

Technical Note

Project:	Portsmouth Water Drought Plan 2021
Subject:	Standard Precipitation Index (SPI) indices
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Document history

Revision	Purpose description	Originated	Checked	Reviewed	Authorised	Date
Rev 1.0	Draft for review	JJ	SB	BP	BA	26/03/21

1. Background

Atkins have been engaged by Portsmouth Water (PW) to support the update of their draft Drought Plan. As part of a review carried out by PW and based on pre-consultation responses from the Environment Agency (EA) a ‘small project’ was required to investigate the use of SPI Indices in the drought plan.

PW currently use a rain gauge at Havant to monitor rainfall as a drought indicator. Havant is situated centrally in the supply area so it is used to be representative for the whole area. We were provided with rainfall data for the rain gauge for the period 1886 – 2019. It is worth noting that for PW sources, the Long-Term Average (LTA) annual rainfall is not a strong drought indicator alone. The quantity of rainfall in the year could be close to ‘normal’ levels, for example in the drought of 1975-1976 the LTA was 95 and 93% respectively, but the timing of rainfall plays an important role (for example winter rainfall was low for 1975-1976(203mm). Winter rainfall plays an important role in the recharge of the aquifer and the quantities of water available from PW’s boreholes and spring source.

As part of the drought permit/order application process PW will need to provide evidence to demonstrate that they have been experiencing an ‘exceptional shortage of rain’. Since each drought situation is unique, it is not appropriate to set a prescriptive approach to assessing this but the approach will be based on the analysis of rainfall deficits.

The identification of SPI indices could potentially benefit PW drought management in the following two ways:

1. Increased notice period and early warning moving into a drought
2. Better links with the ‘exceptional shortage of rainfall’ case that will need to be prepared by PW if a Drought Permit application is necessary.

2. Computation of SPI

The Standardised Precipitation Index (SPI) was developed by McKee et al, in Colorado State University, 1993 and is a statistical indicator which describes the observed rainfall over a given n-month period relative to the long-term rainfall distribution for the same period of time for that location. The SPI is the most commonly used indicator worldwide for detecting and characterising meteorological droughts. The World Meteorological Organization has recommended that the SPI be used by all National Meteorological and Hydrological Services around the world to characterize meteorological droughts (World Meteorological Organization, 2012)¹. The SPI is also the Environment Agency's preferred index for rainfall assessment.

The SPI provides a useful measure of whether rainfall over a given set of months is particularly wet or dry relative to the long-term observations. SPI is calculated using the following formula:

$$SPI = \frac{(P - \mu_p)}{\sigma_p}$$

Where:

P is precipitation over months n

μ_p is mean precipitation for duration n over period

σ_p is the standard deviation of precipitation for duration n over period

Note: SPI is used to characterise the previous n-months duration of rainfall, i.e. a 6 month result for June covers the months January – June of that year.

SPI can be calculated over different precipitation accumulation periods, typically ranging from 1 to 48 months (Copernicus European Drought Observatory-EDO)². It is suggested that the SPI is calculated and compared for different periods.

- SPI-1 to SPI-3: Can be used as an indicator for immediate impacts such as reduced soil moisture, snowpack, and flow in smaller streams.
- SPI-3 to SPI-12: Can be used as an indicator for reduced stream flow and reservoir storage.
- SPI-12 to SPI-48: Can be used as an indicator for reduced reservoir and groundwater recharge

The exact relationship between the SPI period and drought impact depends on the natural environment and human interference.

Positive SPI values indicate greater than median precipitation (wet) and negative values indicate less than median precipitation (dry).

