

# South Staffordshire Water AMP8 Drought Support: Groundwater Drought Triggers



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**South Staffordshire Water AMP8 Drought Support: Groundwater Drought Triggers**

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# 1 Introduction

## 1.1 Background and objectives

The Environment Agency (EA) issued Drought Plan guidelines in March 2025 providing technical guidance for water companies to follow for writing statutory water company drought plans. South Staffordshire Water (SSW) last updated their Drought Plan in 2022 (SSW, 2022). This Drought Plan outlined no formal groundwater-specific triggers for SSW as Blithfield Reservoir is the most drought-sensitive water supply source. For their 2026 Drought Plan, SSW are seeking to better understand the suitability of, and options for, developing groundwater drought triggers. The objectives of this work are to:

- Identify and agree with SSW the most appropriate representation of staged groundwater drought metrics and associated trigger framework for SSW.
- Recommend and agree up to five groundwater sites within the supply area for use as representative groundwater drought trigger sites.
- Develop drought trigger frameworks for each of these representative sites, including testing of trigger metrics against historical data where available.

## 1.2 Scope of this technical note

This technical note comprises:

- A concise summary of the staged groundwater drought metric options considered (Section 2.1).
- A concise summary of the relevant datasets collated for use in drought metrics (Section 2.2).
- Details of data processing for selection of representative sites (Section 2.3).
- Details of the development, testing and comparison of trigger metrics (Section 3).
- Key findings and recommendations for future implementation (Section 4).

## 2 Data Review

### 2.1 Drought metrics

The following groundwater drought metrics were considered in fulfilment of Task 2.

#### 2.1.1 Source Performance Diagrams

Source Performance Diagrams (SPD) describe groundwater level trigger points related to specific drought management actions for a specific groundwater source (Figure 2.1 **Error! Reference source not found.**). The diagrams include operational abstraction and water level data as well as asset constraints (e.g., borehole pump capacity). Groundwater trigger levels are constructed based on operational parameters, for instance: historical groundwater levels, pump capacity, abstraction licence conditions, deepest advisable pumping water level and pump intake depth. Groundwater level data is plotted against pumping rate, along with the practical operational curve and drought curves (based on actual or predicted performance during a drought).

The primary benefit of this method is the simplicity of implementation, and integration with existing operational parameters. However, this approach is not generalised and cannot be compared across sites. It also requires clear changes in abstraction performance caused by groundwater drought conditions to be viable as a groundwater drought trigger. For example, the reference SPD curve from Severn Trent shows lower water levels relative to pumping rate during the drought conditions in 1995 – 1997, and higher groundwater levels during non-drought years such as 2003 (Figure 2.1).

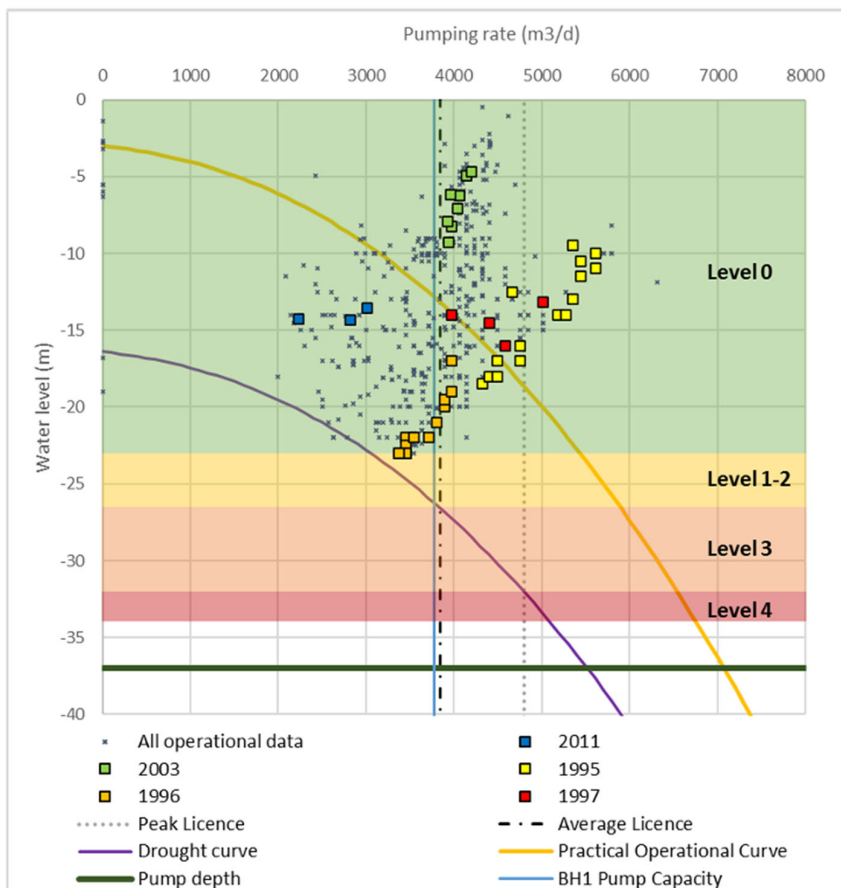


Figure 2.1 Example SPD from Severn Trent drought plan (Severn Trent, 2021)

### 2.1.2 Standardised Groundwater level Index

Standardised Groundwater level Index (SGI) is a statistical method of characterising groundwater drought conditions (Bloomfield and Marchant, 2013). SGI is estimated by transforming monthly groundwater level data (using non-parametric normal scores transform) to produce a continuous index, with SGI values typically ranging from -2.5 to 2.5. SGI compares monthly groundwater level data to the historical distribution of groundwater levels and quantifies how much a given month deviates from the historical distribution. A positive SGI indicates high groundwater levels relative to the historical record, and a negative SGI indicates low groundwater levels relative to the historical record (i.e., drought conditions). This approach is an adaptation of the Standardised Precipitation Index (SPI), which has been used for decades to characterise meteorological drought. The convention set by SPI, which can be carried forward for groundwater drought intensity, is defined according to the values in Table 2.1.

**Table 2.1 SPI drought intensity bands**

SPI Range <sup>1</sup>	Drought Intensity	SGI Range <sup>2</sup>	Drought Intensity
$SPI \leq -2$	Extreme drought	$SGI \leq -2$	Extreme Drought
$-1.5 \geq SPI > -2$	Severe drought		
$-1.0 \geq SPI > -1.5$	Moderate drought	$-1.0 \geq SGI > -2$	Drought
$0 \geq SPI > -1$	Minor drought		
$SPI > 0$	No drought	$SGI > 0$	No drought

<sup>1</sup> Bloomfield and Marchant (2013) <sup>2</sup> Bloomfield et al. (2019)

SGI accounts for differences in the form and characteristics of groundwater level time series and normalises groundwater level data across sites into a single metric. SGI has been shown to correspond with previously independently documented droughts and is a demonstrably robust and meaningful index of groundwater drought (Bloomfield and Marchant, 2013; Brauns et al., 2020).

The principal limitation of the SGI is the requirement for a long groundwater level record (10 years as a minimum) with consistent monthly data available. Observation boreholes (OBHs) operated by the EA often have multi-decade data records and therefore meet this requirement.

### 2.1.3 Other groundwater drought approaches

Other approaches were also considered during the scoping phase of the project but were not developed further for SSW, including:

- **Standardised level profile.** This approach is in use by Sutton and East Surrey (SES) Water. Drought action trigger levels are determined based on approximate annual breach return periods (e.g., frequency at which a groundwater level is exceeded). For instance, a Level 3 drought action trigger corresponds to a drought event expected every 1 in 20 years (SES, 2022).
- **Aquifer recharge deficit profile.** This approach is in use by Cambridge Water. Drought action trigger levels are determined by statistical analysis of meteorological data, observed borehole behaviour during historical drought periods and recharge deficits (Cambridge Water, 2021).

### 2.1.4 Surface water triggers

Current surface water triggers in place for SSW at Blithfield Reservoir operate on trigger curves that are set as a percentage reservoir level as a function of time of year (Figure 2.2). A requirement of this approach is clear seasonal variability; for instance, the Trigger Level 3 reservoir level is lower in August than it is in February, which captures seasonal variability. Surface water triggers may also be usefully applied to assessing

drought related risk to groundwater dependent receptors This approach is most similar to the standardised level profile in use by SES Water.

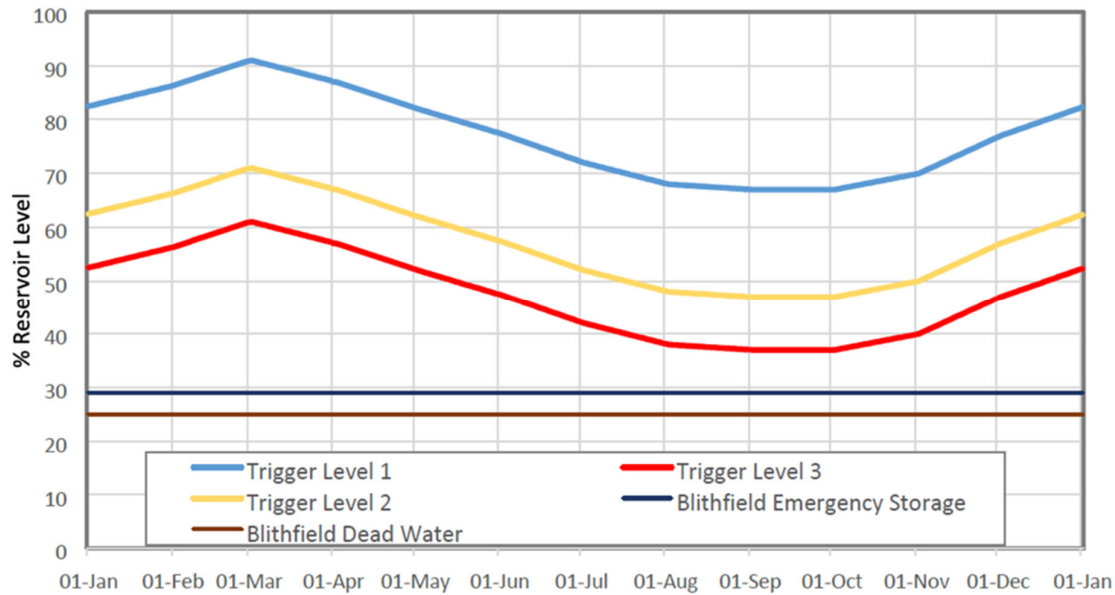


Figure 2.2 Blithfield Reservoir control curves

## 2.2 Relevant datasets

Pumping rate and water level data from abstraction wells were provided by SSW and are summarised in Table 2.2. The SGI requires a long record of groundwater levels from boreholes with negligible impact from abstraction. EA OBH data was collated for use in SGI analysis. 15 EA OBHs were initially selected for preliminary processing with SGI (Table 2.3). The selection was based on data quality, data record length and spatial coverage of Water Framework Directive (WFD) Groundwater Bodies (GWBs) in which SSW operates. The spatial distribution of SSW abstraction boreholes and EA OBHs are shown in Figure 2.3.

**Table 2.2 Summary of pumping rate and groundwater level data provided by SSW**

<b>Public Water Supply (PWS)</b>	<b>Borehole</b>	<b>Data record</b>	<b>Record length (years)</b>	<b>Data provided</b>
Hopwas	BH1	1990-2025	36	Pumping Rate, Water Level
Slitting Mill	BH1	1993-2025	33	Pumping Rate, Water Level
	BH2	1991-2025	35	Pumping Rate, Water Level
Crumpwood	BH1	1968-2025	58	Pumping Rate, Water Level
	BH2	1992-2025	34	Pumping Rate, Water Level
Cookley	BH1	2008-2025	18	Pumping Rate, Water Level
	BH2	2008-2025	18	Pumping Rate, Water Level
	BH3	2008-2025	18	Pumping Rate, Water Level
Ashwood	BH1	2004-2025	22	Pumping Rate, Water Level
	BH2	2009-2025	17	Pumping Rate
	BH3	2009-2025	17	Pumping Rate
	BH4	2009-2025	17	Pumping Rate
	BH5	2009-2025	17	Pumping Rate
	BH6	2009-2025	17	Pumping Rate
Little Hay	BH1	1990-2025	36	Pumping Rate, Water Level
	BH2	1993-2025	33	Pumping Rate, Water Level
Slade Heath	BH1	1977-2025	48	Pumping Rate, Water Level
	BH4	1977-2025	48	Pumping Rate, Water Level
	BH5	2005-2025	21	Pumping Rate, Water Level
Pipe Hill	BH1	2007-2025	19	Pumping Rate, Water Level
	BH2	2007-2025	19	Pumping Rate, Water Level
	BH3	2007-2025	19	Pumping Rate, Water Level
	BH4	2007-2025	19	Pumping Rate, Water Level

**Table 2.3 Summary of groundwater level data collated from EA OBHs**

<b>OBH name</b>	<b>Nearby PWS</b>	<b>Grid reference</b>	<b>Groundwater Body</b>	<b>Data record</b>	<b>Record length (years)</b>
Maple Hayes	Pipe Hill	SK09990977	Tame Anker Mease	1999-2025	27
Footherley Deep	Little Hay	SK10340290	Tame Anker Mease	2007-2025	19
Four Crosses	Slitting Mill	SK95790970	Staffordshire Trent Valley	1969-2025	57
SunnyBank Farm	Crumpwood	SK03584064	Dove	2009-2025	17
Nuttalls Farm	Little Hay	SK06650111	Tame Anker Mease	2014-2025	12
Summerfield Park E	Little Hay	SO90347844	Tame Anker Mease	1997-2025	29
Broome	Cookley	SO90347844	Worcestershire Middle Severn	2001-2025	25
Bissell Wood	Cookley	SO86337738	Worcestershire Middle Severn	2007-2025	19
Hurcott	Cookley	SO85937804	Worcestershire Middle Severn	2002-2022	21
Puxton Deep	Cookley	SO82707780	Worcestershire Middle Severn	2007-2025	19
Check Hill	Cookley	SO8601988359	Worcestershire Middle Severn	2014-2025	12
Checkhill Bogs	Cookley	SO8494087852	Worcestershire Middle Severn	2011-2025	15
Kingswood	Slade Heath	SJ83590245	Worcestershire Middle Severn	1998-2025	28
Tong Forge	Slade Heath	SJ78300818	Worcestershire Middle Severn	1999-2024	27
Marsh Lane	Slade Heath	SJ76641106	Worcestershire Middle Severn	1999-2024	27

