not have as much water present as assumed, the project is not achievable within the 30% GDE impact criteria but this cannot be assessed due to a lack of predictive uncertainty analysis on their drawdown predictions in the context of GDE impacts.	?
	4. Define endpoints for the groundwater system in terms of metrics for quantifying groundwater system health.	Yes, but high amount of uncertainty	Y
	5. Indicate the timeframe for achievement, including where durations exceed that of the project.	Project timeframes understood, drawdown impacts are likely to persist until well after the active project timeframe. Drawdown may never fully recover in a meaningful timeframe but accepting of 80% decrease in aquifer storage in the Allocation Plan has this inherent in it i.e. is not sustainable.	Y
	6. Contain measures, timing and target levels of uncertainty reduction.	No	N
Management alternatives	1. Adaptive decision making involves selecting a management action at each decision point, on the basis of the condition of the groundwater system at the time	Yes however frequency this will occur with regard to stakeholder involvement is not explicitly included in their trigger breach response.	Y

	2. Management alternatives in adaptive groundwater management often focus on a potential change in groundwater system status or the alteration of process rates (e.g. groundwater abstraction, groundwater recharge/discharge fluxes)	Yes but no "stop pumping" criteria have been proposed only pumping reductions. What would cause them to stop pumping groundwater?	Y?
	3. Alternatives should be explicitly documented and quantitatively assessed	Much of the modelling has been focussed on bore field design to minimise on-site and off-site impacts but regardless without quantitative predictive uncertainty analysis I'd question the veracity of the quantitative assessment. A tier 1 possible management action for GDE impacts is listed as "Implement further ecological investigation" in FAFM AMP. What does this entail? Need to be specific and quantitative.	N
Predictive modelling	1. The models used in adaptive groundwater management generally share the following certain attributes: a. The groundwater system is described as changing through time, to allow learning to occur and management to adapt to learning.	No, recharge is not seasonally modelled and predictive hydrographs for most of the model domain are flat with no seasonal fluctuations. Transient data should have been collected prior to approval and used in impact assessment models to rectify this prior to approval.	N
	b. The hydrological system is characterised by key components of interest (e.g. groundwater level, solute concentration, ecological health indicators) that are the focus of management and the targets of monitoring.	No substantive data collected by FAFM, regional baseline data is often old and few timeseries are available, almost no data near the proposed SHP bore field.	N
	c. Changes often are described in terms of processes (e.g. drawdown propagation, seawater intrusion, baseflow and/or spring flow) that are thought to be directly influenced by management.	Yes, but high uncertainty not presented.	Y
	d. Fluctuating environmental conditions (e.g. seasonal variability in rainfall) are incorporated as needed to characterise resource dynamics.	No	N
	e. Management impacts are described in terms of costs, benefits, and influences on components of the groundwater system or processes that are highlighted in the model.	Investigation and analysis are too preliminary to get to this level of cost benefit analysis. Cost of GDE/cultural value impacts difficult to quantify compared with economic benefits.	?
	f. Models are calibrated with available data and knowledge, to ensure compatibility with current understanding about resource structures and functions.	Although the available data has been used there is very little time series (and none near the SHP). No drilling or aquifer testing done on site so aquifer conditions are highly uncertain.	Y but

	2. The suite of models should capture key uncertainties (or disagreements) about resource processes (e.g. source aquifer of GDE water) and management effects	Not presented.	N
	3. Quantitative modelling should be performed for the range of actions proposed during the “management alternatives” stage under each system conceptualisation.	No	N
	4. Quantitative uncertainty analysis with respect to predictions of interest should be performed. This uncertainty assessment should be repeated over the lifespan of a project to quantify uncertainty reduction achieved through project activities.	No and has been a theme in the CLC discussions with FAFM. Non proposed.	N
Monitoring and analysis protocols	In general, monitoring and analysis provide data for four key purpose 1. To evaluate progress toward achieving objectives.	Proposed monitoring networks and investigations (both groundwater and ecological) are not currently available (redacted EIS maps) or to be developed post approval so it is unclear how suitable they are.	?
	2. To determine the state of key indicators of the groundwater system, in order to identify appropriate management actions.	As above.	?
	3. To increase understanding of groundwater system dynamics via the comparison of predictions against survey data.	This will occur, but will it be sufficient?	Y
	4. To enhance and develop models of groundwater system dynamics as needed and appropriate.	This will occur, but will it be sufficient?	Y
	5. To provide additional data required for uncertainty analysis.	No commitment to predictive uncertainty analysis in the SHP AMP.	?
Project approval and regulatory conditions	Where uncertainty in the functioning of the hydrogeological system is high, AGM may include: 1. Approval conditions set (or revised) based on demonstration of uncertainty reduction in hydrogeological system functioning and project impact.	No approval conditions set for uncertainty reduction (and no commitment to even undertake uncertainty analysis). Also note that SHP decision review panel recommended different (smaller) stage volumes and longer stage times than have been adopted by the regulators.	N
	2. A range of actions that modify core project activities that are linked to uncertainty reduction outcomes, such that project operations are contingent on the achievement of uncertainty objectives.	Collecting and analysing data will reduce uncertainty and there is a commitment to adapt the AMP as more is available.	Y
	3. Knowledge gains are assessed against uncertainty reduction objectives to determine the extent of allowable core project activities	No uncertainty reduction targets proposed.	N