2.1. SPI Calculation for Havant

Rainfall data has been provided from 1886 – 2019 for the Havant rain gauge. SPI has been calculated in Python programming language using the above formula for 6-, 12- and 24-month periods to allow assessment of the impact of differing SPI durations. PW has a significant number of groundwater sources and the 6-mth SPI duration could capture the winter rainfall and subsequent winter recharge important for those sources and the lack of which can be a key indicator of impending drought. Longer term SPIs (SPI-12, SPI-24), that are typically used to understand impacts on reservoirs and groundwater recharge, were additionally computed

The SPI for the 6-, 12- and 24-month periods are presented in Figure 3-1, Figure 3-2 and Figure 3-3 respectively. The plots indicate periods of both positive and negative SPI throughout the timeseries; key drought periods such as the early 1920's and the 1975/6 droughts are coincident with negative SPI within all the SPI series, these are especially illustrated in the 12- and 24- months periods. The shorter durations observed values typically show slightly greater maximum magnitudes due to the mean rainfall for that period being more influenced by extreme values (i.e. particularly wet/dry months are less averaged out).

¹ World Meteorological Organization. 2012. Standardized Precipitation Index User Guide

² Copernicus European Drought Observatory (EDO), European Commission, 2020 [factsheet spi.pdf \(europa.eu\)](https://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&plugin=1)

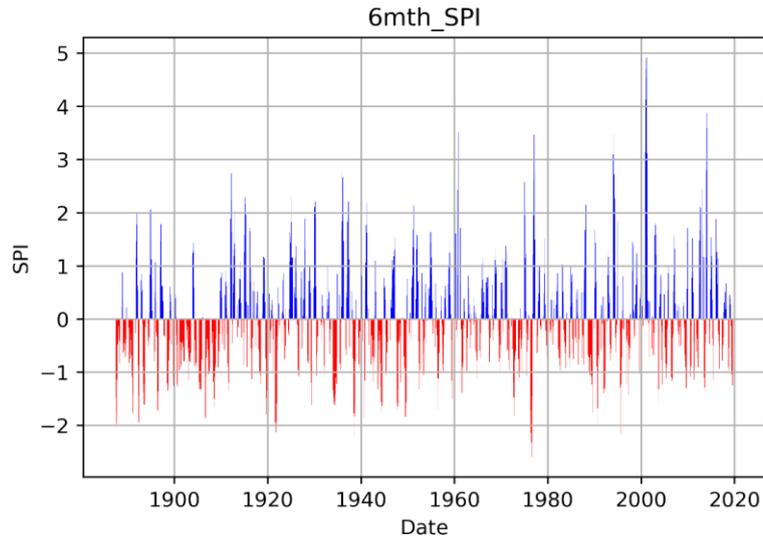


Figure 1. 6-month SPI for 1886 – 2019, Havant rain gauge.

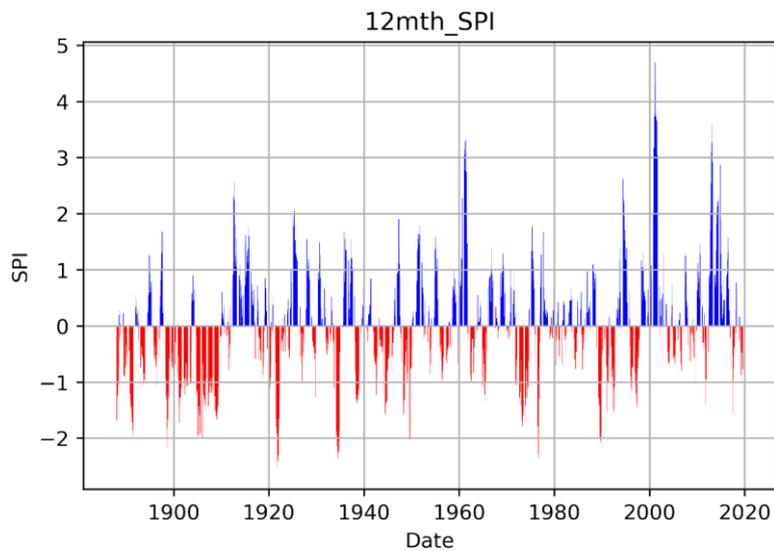


Figure 2. 12-month SPI for 1886 – 2019, Havant rain gauge.