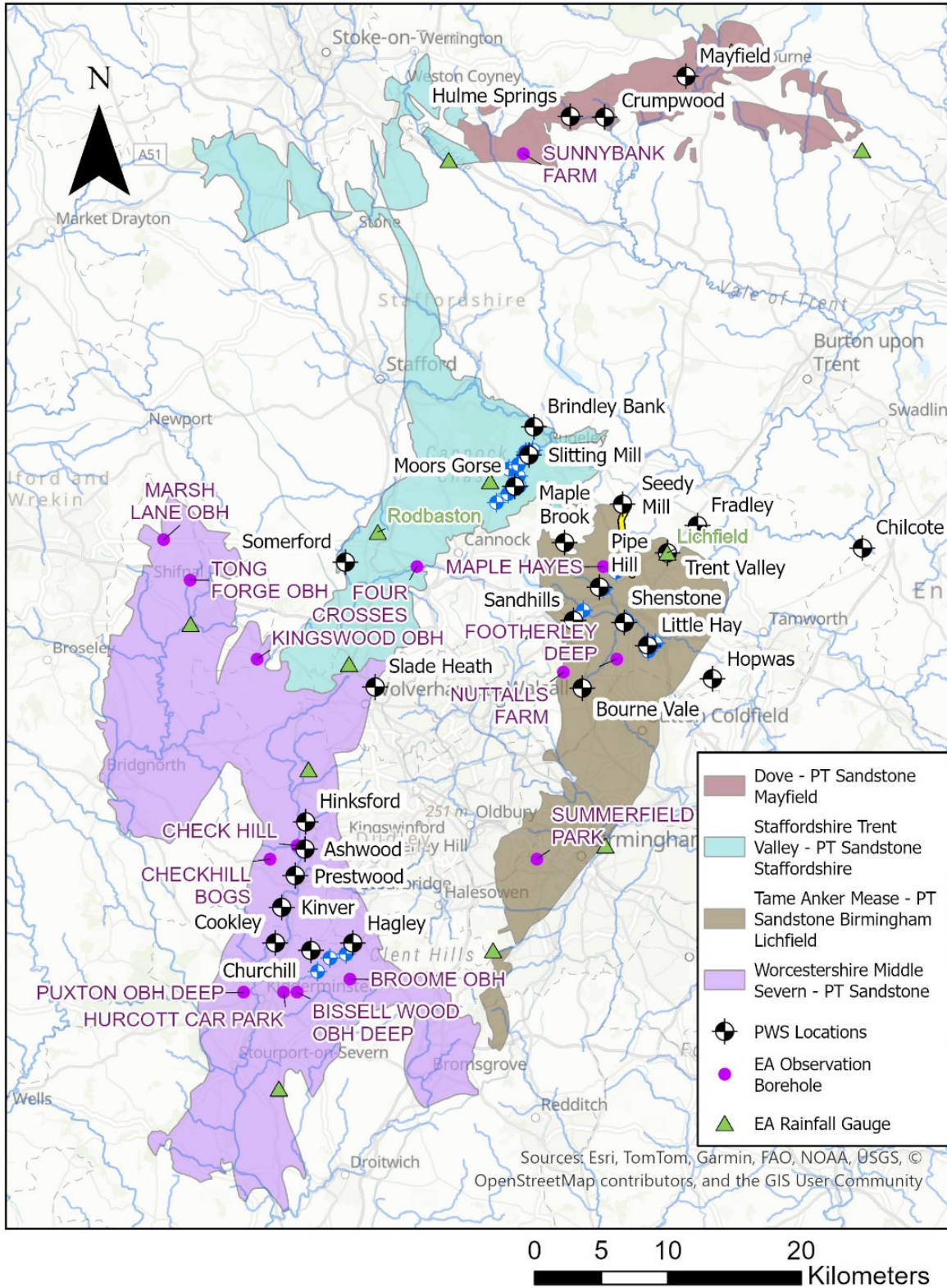


Figure 2.3 SSW operating region showing PWS abstractions, EA OBHs and GWBs

## 2.3 Data processing

### 2.3.1 SPD

Preliminary data processing was conducted on pumping rate and groundwater level data at abstraction locations provided by SSW to determine data suitability for use with SPD. The available data was assessed based on the following criteria: borehole location, data quality (e.g., no unexplained variations in water levels), data gaps, seasonal variability and sensitivity to abstraction.

Abstraction borehole data was processed as follows:

- Hydrographs were created to assess data quality and determine whether seasonal variability and previous drought events were evident at the abstraction boreholes.
- Pumping rate was plotted against water level to assess data quality and identify trends of water level dependence on abstraction rate. This is the preliminary data processing required for application of SPD and allows analysis of data suitability for SPD triggers.

### 2.3.2 SGI

Preliminary data processing was conducted on EA OBHs to determine data suitability for use with SGI. 15 OBHs within relevant GWBs were selected from the EA database and groundwater level data was extracted. SGI was calculated using an open-source Python package for hydrogeological time series analysis 'Pastas' (Collenteur et al. 2019).

Data quality for the 15 OBHs was then assessed for site selection. Site selection criteria included:

- Data record length; preference for records beginning prior to 2000.
- Good coverage of GWBs.
- Seasonality evident in data, with no suspect long-term rising or falling trends.
- Negligible impact on groundwater levels from nearby abstraction.

# 3 Results

## 3.1 Drought metric evaluation

The performance of drought triggers was assessed using the following criteria:

- Agreement with historical benchmark droughts: 1975–76; 1988–93; 1995–98; 2004–06; 2010–12 (GSEU, 2025).
- Seasonality evident in data, with no suspect long-term rising or falling trends.
- Consistency in drought trigger behaviour across GWBs where SSW operates.

### 3.1.1 SPD

Processing of available abstraction well data from SSW demonstrates that SPD is not suitable as a drought trigger for SSW. The groundwater levels do not show impacts from seasonality. They are primarily impacted by abstraction rates rather than drought conditions, as shown in the analysis of hydrographs and pumping rate against water level plots below. The complete set of processed data is included in Appendix A (Pumping rate vs. water level plots) and Appendix B (Hydrographs).

Analysis of hydrographs (e.g., Figure 3.1) demonstrated the following:

- Seasonality is not evident in water level data, and the water level data is therefore not capturing the fluctuations in water levels over yearly periods.
- Abstraction points do not show evidence of drought condition impacts during benchmark droughts.

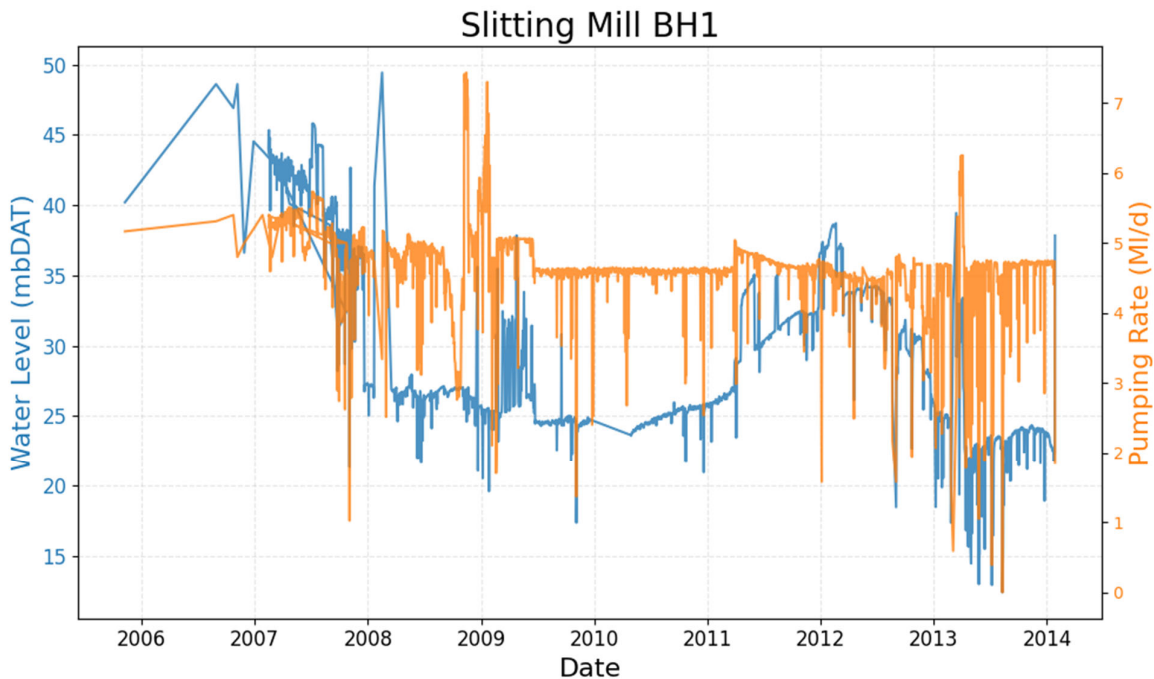


Figure 3.1 Slitting Mill BH1 hydrograph

Analysis of plots of pumping rate against water level (Figure 3.2 – Figure 3.4) demonstrated the following:

- At some abstractions (e.g., Slitting Mill, BH1, Figure 3.2), lower groundwater levels are correlated with higher pumping rates. However, other sites (e.g., Crumpwood BH1, Figure 3.3), groundwater levels are not sensitive to abstraction rates.
- The majority of the abstraction wells show no distinct difference in pumping rate and water level behaviour between drought and non-drought years, demonstrating resilience in drought conditions. The exception is Pipe Hill (e.g., Pipe Hill BH1, Figure 3.4); at Pipe Hill, the drought condition data falls within a cluster at the bottom of the range of water levels. However, the data is still within the non-drought operational bounds, suggesting resilience to drought.
- Abstraction boreholes are more sensitive to abstraction rate than to drought conditions and will not be suitable for use in developing drought triggers.