	4. The recommendations for project approval and regulatory conditions listed under passive AGM are a requirement of active AGM.	Noted	NA
Decision-making	1. At each decision point in the timeframe of an adaptive groundwater management project, an action is chosen from the set of available management alternatives	TBC	NA
	2. Management is adjusted in response to both changing groundwater system conditions and learning	Proposed to be adjusted but there is a high amount of uncertainty regarding impacts and proposed mitigation measures. Most of this is to be developed if project is approved.	NA
	3. Analyses are selected based on the condition of the groundwater system and the level of uncertainty reduction that has been achieved.	No uncertainty reduction targets proposed.	N
Follow-up monitoring and analysis	1. Monitoring is used in adaptive groundwater management to track system behaviour, and in particular to track the responses to management through time.	Yes proposed.	Y
	2. In the context of adaptive groundwater management, monitoring is seen as an ongoing activity, producing data after each management intervention (e.g. extraction reduction) to evaluate the intervention, update the measures of model confidence, and prioritise management options in the next time period	Yes proposed.	Y
	3. Analyses are undertaken that target the reduction of key uncertainties.	No uncertainty reduction targets proposed but proposed activities will reduce uncertainty but how much is unclear due to a lack of detail.	N/Y
Assessment	1. Assessment/analysis includes parameter estimation, comparative assessments, and prioritisation of management alternatives	Yes but focussed on bore field design at this stage. There is significant possibility that sites which are GDEs and have not been identified as such, particularly for small sites as GDEs have been identified primarily based on remote sensing data analysis so pixel size (25m?) is the smallest GDE size that can be detected. Springs and sacred trees could occur on a smaller scale than this.	?
	2. Comparison of predicted and actual responses is used to update understanding of management impacts	Proposed to occur	Y
	3. Comparison and ranking of projected outcomes for management alternatives is used in selection of management actions	Unclear	NA

	4. Assessment is supported by the results of hydrogeological analyses and investigations.	Unclear what the scope of these investigations and analyses is. Current investigations and analyses are insufficient.	N but ?
	5. Reductions in the uncertainty of key groundwater system attributes are assessed.	No uncertainty reduction targets proposed.	N

Stage 3 - Comparison between key statements from Thomann et al. (2022) and the current SHP AMP

In this section passages of text (or tables) from Thomann et al. (2022) are presented followed by my comment on how the AMP and other aspects of the SHP EIS meet or fail against these statements. There is subjectivity in some of these comments often due to a lack of data, analysis and detail in the SHP AMP and impact assessment. However, many are not subjective.

Quotes from Thomann et al. (2022)

"Three key factors emerge that are critical in the design of AGM strategies, including:

(1) the severity of groundwater impacts from project operations,

(2) the permanence of groundwater impacts, and

(3) the level of uncertainty in groundwater system responses to project operations.

The above three key factors are integrated into definitions of "active" and "passive" forms of AGM. Passive AGM strategies meet minimum thresholds for structured and iterative management approaches that incorporate uncertainty reduction, while active AGM strategies include additional constraints that place a greater emphasis on uncertainty quantification and reduction."

> Comment - Note the key difference between active and passive AGM, is that active AGM strategies include additional constraints that place a greater emphasis on uncertainty quantification and reduction. Currently no predictive uncertainty quantification let alone reduction proposed.