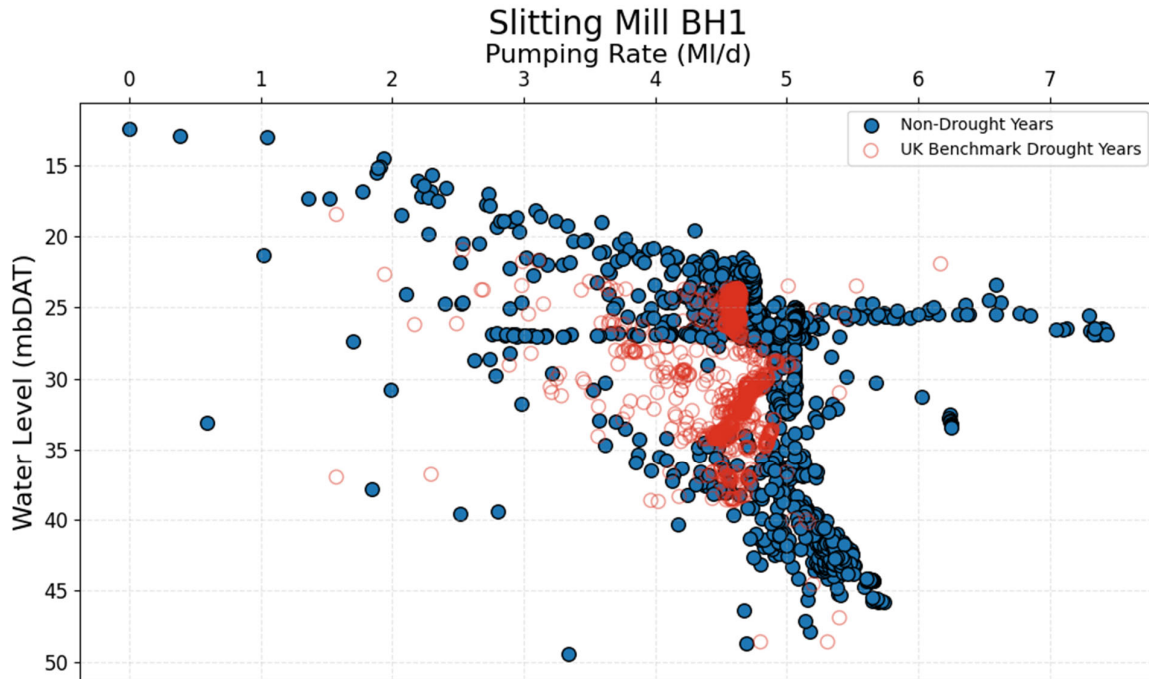


Figure 3.2 Slitting Mill BH1 pumping rate plotted against water level

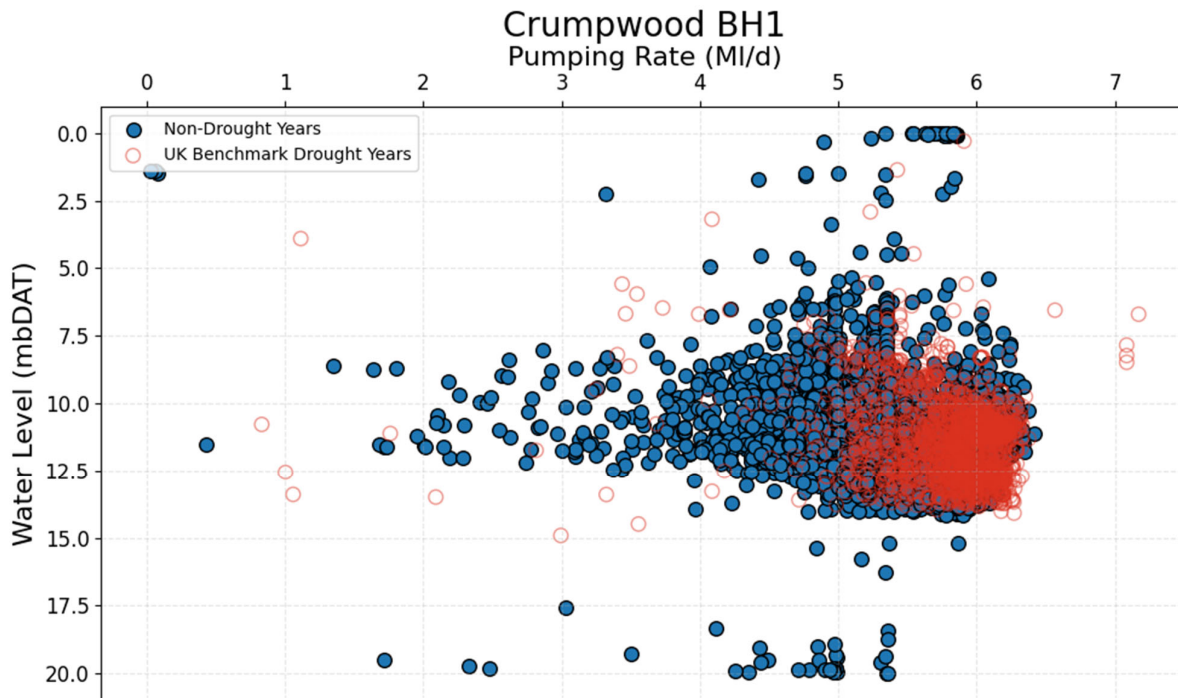


Figure 3.3 Crumpwood BH1 pumping rate plotted against water level

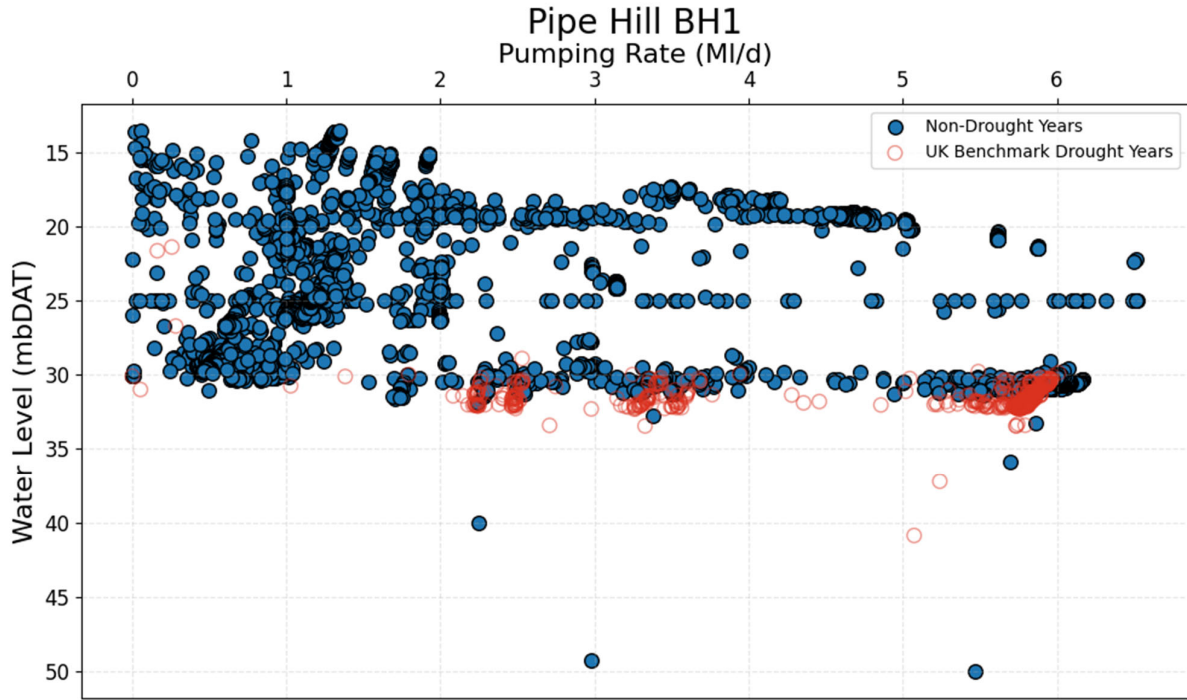


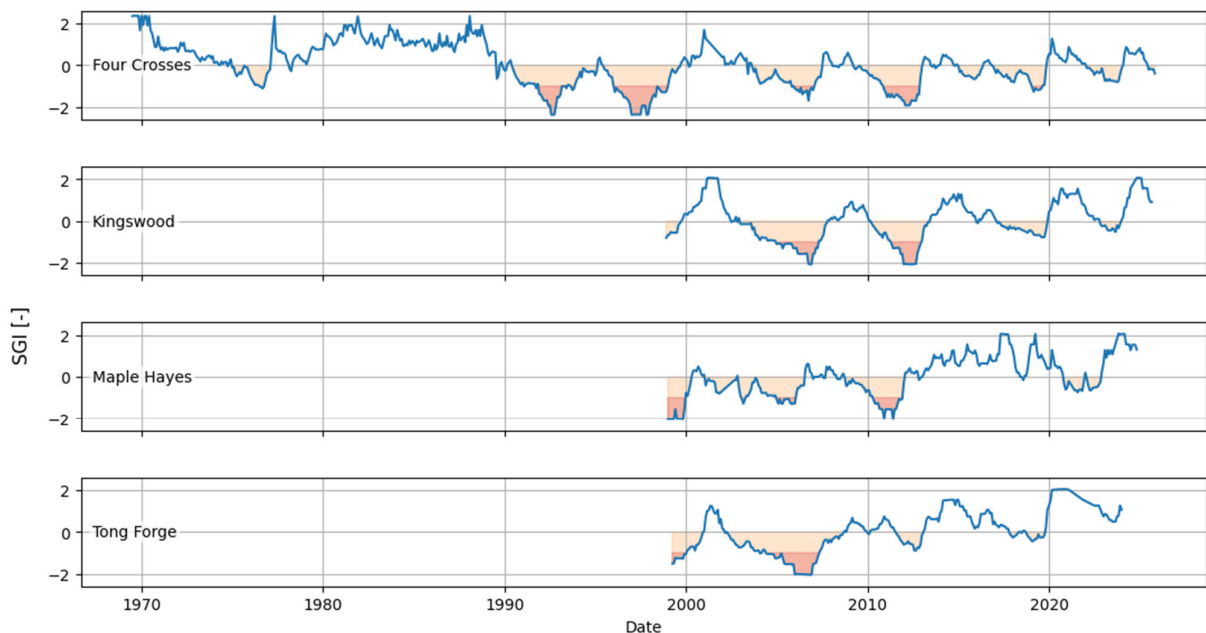
Figure 3.4 Pipe Hill BH1 pumping rate plotted against water level

### 3.1.2 SGI

Following processing and based on the selection criteria described in Section 2.3.2, four EA OBHs were selected (Figure 3.5):

- Four Crosses (Staffordshire Trent Valley GWB).
- Kingswood and Tong Forge (Worcestershire Middle Severn GWB).
- Maple Hayes (Tame Anker Mease GWB) .

No OBH was selected for the Dove GWB as the only available OBH, SunnyBank Farm, has a relatively short data record from 2009–2025. All 15 OBHs were processed with SGI; the complete set of figures is shown in Appendix C.



**Figure 3.5 SGI outputs for the four selected EA OBHs**

The SGI outputs demonstrate the following key findings:

- Seasonal variability is evident in all selected OBHs.
- Impacts from abstraction are not evident, meaning SGI will provide a more robust signal of drought conditions across the relevant GWBs.
- SGI captures UK benchmark droughts. All four OBHs capture the 2004–06 and 2010–12 drought periods, and Four Crosses also captures the 1992 and 1995–98 drought periods.
- Drought characterisation is relatively consistent across representative sites. Maple Hayes deviates slightly in timing of droughts; for instance, the 2010–12 drought at Maple Hayes shows drought conditions in 2008, and recovers before Four Crosses and Kingswood. This may be a function of the hydrological or hydrogeological setting of Maple Hayes.

## 3.2 Drought metric comparisons

### 3.2.1 SPD and SGI

Given the SGI performance in capturing historical droughts, a comparison was made between pumping rate and water level data from abstraction wells with SGI at nearby EA OBHs to verify abstraction wells are resilient in drought conditions. The analysis was undertaken as follows:

- Two abstraction wells (Slitting Mill BH1 and Little Hay BH1) were selected based on data quality and proximity to the EA OBHs selected for SGI analysis.
- The selected abstraction wells were paired with their closest EA OBH; Slitting Mill BH1 was paired with Four Crosses OBH, and Little Hay BH1 with Maple Hayes OBH.
- Average pumping rate and water level data from the abstraction wells was binned by month and year.
- Pumping rate and water level data from the abstraction wells was assigned an SGI corresponding to the month and year bins; for example, all pumping rate and water level data from Slitting Mill BH1 in July 2007 was assigned the SGI value at Four Crosses OBH from July 2007 of -1.51.
- Pumping rate was plotted against water level at each abstraction well; the colour of the dots was used to indicate the corresponding SGI value for every data point (Figure 3.6, Figure 3.7).

The comparison between SGI on the pumping rate against water level data shows that drought conditions loosely correspond with lower water levels for similar pumping rates; for example, at Little Hay, more negative SGI values correspond to lower water levels when pumping between 1–5 Ml/d (Figure 3.7). This is expected, as drought conditions will broadly lower groundwater levels in the GWB.

If abstraction wells are sensitive to drought conditions, it is expected that negative SGI values will correspond with the lowest water levels over the entire range of pumping rates and will noticeably deviate from typical performance. This is not the case with the SSW abstractions analysed. The negative SGI data points also overlay with near-zero and positive SGI data points; the abstraction well performance does not noticeably deviate from typical performance during drought conditions. This demonstrates that the abstraction wells are resilient in drought conditions, as pump performance is not impacted during established drought periods. This finding provides further evidence to support SGI being the most suitable metric for characterising groundwater drought in the Midlands GWBs where SSW operates.

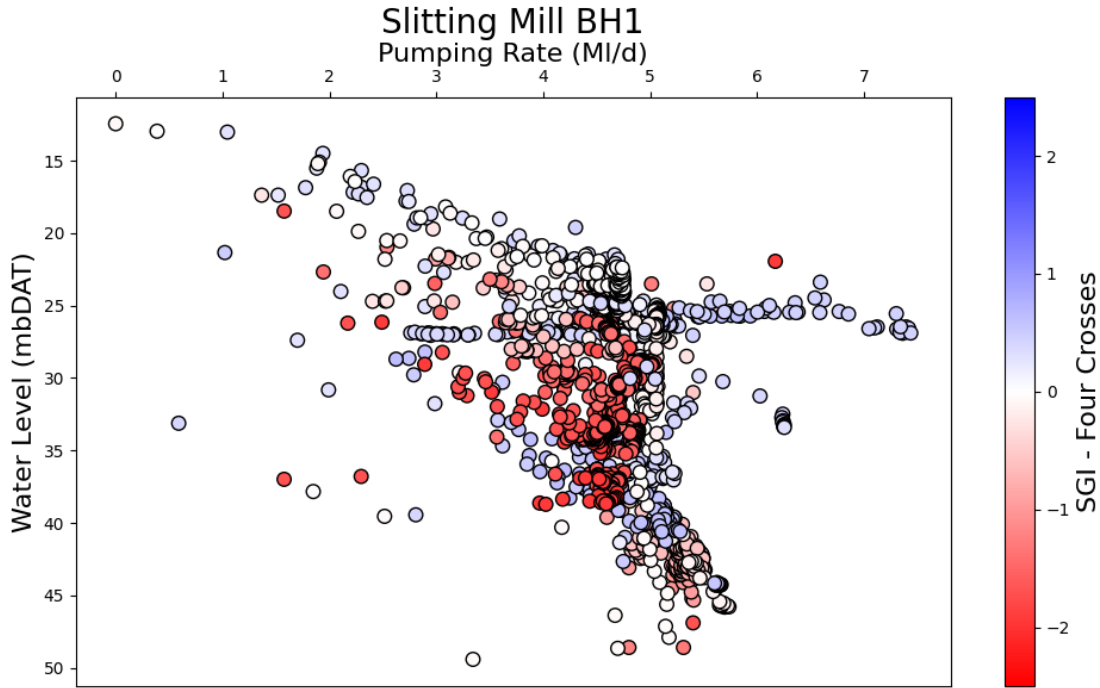


Figure 3.6 Slitting Mill BH1 pumping rate against water level, compared with closest SGI data from EA OBH Four Crosses

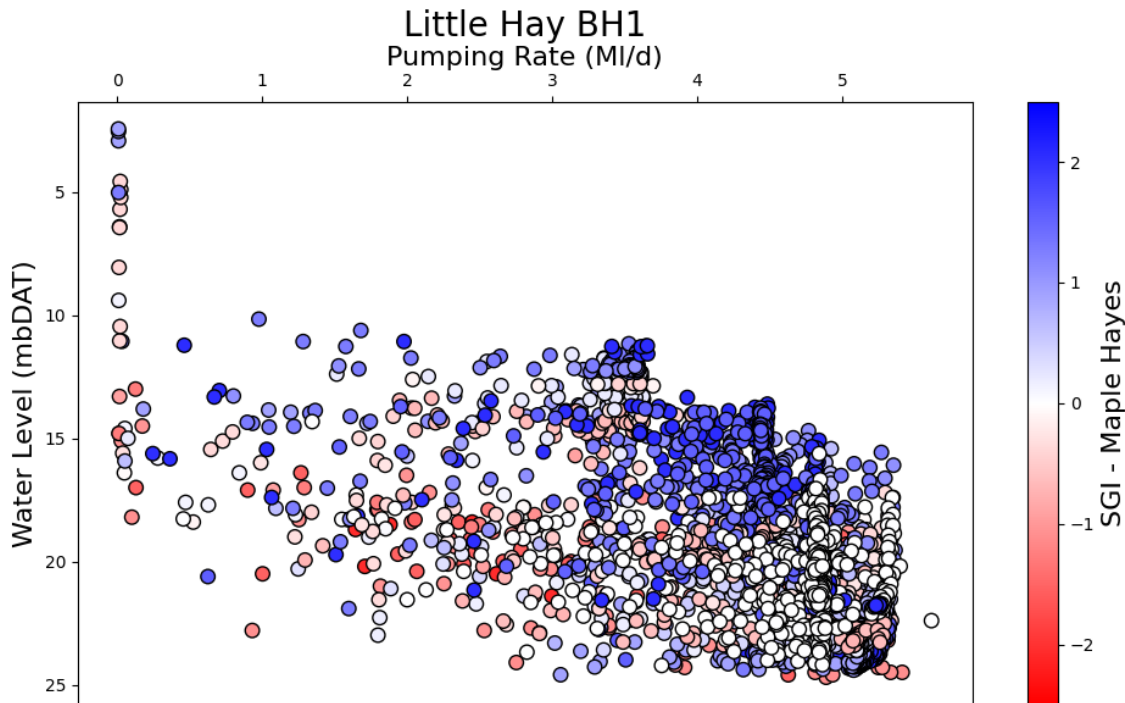


Figure 3.7 Little Hay BH1 pumping rate against water level, compared with closest SGI data from EA OBH Maple Hayes

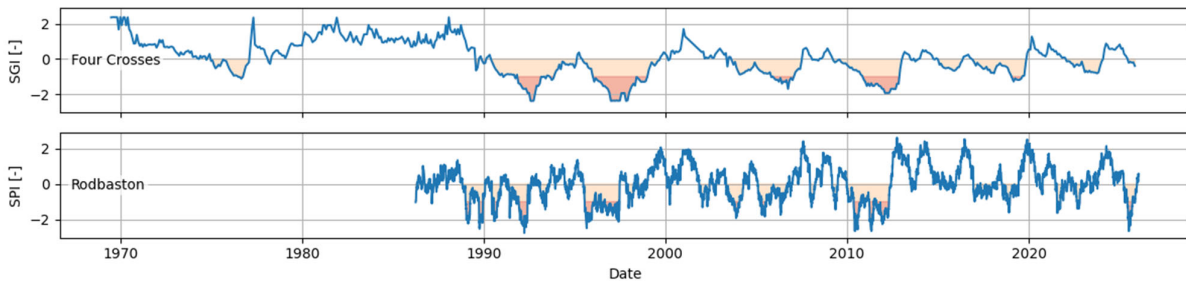
### 3.2.2 SPI and SGI

SPI, used to quantify meteorological droughts, has been shown to correlate with SGI (Bloomfield and Marchant, 2013). SPI and SGI were compared at two EA OBHs, paired with their nearest EA rainfall gauge: Four Crosses OBH paired with Rodbaston (Staffordshire Trent Valley GWB), and Maple Hayes OBH paired with Lichfield (Tame Anker Mease GWB). Daily precipitation data was acquired from the EA, and SPI was calculated using an open-source Python package (Vonk, 2024). The SPI was calculated using a 6-month accumulation period; rainfall is summed over a 6-month period and compared against the long-term historical distribution.

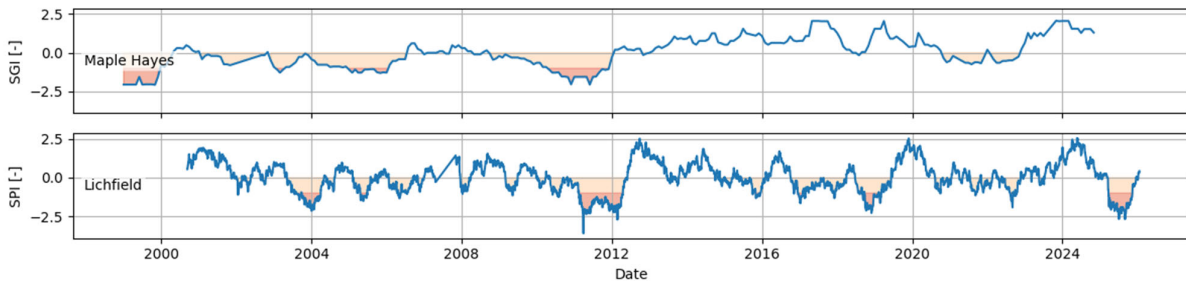
Comparison between SGI at Four Crosses OBH and SPI at Rodbaston (Figure 3.8) shows strong correlation between the two indices, as both capture the same drought periods (e.g., 2010–12, 2004–06). There is a temporal lag between SPI and SGI in this pairing, which is most evident during the 2004–06 drought. SGI is expected to be a lagging indicator relative to SPI owing to aquifer- and area-specific recharge and flow processes impacting groundwater levels. However, they are generally well-correlated.

Comparison between SGI at Maple Hayes OBH and SPI at Lichfield (Figure 3.9) does not show strong correlation, as many of the drought periods are not aligned temporally. This suggests that groundwater levels at Maple Hayes may be influenced by other factors such as nearby pumping from Pipe Hill PWS, or site-specific recharge processes.

These findings highlight a key difference between SPI and SGI. SPI produces a drought index that directly reflects meteorological drought conditions. SGI, however, is impacted by geographical location, owing to site specific recharge and flow processes including orographic influences and soil or land use influences on recharge. A key benefit of SGI is it measures not only meteorological drought conditions but also the hydrogeological context of the observation borehole (Bloomfield and Marchant, 2013).



**Figure 3.8 Comparison of SGI at Four Crosses OBH and SPI at Rodbaston**



**Figure 3.9 Comparison of SGI at Maple Hayes OBH and SPI at Lichfield**

### 3.3 Trigger development

Two options are proposed as actionable triggers: the use of monthly SGI as a trigger, and the use of groundwater levels as triggers based on historical SGI data.

Using monthly SGI as a trigger is a statistically robust approach and will provide a high level of confidence for classification of droughts. The thresholds proposed are:

- Drought ( $-1.0 \geq \text{SGI} > -2$ ), and
- Extreme Drought ( $\text{SGI} \leq -2$ ).

Monthly monitoring of SGI is currently in use at the UK Centre for Ecology and Hydrology (CEH) to classify groundwater drought (Barker et al., 2022). However, this approach is much better suited to classifying historical droughts, rather than acting as a real-time operational trigger because there is a time-lag of at least one month before a drought can be recognised.

The alternative proposed is the use of groundwater levels as triggers, based on the historical relationship between groundwater level and SGI at individual OBHs. The monthly average groundwater level at a given OBH has an associated SGI value. The maximum (monthly average) groundwater level within each drought intensity band is proposed as the drought band trigger; for example, at Four Crosses OBH, the maximum observed groundwater level in Drought conditions ( $-1.0 \geq \text{SGI} > -2$ ) is 113.13 mAOD, and the maximum observed groundwater level in Extreme Drought conditions ( $\text{SGI} \leq -2$ ) is 112.55 mAOD (Figure 3.10). This approach provides a conservative approximation of the range of groundwater levels corresponding to groundwater drought conditions. The complete set of triggers for the selected EA OBHs is in **Error! Reference source not found.**, and the complete set of groundwater level vs SGI plots is in Appendix D. Historical groundwater level data with the proposed groundwater drought triggers is shown in **Error! Reference source not found.**

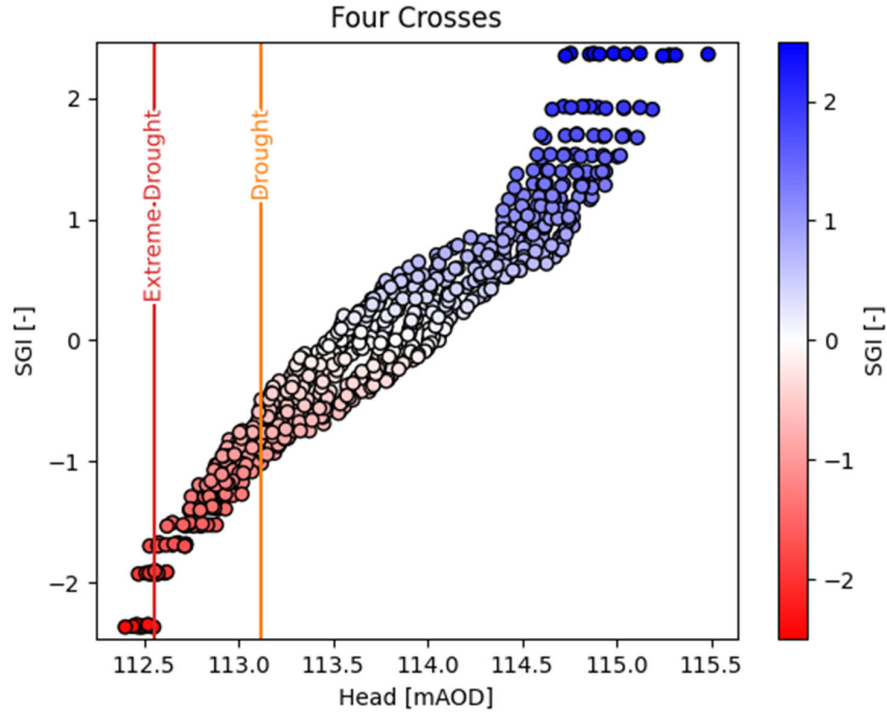
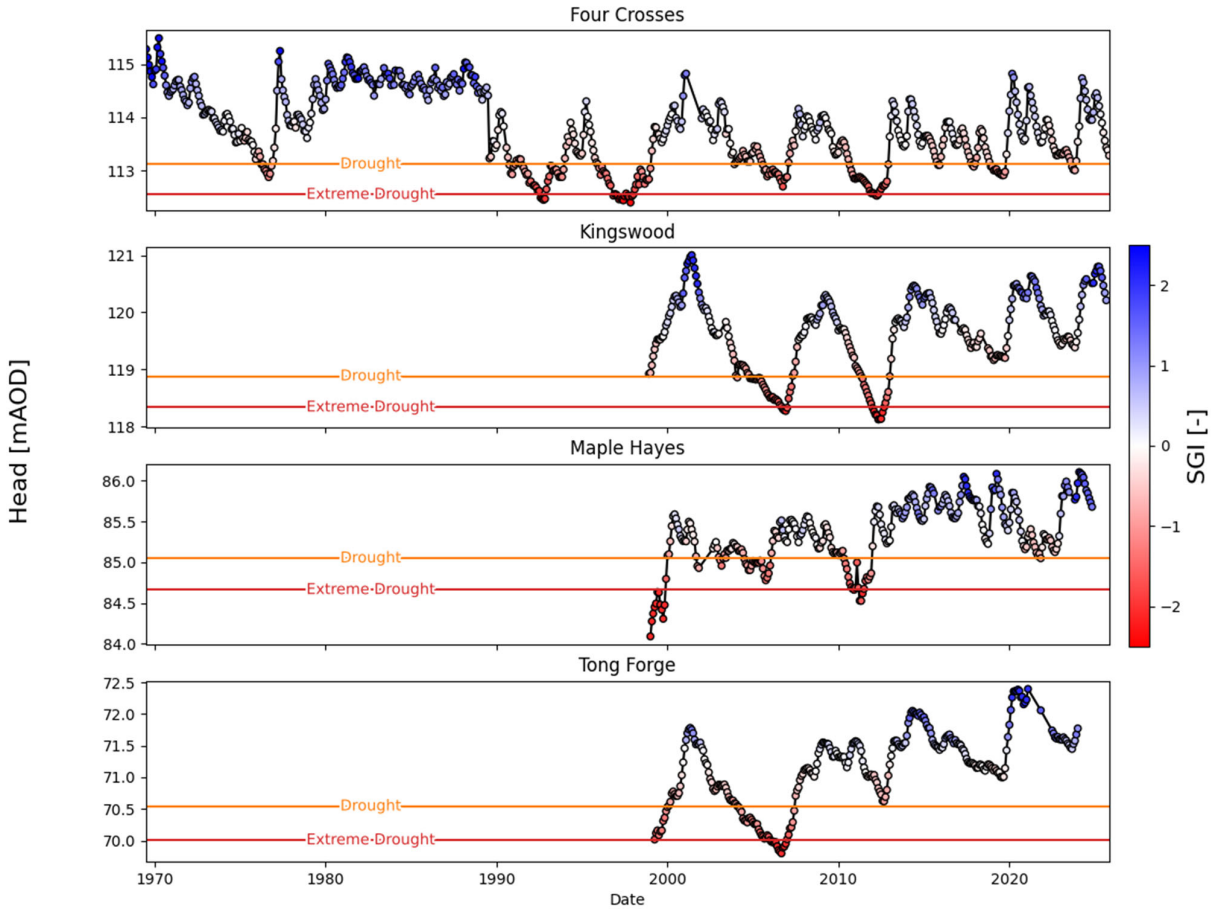


Figure 3.10 Four Crosses OBH groundwater levels plotted against SGI, with groundwater drought trigger levels indicated

Table 3.1 Groundwater level drought triggers

OBH	Drought Trigger (mAOD)	Extreme Drought Trigger (mAOD)
Four Crosses	113.12	112.55
Kingswood	118.88	118.34
Maple Hayes	85.05	84.66
Tong Forge	70.54	70.00



**Figure 3.11 Historical groundwater levels at four selected EA OBHs, with groundwater drought trigger levels indicated**

The suitability of this approach is demonstrated by comparing historical SGI drought periods with the approximated drought periods based on groundwater level (Figure 3.12). The proposed groundwater level triggers capture the Drought periods classified by SGI in 1991–1993, 1995–1999, 2005–2007, and 2010–2012, and the Extreme Drought periods classified by SGI in 1992 and 1996–1998. The groundwater level trigger also identified Drought periods that are not classified as Drought by SGI in 1975–1976 and briefly in 2023. These periods do however have negative values of SGI, indicating dry conditions. The groundwater level trigger also classifies a brief period in 2012 as Extreme Drought; while SGI does not classify this period as Extreme Drought, the value of SGI is -1.95 which is approaching Extreme Drought. The classification of these periods as droughts highlights the conservative nature of the groundwater-level based approach, which is considered appropriate. The complete set of comparison between SGI drought periods and groundwater level drought periods is in Appendix E.