"However, previous research into AM across various environmental disciplines has shown that AM principles are commonly misinterpreted (Allen and Garmestani, 2015). For example, AM is often considered, erroneously, to refer to a willingness to modify a management approach through ad hoc changes to management practices (Allen and Garmestani, 2015). This has led to management plans being labelled as AM to avoid detailed up-front assessment, despite plans omitting key attributes of AM (Lee and Gardner, 2014; Slattery, 2016)."

> Comment - I would suggest that the AMP for FAFM falls into the "being labelled as AM to avoid detailed up-front assessment" category.

"Typical shortcomings in AM plans included a lack of specific objectives, unclear monitoring approaches, an absence of substantiative mitigation measures, and/or under-developed predictive models for assessing alternative management actions (Ruhl and Fischman, 2010). A subsequent review by Fischman and Ruhl (2015) found that indicator thresholds of system health and the corresponding actions triggered by those thresholds were commonly lacking in purported AM applications. Management plans with poorly defined thresholds lack the explicit structure of rigorous planning and analysis required to meet published guidance on AM (Ruhl and Fischman, 2010;

Fischman and Ruhl, 2015). As such, these approaches can be classified more accurately as trial-and-error management (e.g. Allen and Garmestani, 2015)."

Comment - I would suggest that the AMP for FAFM falls into this category.

Table 1
Conditions that warrant AM and that limit the application of AM, verbatim from Williams et al. (2009).

Type	Condition
Conditions that warrant AM application	1. There must be a mandate to take action in the face of uncertainty. 2. There must be the institutional commitment and capacity to undertake and sustain an adaptive program. 3. A real management choice is to be made. 4. There is an opportunity to apply learning. 5. Clear and measurable management objectives can be defined. 6. The value of information for decision making is high. 7. Uncertainty can be expressed as a set of testable models. 8. A monitoring system can be established to reduce uncertainty.
Conditions that limit AM application	1. Decision making only occurs once. 2. Monitoring cannot provide useful information for decision making. 3. There are irresolvable conflicts in defining explicit and measurable management objectives and alternatives. 4. Decisions that affect resource systems and outcomes cannot be made. 5. Risks associated with learning-based decision making are too high.

Comment - much of the comparison between the AGM proposed and the current SHP AMP is covered elsewhere in this review (and in my other reviews). However to assess the project against the conditions that limit AM application I would conclude for each condition from Table 1:

1- Passed (conditionally) although there are issues with the decision-making process the stage license approach allows the project expansion to be stopped. But the Stage 1 license alone could cause serious impacts.
2- Failed - not enough monitoring data, particularly time series of groundwater, measured groundwater depth for GDE depth to groundwater assessment, understanding of GDE locations, relative biodiversity and cultural values etc.
3- Failed from a CLC perspective - Cultural asset could be destroyed by drawdown from Stage 1.
4- Passed - But I would question if the decision should have been made on the current data and analysis.
5- Failed - CLC could see cultural assets destroyed.

"Consequently, adapted forms of the recommendations from Allen and Gunderson (2011) are offered here, thereby defining three key factors critical to the development of AM strategies for groundwater-affecting activities, given as:

(1) the severity of groundwater impacts from project operations,

(2) the permanence of groundwater impacts from project operations, and

(3) the level of uncertainty in groundwater system responses to project operations."

With respect to severity

"Where potential groundwater impacts are severe, there is a heightened need to develop sound hydrogeological knowledge of the system response to project activities. Also, the need to understand both the reversibility (or conversely the permanence) and uncertainty in more severe impacts is greater. Furthermore, where potential impacts are more severe, the need for clear and effective mitigation and monitoring strategies is heightened, particularly for the purposes of stakeholder involvement, which is likely to be more consequential to AM strategies where threats to critical assets are higher."

> Comment - From a CLC perspective the potential for impacts is severe, impacts are likely non reversable in a meaningful timeframe, mitigation and monitoring strategies are not fully developed (to be complete post approval), stakeholder involvement has been minor for CLC in my experience.

"In general, a more comprehensive characterisation of potential impacts on groundwater systems, along with a clearer demonstration of impact detection and mitigation techniques, is warranted prior to project approval where the plausible range of groundwater impacts includes those that are unacceptably severe."

> Comment - No baseline data or even exploratory drilling and aquifer testing, project stage 1 approved but impacts are potentially unacceptable severe. More investigation and assessment warranted prior to approval.