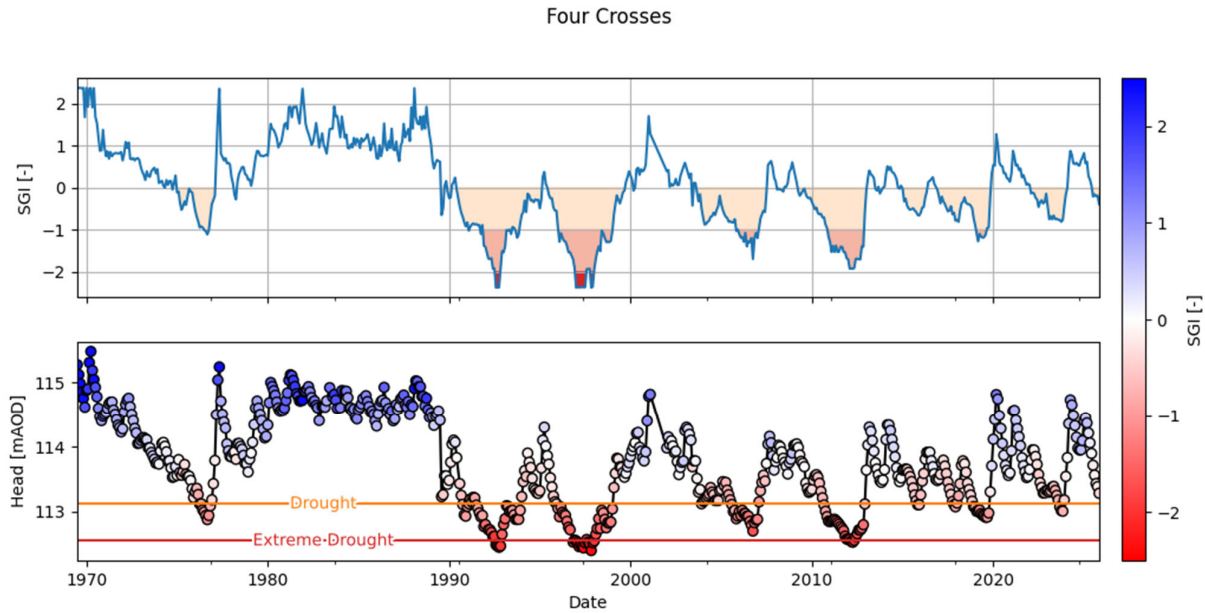


Figure 3.12 Comparison of SGI and groundwater level drought triggers at Four Crosses OBH

It is proposed that 'Drought' status should be triggered when two of the four selected OBHs have groundwater levels below the Drought trigger groundwater level. Triggering drought status when at least two OBHs enter Drought conditions provides higher confidence in drought conditions. Based on historical data between 1998–present (the period in which all OBHs have data available), drought status would be triggered in 1998–1999, 2004–2006 and 2010–2012, capturing all three UK benchmark droughts from 1998–present (**Error! Reference source not found.**).

Groundwater levels should be monitored using daily groundwater level data, as daily data will serve as a leading metric of drought status, as opposed to waiting for monthly data to be processed. This is supported by the low variability of groundwater levels on a daily-to-monthly timescale, particularly during drier periods, and therefore daily groundwater levels will provide a signal appropriate to compare with monthly-derived SGI.

Groundwater level triggers should be reviewed regularly (suggested annually) as SGI data is updated to provide the most accurate approximation of drought conditions. Overall, these groundwater level triggers are expected to perform well for monitoring drought conditions and would be suitable as a conservative operational drought trigger.

# 4 Conclusion

## 4.1 Summary

The objectives of this work were addressed as follows:

- The most appropriate representations of staged groundwater drought metrics were identified: SPD and SGI are the two most suitable metrics for potential use by SSW.
- Representative groundwater drought sites were selected: eight PWS locations (data supplied by SSW), and regional groundwater monitoring data was collated from 15 EA OBHs for use as representative groundwater drought trigger sites.
- Drought trigger frameworks at each of the representative sites were tested and compared against historical data: pumping rate and water level data from abstraction wells were used to generate hydrographs and plots of pumping rate vs water level (the basis for SPD graphs). EA OBH data was analysed using the SGI, and outputs were compared against benchmarked UK droughts.
- The suitability of groundwater drought triggers was assessed; data processing of abstraction well data demonstrated that the SPD approach was not suitable for use by SSW due to the abstraction wells resilience in drought conditions and lack of seasonal variability. SGI outputs were able to characterise groundwater drought. SGI behaviour was consistent across sites and relevant GWBs and captured key UK benchmark droughts.

## 4.2 Recommendations

The SGI was identified as the most suitable approach for characterising groundwater droughts in SSW's operational GWBs. Historical UK benchmark droughts are captured at every EA OBH analysed, and SGI classifications of drought are consistent across sites and relevant GWBs. SGI is a robust and well-tested metric and is increasingly being used to quantify groundwater droughts globally (e.g., Bloomfield and Marchant, 2013; Brauns et al., 2020).

Analysis of hydrographs, plots of pumping rate against water level, and comparison between pumping rate and water level with SGI demonstrate that the SSW abstraction wells are resilient in drought conditions and are not sensitive enough to droughts to require development of an actionable trigger framework. It is therefore recommended that SSW continue to use and develop surface water triggers at Blithfield reservoir as their principal operational drought trigger.

If application of groundwater drought triggers is deemed appropriate, it is recommended:

1. That the groundwater level drought triggers proposed in Section 3.3 be applied.
2. The data provision of groundwater levels in the four selected OBHs should be reviewed to ensure near-live data is available to SSW such that early-warning of drought classification is available.
3. 'Drought' status should be triggered when two of the four selected OBHs reach Drought conditions.
4. Groundwater level drought trigger thresholds are reviewed annually as SGI data is updated.

## 5 References

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# APPENDICES

# Appendix A

## Pumping Rate vs Water Level Plots

Data notes:

- Cookley BH2 and BH3 have two data clusters, one for pumping rates between 0 and 2 MI/d, and the other for between 4 and 6 MI/d. This is likely a data issue.
- Ashwood BH1 has two data clusters, one at 40 m water level and one at 60 m water level, suggesting an issue or change in water level datum over the data period covered.

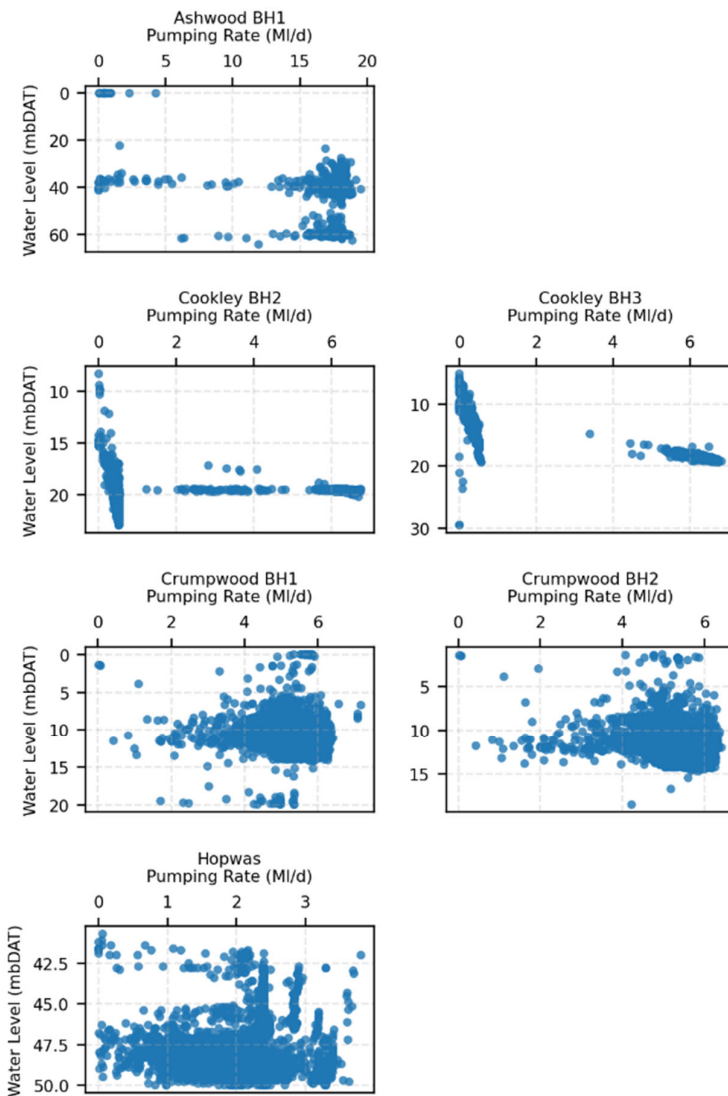


Figure A-1 Pumping rate against water level for complete set of SSW abstraction wells

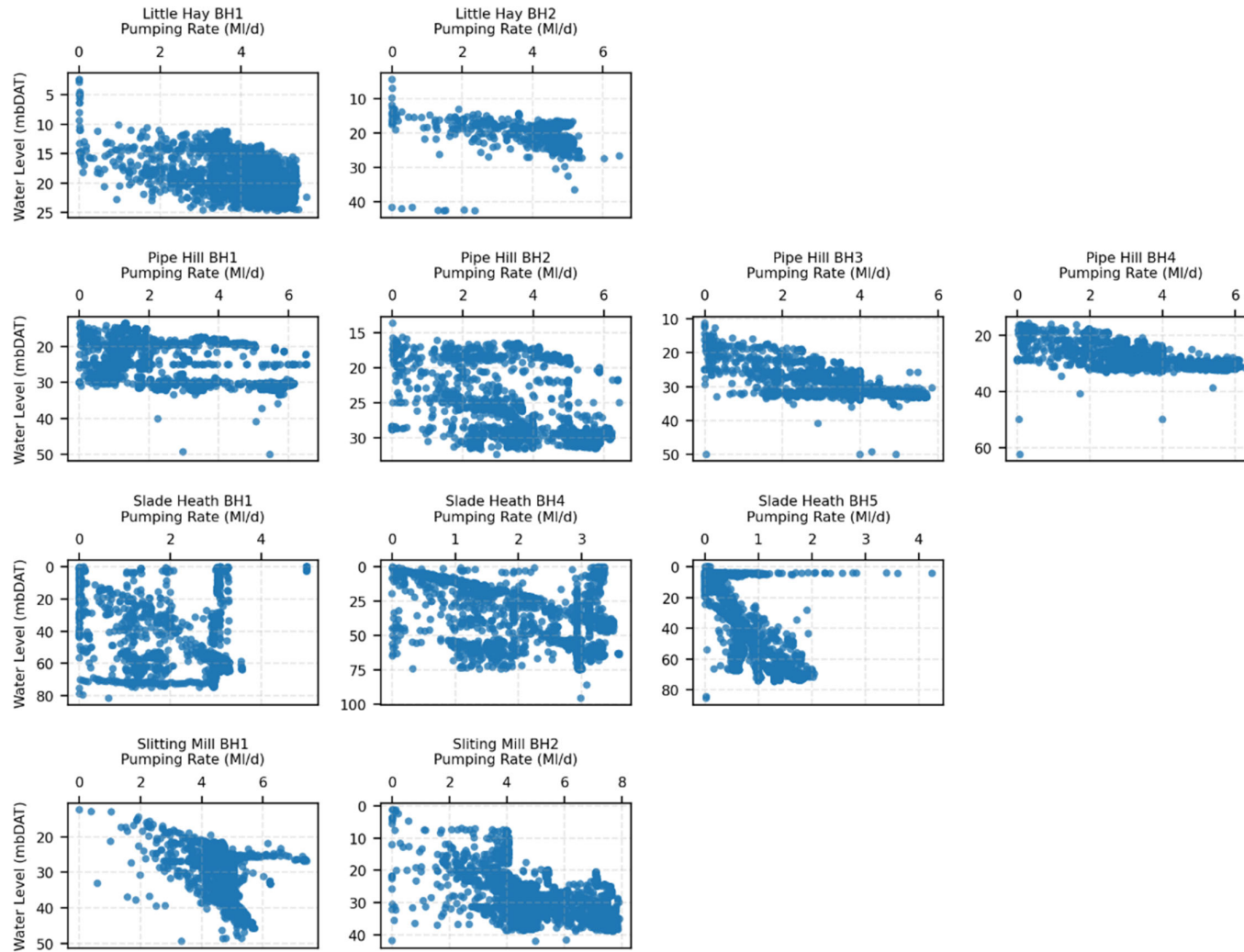


Figure A-1 Pumping rate against water level for complete set of SSW abstraction wells (cont.)

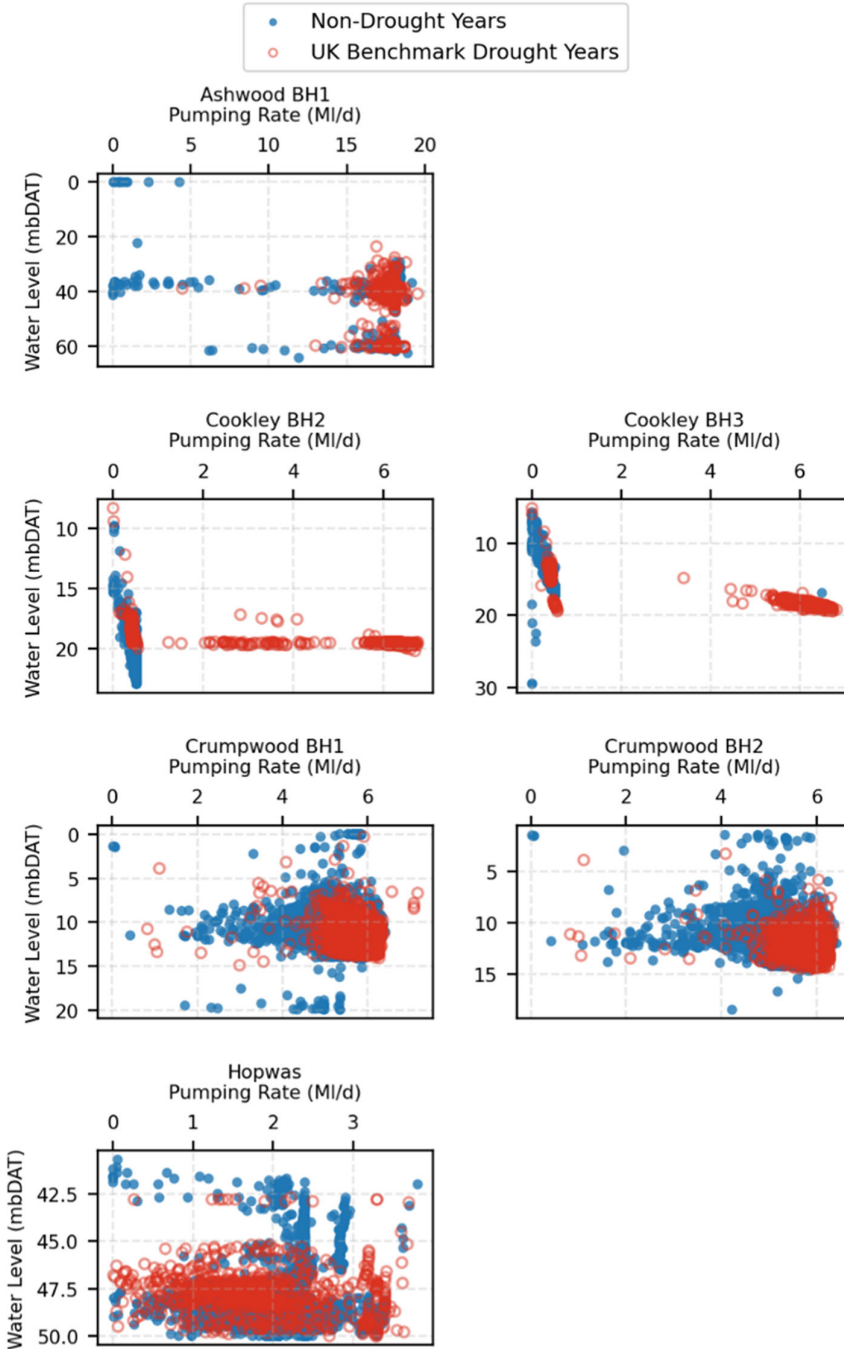


Figure A-2 Pumping rate against water level for complete set of SSW abstraction wells with drought years highlighted in red

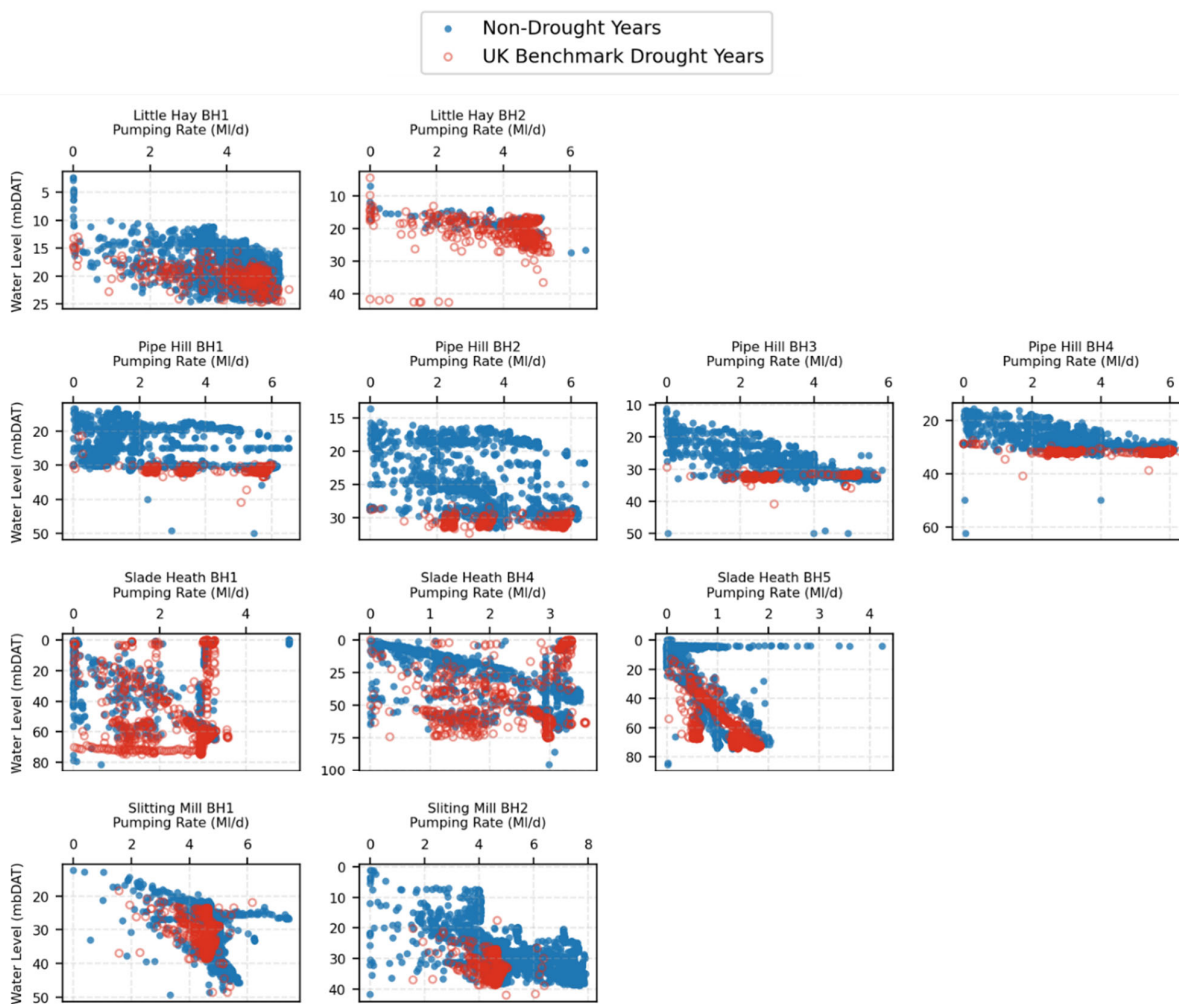


Figure A-2 Pumping rate against water level for complete set of SSW abstraction wells with drought years highlighted in red (cont.)

# Appendix B

## Hydrographs

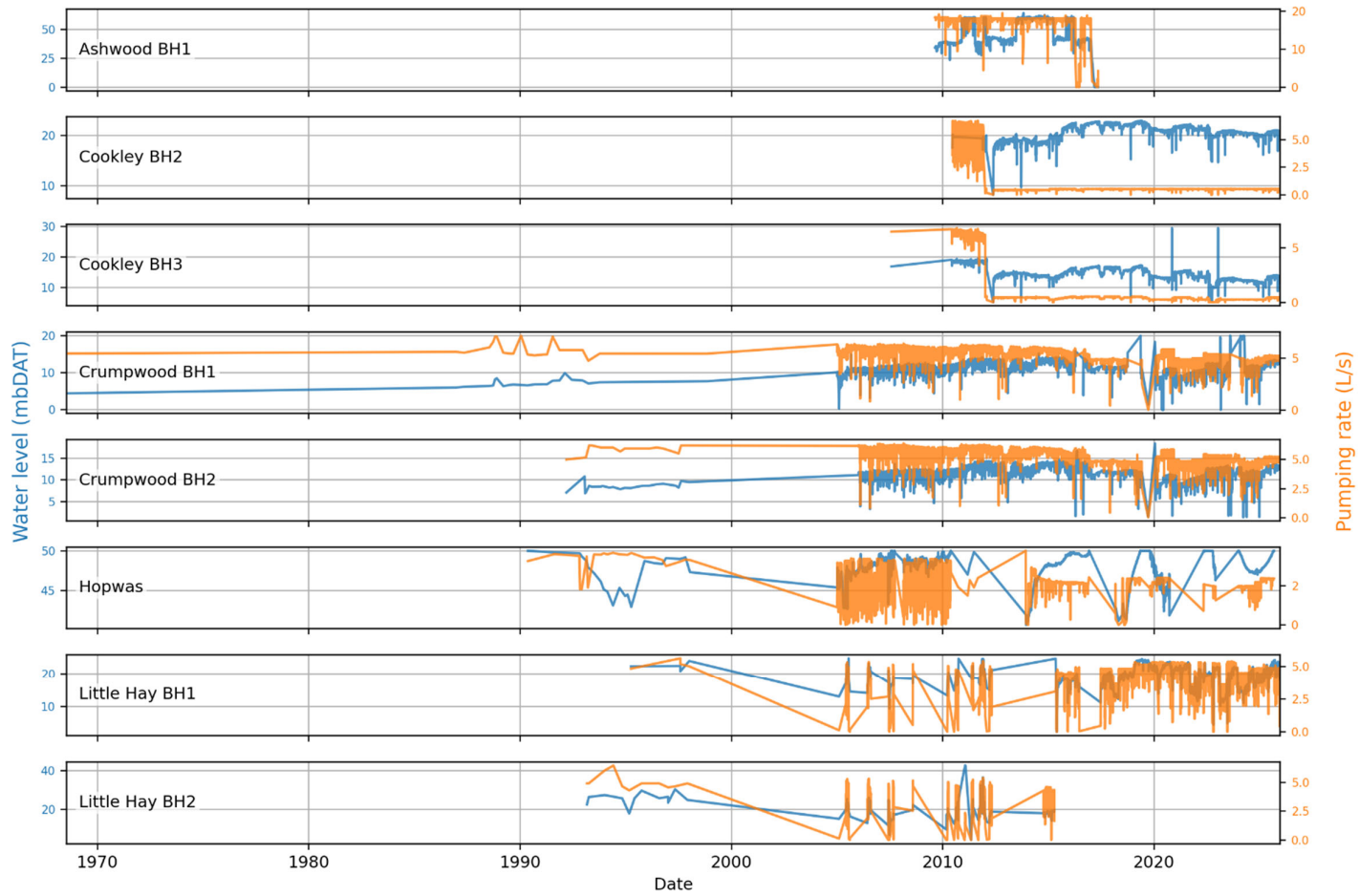


Figure B-1 Hydrographs for complete set of SSW abstraction wells

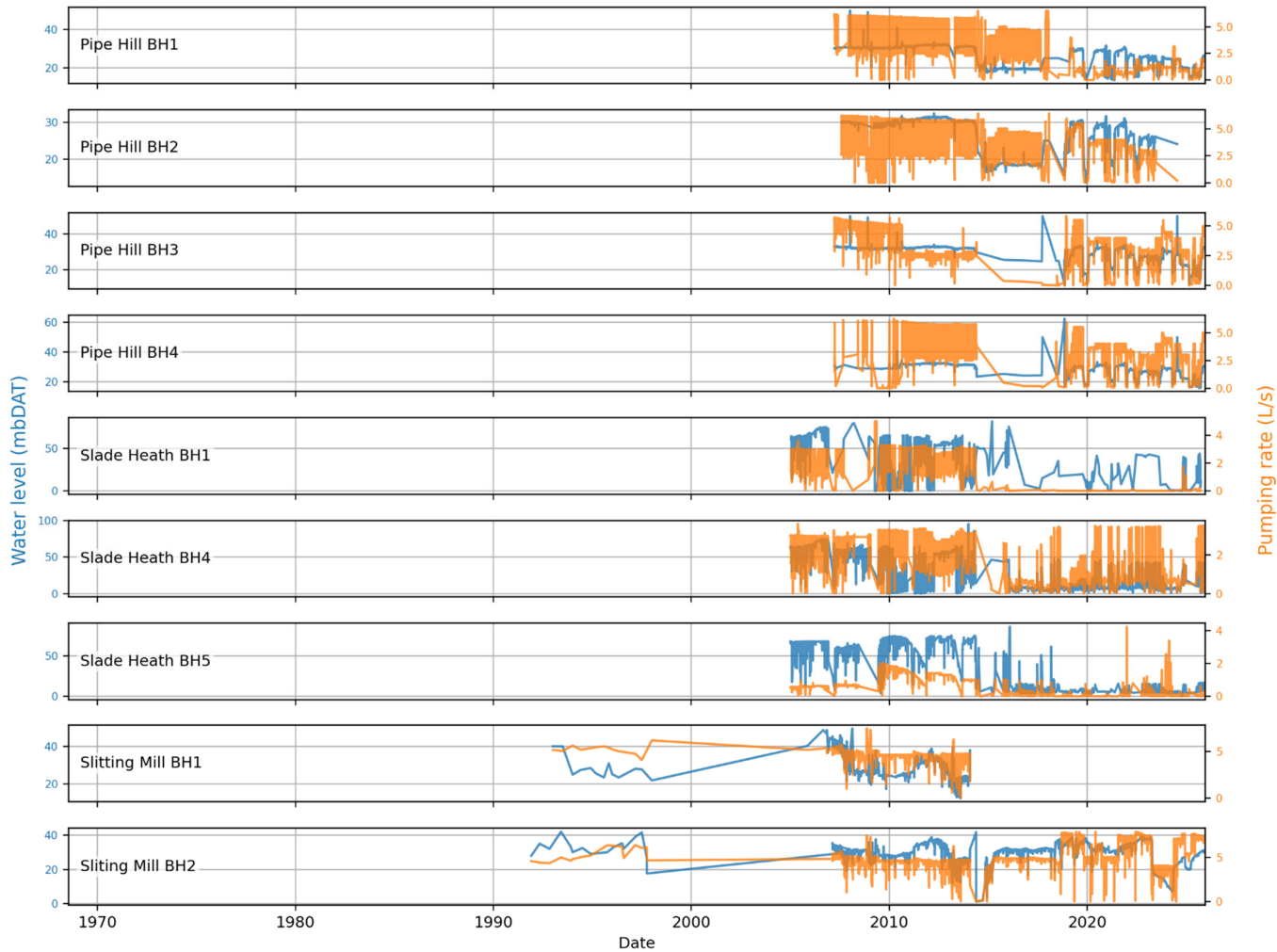


Figure B-1 Hydrographs for complete set of SSW abstraction wells (cont.)