With respect to Permanence

"Whether or not an impact can be reversed influences the feasibility and efficacy of iterative reassessment, and subsequent improvement, of management practices aimed at protecting critical assets (Williams et al., 2009), thereby limiting the applicability of AM in managing some groundwater-affecting projects. Thus, in accordance with general AM definitions (e.g. Williams et al., 2009), AM is likely unsuitable to protect against permanent or irreversible impacts on groundwater systems."

> Comment - There is potential for permanent impacts from the project (GDE/cultural assets). Drawdown could be greater that predicted and could manifest in locations currently not precited to have any impact so will not necessarily be identified. AM is likely unsuitable to protect against permanent or irreversible impacts on groundwater systems.

"Groundwater-dependent ecosystems (GDEs), particularly those related to springs, are examples of this, whereby the spring ecosystem may decline and recover if aquifer conditions change within a certain threshold range, whereas complete cessation of spring flow may lead to the irreversible loss of aquatic organisms in many cases (e.g. Currell et al., 2017; Devitt et al., 2019)."

> Comment - Note this in the context of impact to aquatic GDEs.

"The long timescales of most hydrogeological processes create major obstacles to learning within the context of groundwater management practices (Currell et al., 2017), in a similar way to the difficulties in addressing permanent impacts within an AM approach.

For example, an assessment should be performed to determine whether substantial, irreversible impacts may occur before managers can reliably assess whether thresholds (i.e. after which impacts are effectively irreversible) have been passed.

The use of AM is also not appropriate where critical thresholds or remedial approaches to possible impacts are poorly understood, because remediation may be precluded by technical barriers, particularly for situations involving long groundwater system timescales and time-lagged impacts (Williams et al., 2009; Nichols et al., 2014; Thomann et al., 2020)."

> Comment - substantial, irreversible impacts may occur and thresholds are not based on a site-specific understanding of ecosystem tolerances and thresholds.

With respect to uncertainty

"Thus, it is critical for project proponents, stakeholders and regulatory authorities to have a clear understanding of both the uncertainty of impacts on groundwater-dependent assets and the methods to lower uncertainty, prior to project approval, where AM is adopted. This is particularly critical when AM is intended to offset the lack of reliable estimates of groundwater impacts at the project outset.

Where uncertainties in groundwater system behaviour are important, clear quantification of the uncertainties of potential impacts and practical and realistic approaches to uncertainty reduction are required before the effectiveness of proposed AM strategies can be known.

Uncertainty in the prediction of groundwater impacts plays a complicated role in project approval. Even where AM can be shown to offset impact risks, it may be necessary to delay approval while critical knowledge gaps are addressed, or at least, uncertainties are quantified and communicated to stakeholders and decision-makers. Approval conditions may additionally include thresholds for uncertainty reduction, notwithstanding the issues of impact permanence, reversibility and time lags, as discussed above.

Strategies for reducing uncertainty within high-uncertainty groundwater-affecting activities are critical in AM plans, because in some cases, data-gathering and other investigative tools may not adequately inform impact predictions, rendering AM largely ineffective (e.g. Williams et al., 2009)."

> Comment - No uncertainty analysis completed and not proposed, let alone targets for reduction therein.

Translation of AM into AGM

"Baseline hydrogeological data are essential for deliberate phase activities, given the complexities of hydrogeological systems. This is especially the case for greenfield sites, which present substantial challenges for the development of AGM strategies because of weaknesses in groundwater system understanding, at least in the context of the anticipated project stresses.

Initiating hydrogeological investigations early in the deliberative phase provides opportunities to attain time-series datasets, that are essential for developing baseline knowledge of groundwater processes and for building predictive models and devising future monitoring protocols."

> Comment - very little baseline data on groundwater levels or GDEs. Note that the deliberate phase is prior to project approval in the Thomann et al. (2022) framework.

"Therefore, stakeholder involvement often leads to knowledge exchanges that inform hydrogeological investigations and that assist in prioritising the goals of AGM monitoring and mitigation strategies."

> Comment - The CLC could have helped target investigations prior to approval in terms of cultural assets but no dedicated data collection has occurred.

"The use of trigger levels, whereby exceedance of an objective level of an indicator (e.g. groundwater drawdown, salinity threshold or an ecological health indicator) initiates a pre-defined corrective action, is another example (Evans et al., 2004; Werner et al., 2011).Trigger-level responses within an AGM approach need to be transparent, structured and evidence-based, whereas ad-hoc trigger-level responses are indicative of trial-and-error management (Schultz and Nie, 2012; Fischman and Ruhl, 2015)."