# Appendix C

## SGI Outputs

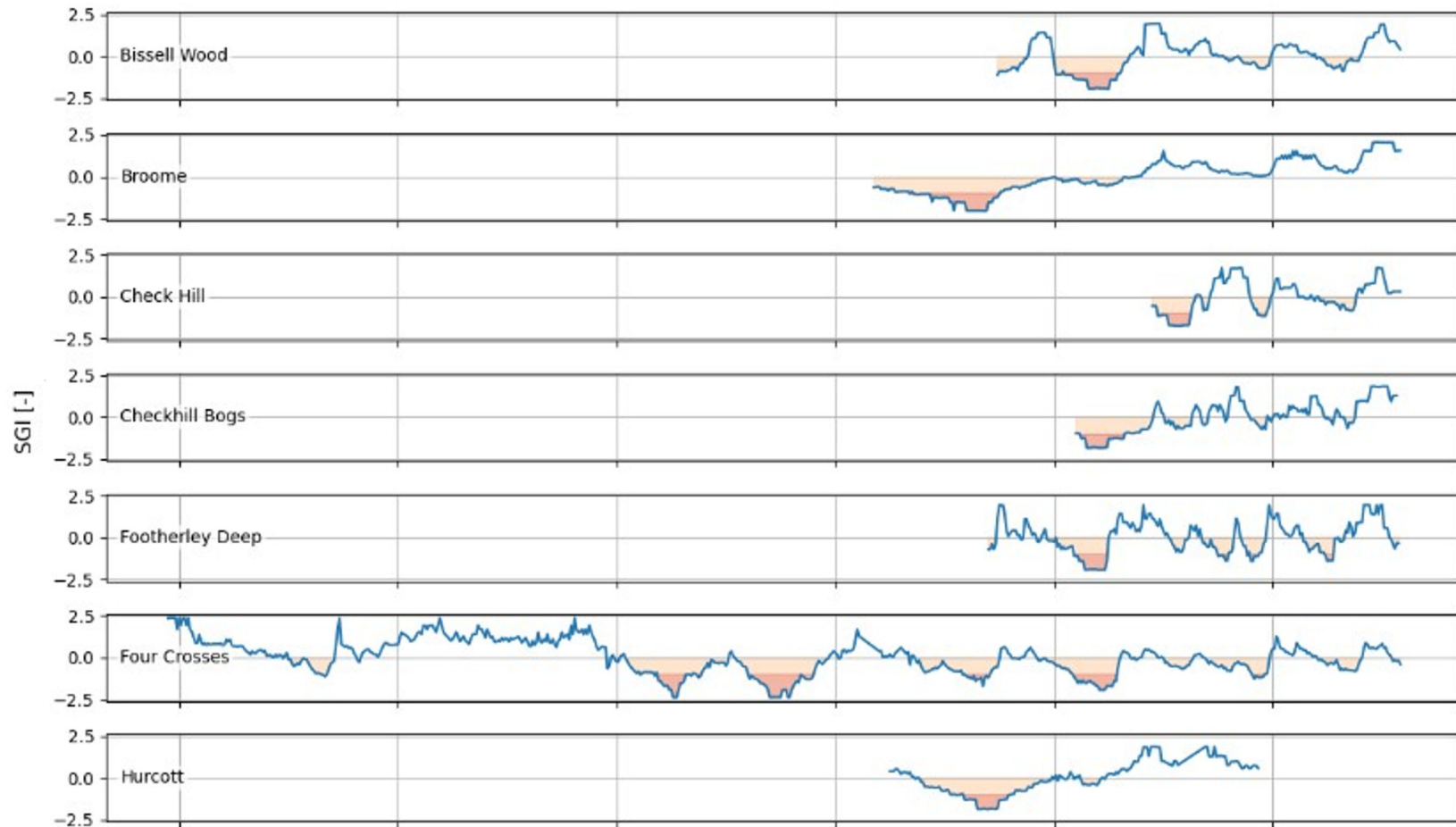


Figure C-1 SGI Outputs for 15 EA OBHs in GWBs where SSW operates

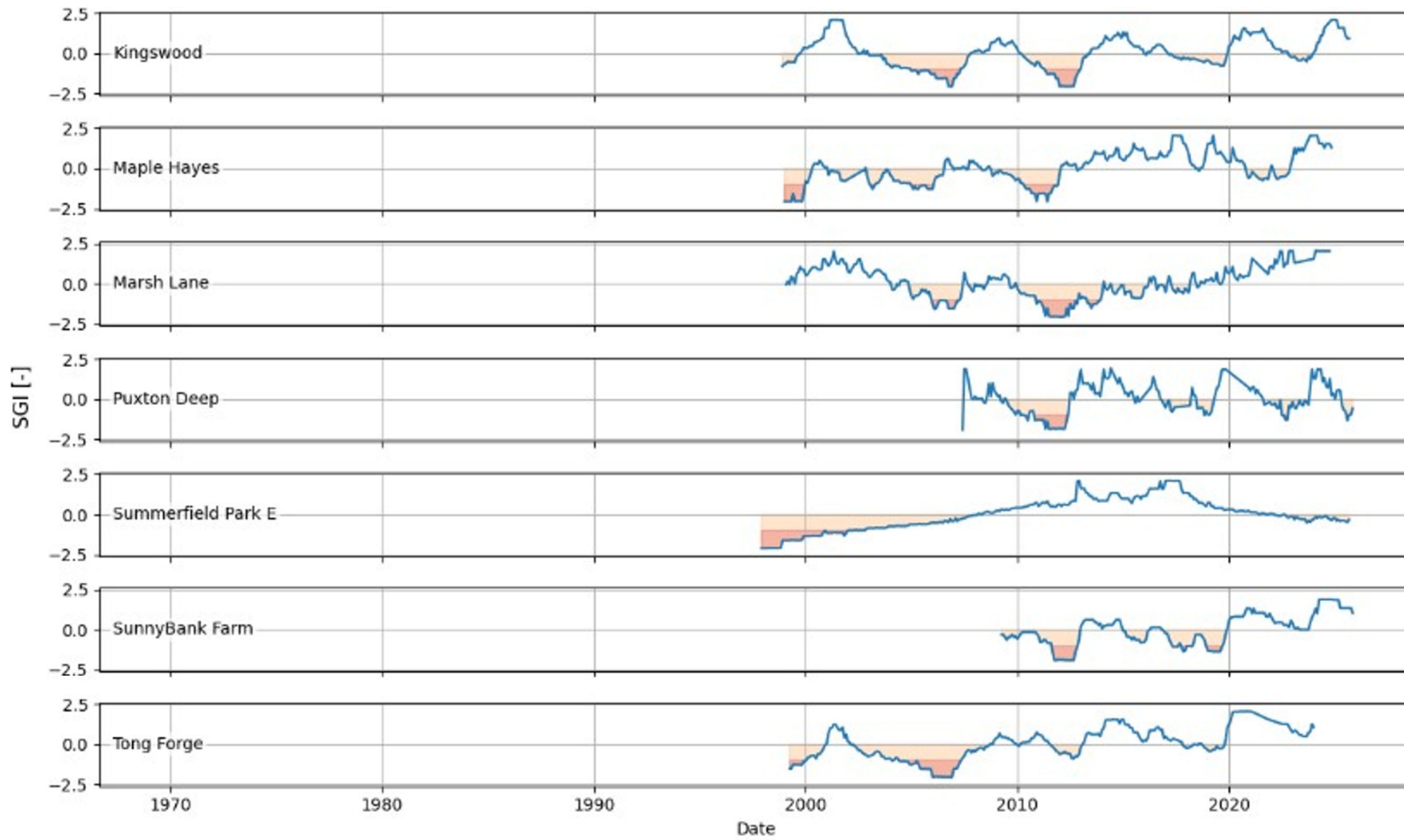


Figure C-1 SGI Outputs for 15 EA OBHs in GWBs where SSW operates (cont.)