> Comment - Non bore field trigger levels are difficult to set as most GDEs/cultural assets do not have any monitoring data or ranking of importance and no firm plan to address this has been presented in my opinion. The current plan is a primarily plan to make a plan upon approval. This is not supported by my interpretation of the Thomann et al. (2022) framework. Trigger level responses are not transparent, structured and evidence-based, hence the ad-hoc trigger-level responses are indicative of trial-and-error management. According to Thomann et al. (2022) framework this project requires active adaptive management at minimum. My interpretation of the Thomann et al. (2022) framework is that for this project they would recommend not to use adaptive management with the current SHP level of assessment.

"The following four features of active AGM are suggested that add to the minimum requirements for passive AGM: (1) a stronger emphasis on the quantification of uncertainty and its reduction, (2) a broader scope for stakeholder involvement, (3) a staged approval process where project progression is contingent on uncertainty reduction, and (4) independent peer review of the AM strategy and the progress of its operationalisation."

> Comment - (1) no uncertainty analysis and no plan to reduce, (2) stakeholder involvement in AGM minimal, (3) staged approach yes but uncertainty reduction (or even analysis) no and (4) no peer review presented.

"The increased focus on uncertainty quantification and reduction within active AGM necessitates a greater degree of scientific rigour. For example, stochastic representations of key variables (e.g. hydraulic conductivity) in predictive models, rather than deterministic predictions, allows for a more comprehensive quantification of uncertainty."

Comment - has not occurred, currently low scientific rigor.

"Alternatively, multiple conceptual models may be numerically simulated in groundwater flow models, with conceptual models excluded from the set as new data and hydrogeological interpretations are obtained that are sufficient to do so."

Comment - has not occurred, not proposed.

"The development of uncertainty reduction targets is an important stage of active AGM, requiring rigorous uncertainty quantification as part of the predictive modelling element (e.g. Doherty and Moore, 2020). Uncertainty reduction is a key focus of the investigation element (Fig. 2), including during revisitation of this stage after periods of project operations, whereby the collection of data and targeted analysis is explicitly used to reduce hydrogeological and ecological uncertainty, especially in regard to the potential impacts of project operations. This is likely to require drilling and other, non-invasive hydrogeological techniques at locations outside of the region of the project's primary activities."

Comment - has not occurred, what is proposed has no substantive detail prior to approval. Some uncertainty reduction will occur via investigations and subsequent analysis but predictive uncertainty analysis and quantitative reductions targets are not proposed.

Conclusion

Assessing the AGM for SHP against the high-level criteria in Thomann et al. (2022) (Stage 1 on Figure S3) there are some criterion that are currently difficult to assess as yes or no due to high uncertainty. There is a lack of basic information on groundwater levels, relative value of GDEs (including cultural assets) and an impact assessment with a groundwater model that has high uncertainty and no uncertainty presented for key predictions. None are however definitely a no so by that first stage of that Figure AGM could be considered.

However, when the SHP AMP is assessed against the more detailed Stage 2 of Figure S3 in Thomann et al. (2022) (including the risk diagram) AGM is either not recommend or at the very least must be active. A key difference between active and passive AGM is the incorporation of uncertainty analysis and explicit targets for reduction of uncertainty through the adaptive management process. No uncertainty analysis has been provided and none is proposed.

When the detailed assessment against the elements and criteria from Table S2 from Thomann et al. (2022) was undertaken, my interpretation is that there are 13 yes (criteria met), 19 no (criteria failed) and 13 are difficult to assess or are premature to assess at this stage of the project.

I would summarise the current AMP is a primarily plan to make a plan once the project is approved. This is not supported by my interpretation of the Thomann et al. (2022) framework. In my opinion trigger level responses are not transparent, structured and evidence-based, hence the ad-hoc trigger-level responses are indicative of trial-and-error management. According to Thomann et al. (2022) framework this project requires at least active adaptive management. My interpretation of the Thomann et al. (2022) framework is that for this project they would recommend not to use AM with the current SHP level of assessment. Regardless if AGM is to be used predictive uncertainty is required pre approval, at each stage of the reiteration of the AGM plan and an explicit plan must be presented to stakeholders to reduce the uncertainty.

To quote Thomann et al. (2022) "Use of AGM may result in failed objectives and long-lasting severe consequences. Assess stakeholder priorities and risk/reward tolerance to determine if the project should proceed."