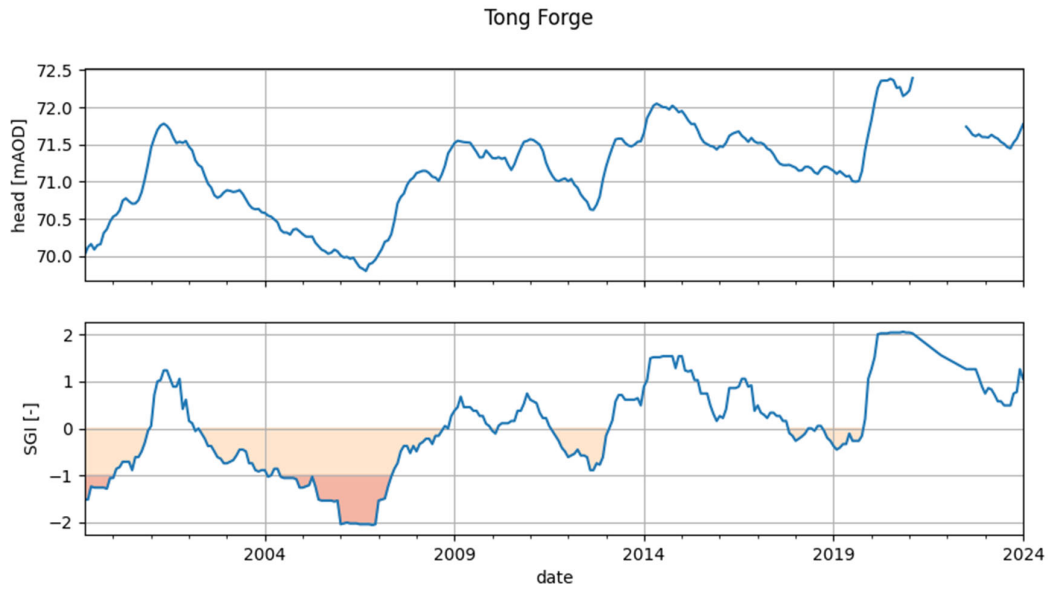


Figure C-2 Tong Forge OBH monthly water level and SGI

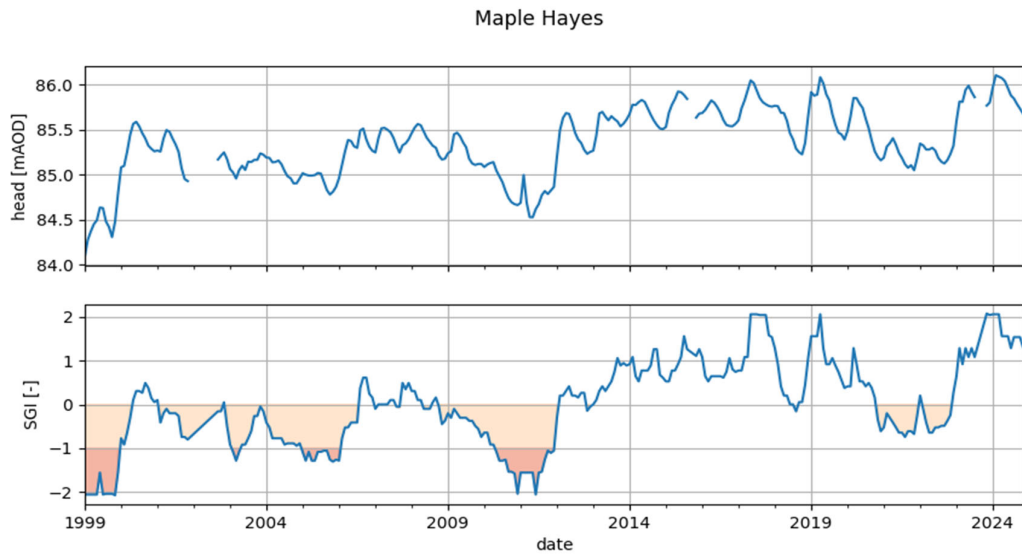


Figure C-3 Maple Hayes OBH monthly water level and SGI

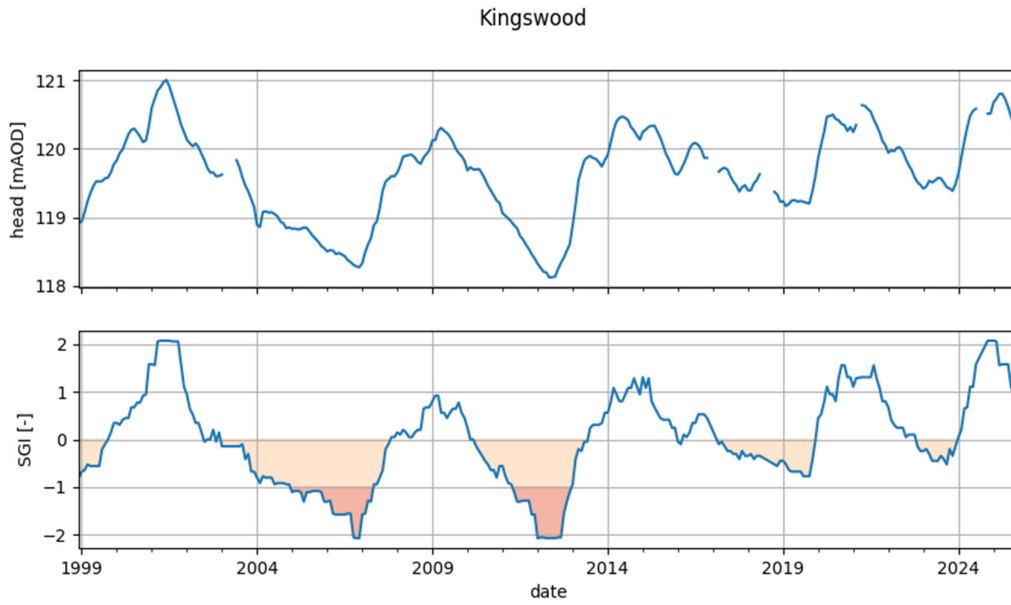


Figure C-4 Kingswood OBH monthly water level and SGI

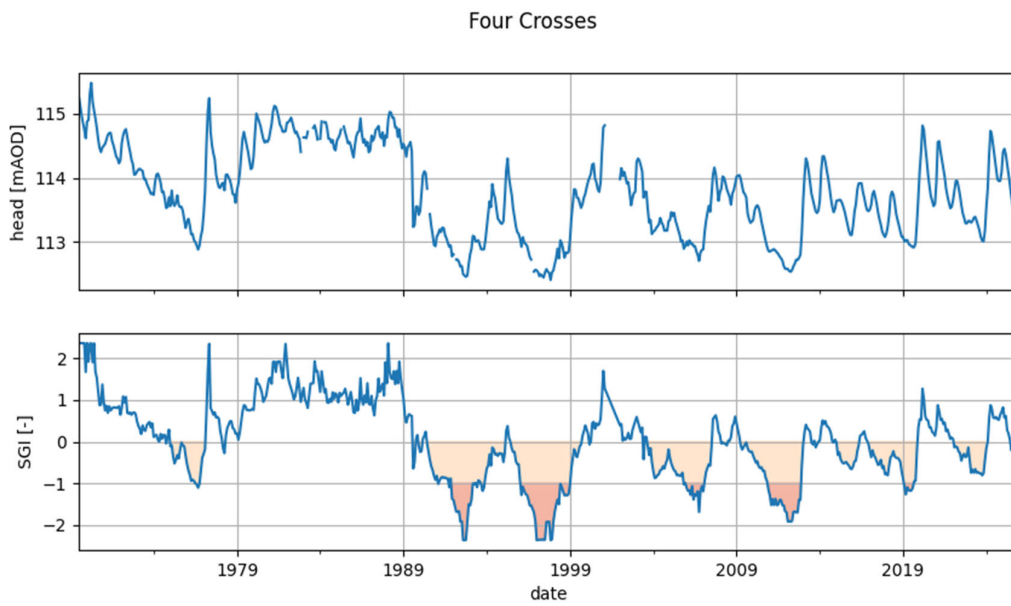


Figure C-5 Four Crosses OBH monthly water level and SGI



# Appendix D

## Groundwater level vs SGI plots

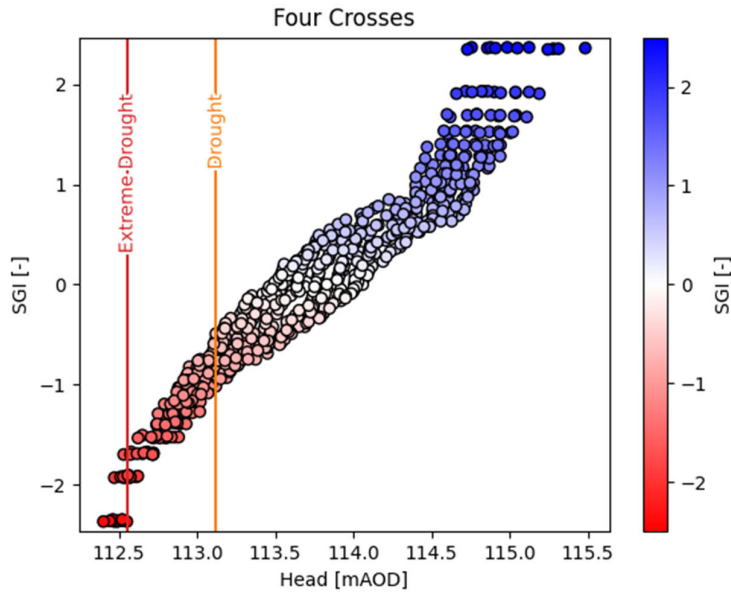


Figure D-1 Four Crosses OBH monthly groundwater level vs SGI, with drought triggers

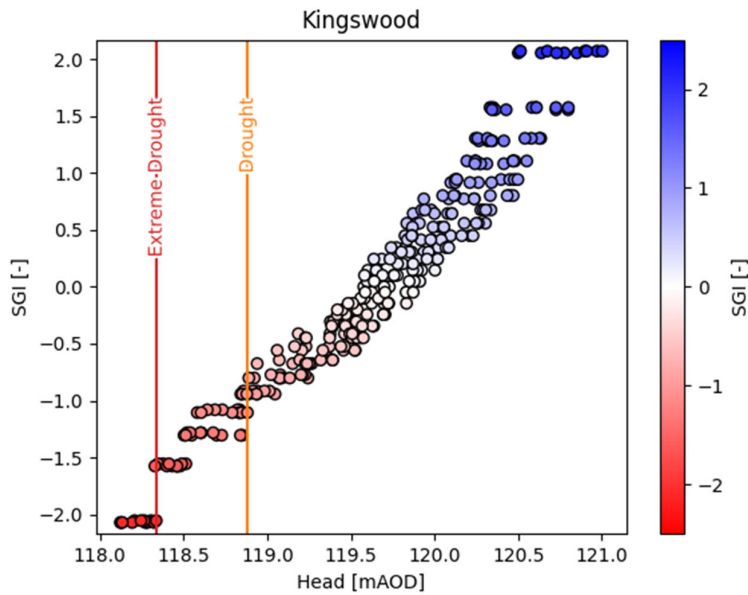


Figure D-2 Kingswood OBH monthly groundwater level vs SGI, with drought triggers

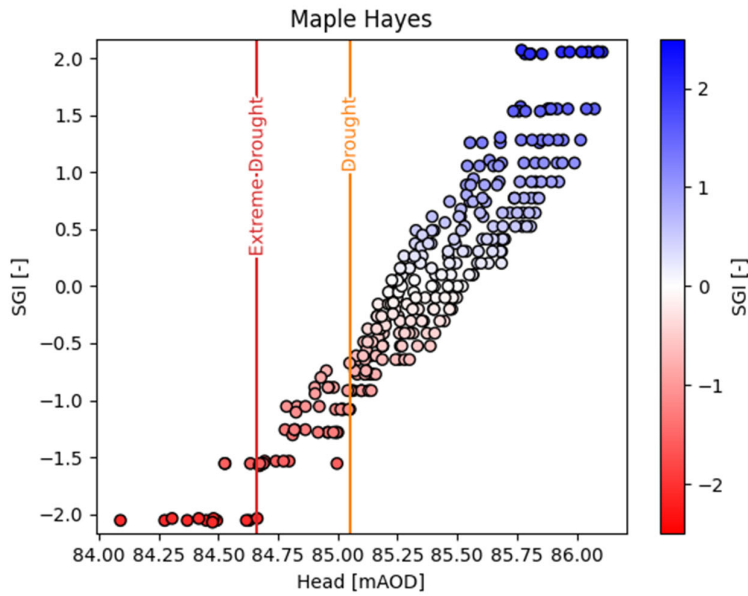


Figure D-3 Maple Hayes OBH monthly groundwater level vs SGI, with drought triggers

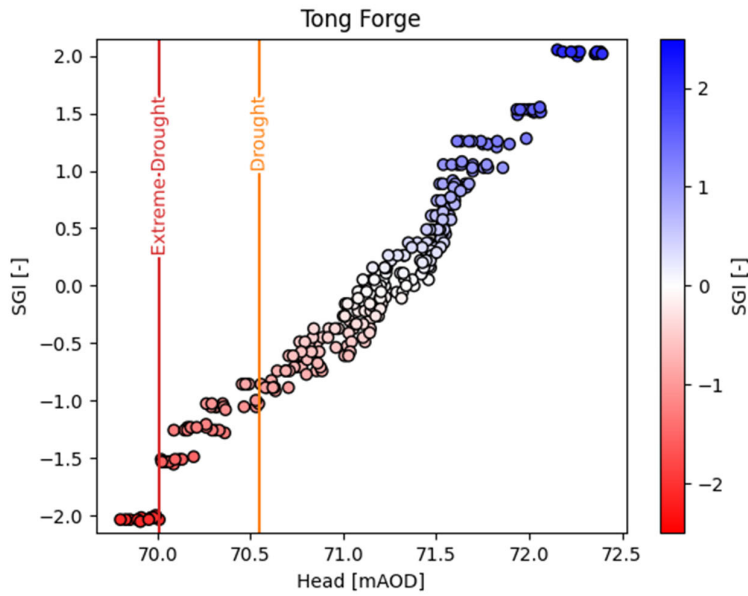


Figure D-4 Tong Forge OBH monthly groundwater level vs SGI, with drought triggers

# Appendix E

## Groundwater level drought triggers

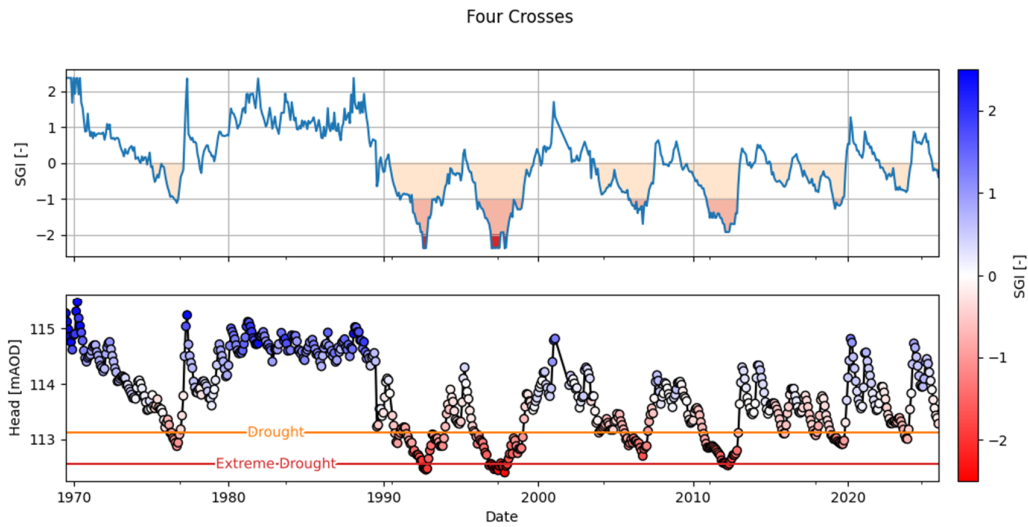


Figure E-1 Comparison of SGI and groundwater level drought triggers at Four Crosses

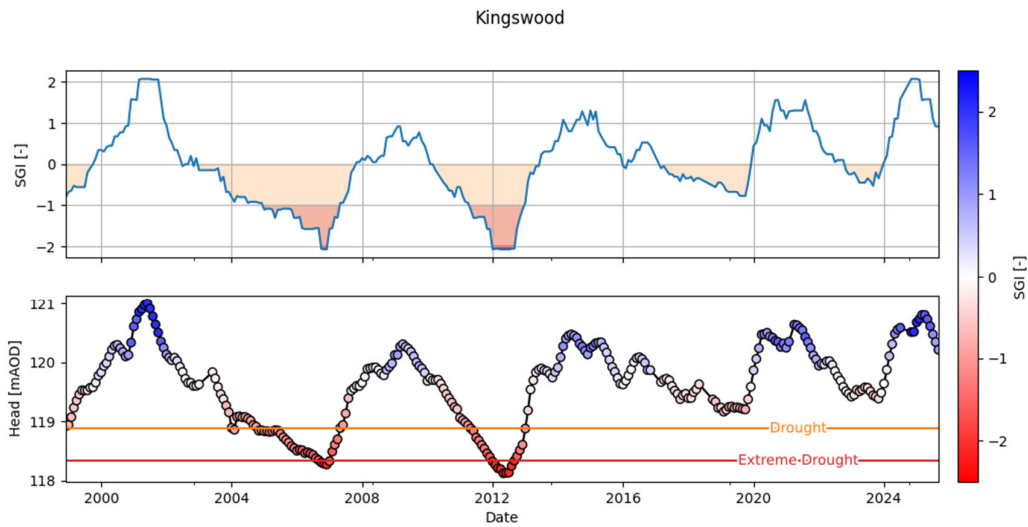


Figure E-2 Comparison of SGI and groundwater level drought triggers at Kingswood

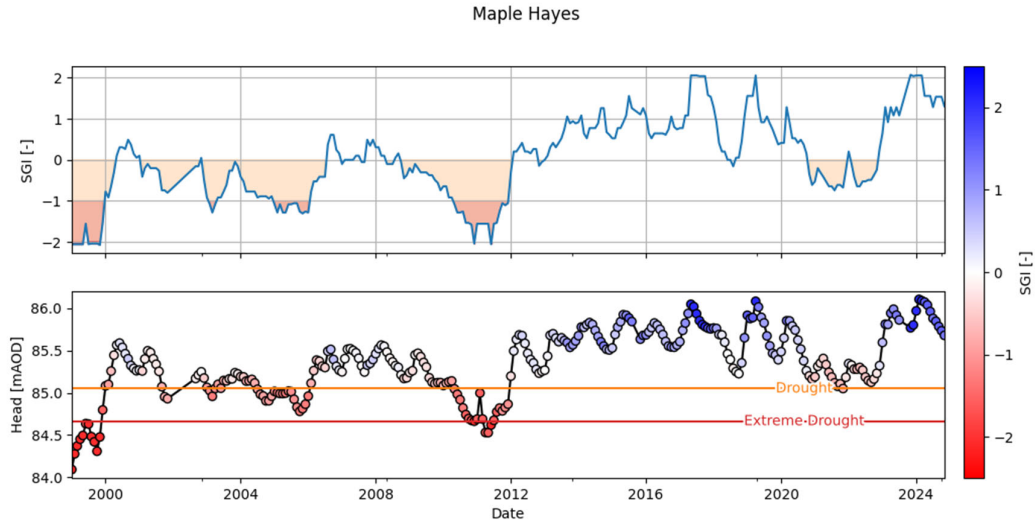


Figure E-3 Comparison of SGI and groundwater level drought triggers at Maple Hayes

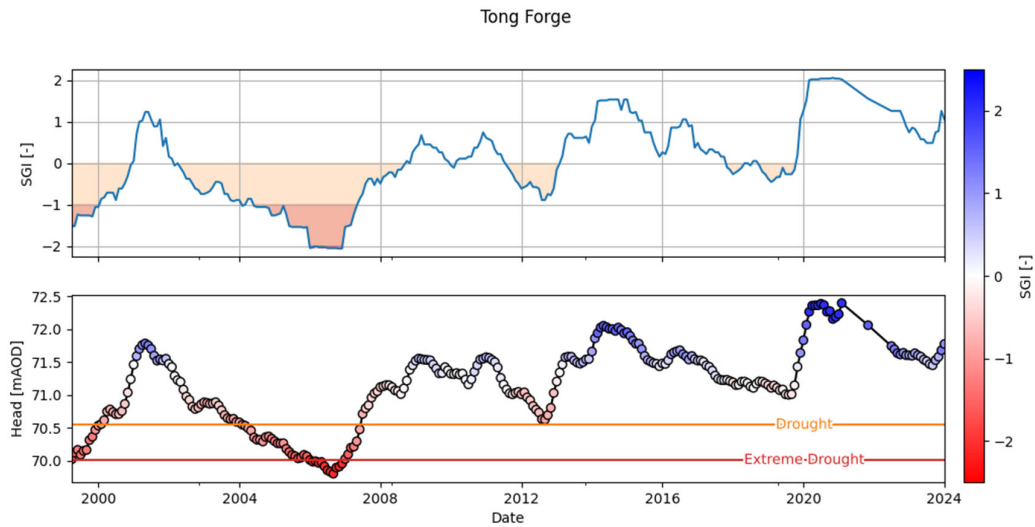


Figure E-4 Comparison of SGI and groundwater level drought triggers at Tong Forge