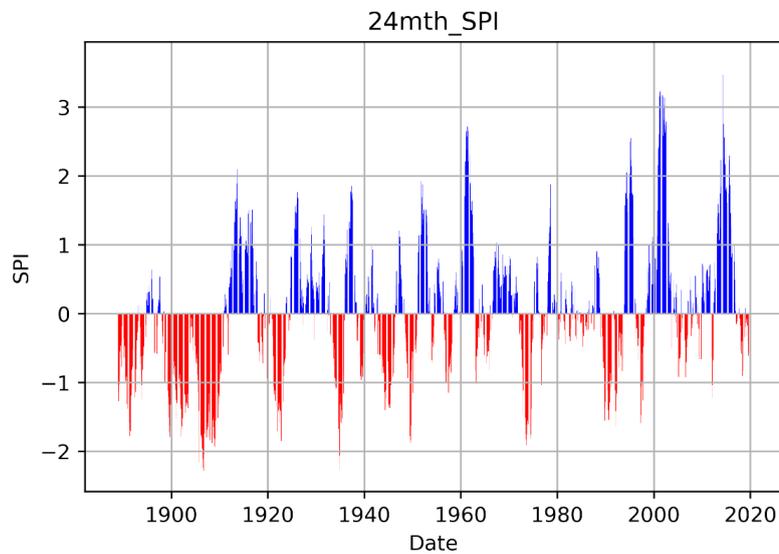


Figure 3. 24-month SPI for 1886 – 2019, Havant rain gauge.

McKee and others (1993) used the classification system shown in the SPI value table below (Table 1) to define drought intensities resulting from the SPI. They also defined the criteria for a drought event as: ‘A drought event occurs any time the SPI is continuously negative and reaches an intensity of -1.0 or less. The event ends when the SPI becomes positive.’ This definition applies for any of the computed timescales of SPI.

Each drought event, therefore, has a duration defined by its beginning and end, and an intensity for each month that the event continues. The positive sum of the SPI for all the months within a drought event can be termed the drought’s “magnitude” (WMO).

Table 1- SPI values

2.0+	extremely wet
1.5 to 1.99	very wet
1.0 to 1.49	moderately wet
-.99 to .99	near normal
-1.0 to -1.49	moderately dry
-1.5 to -1.99	severely dry
-2 and less	extremely dry

The Environment Agency has produced additional technical guidance for undertaking an Exceptional Shortage of Rain (ESoR) to help water companies undertaking ESoR assessments understand what is required (Hydrological guidance for the assessment of an Exceptional Shortage of Rain (ESoR) -DRAFT, EA 2021). The guidance provides additional detail on best practice for ESoR assessments, and is supplementary to the Environment Agency’s supplementary guidance on drought permits and drought orders.

The Environment Agency suggest that it is likely that, as evidence of an ESoR case, the SPI results should demonstrate an SPI of less than -2.0, which according to the classification system (Table 1) is “exceptionally dry”.

It is not appropriate to define a specific SPI value as a determinant for an ESoR case as every case will be unique. However, as evidence of an ESoR case, it is likely that the SPI results for your period of analysis would demonstrate an SPI of less than -2.0, ‘exceptionally dry’. If this is not the case, but an ‘exceptionally dry’ SPI is demonstrated for a shorter period within your period of analysis, there may still be justification for an ESoR if these are shown to be critical to the water resource situation, e.g. winter refill period. Where results are not definitive, it is expected that the other analysis methods / evidence provided clearly demonstrate an ESoR.

NOTE: This guidance has been made available following the assessment of SPIs for Portsmouth Water using the Havant rain gauge and as such was just used as a check and recommendations for further consideration.

2.2. Comparison with areal datasets (UKCEH)

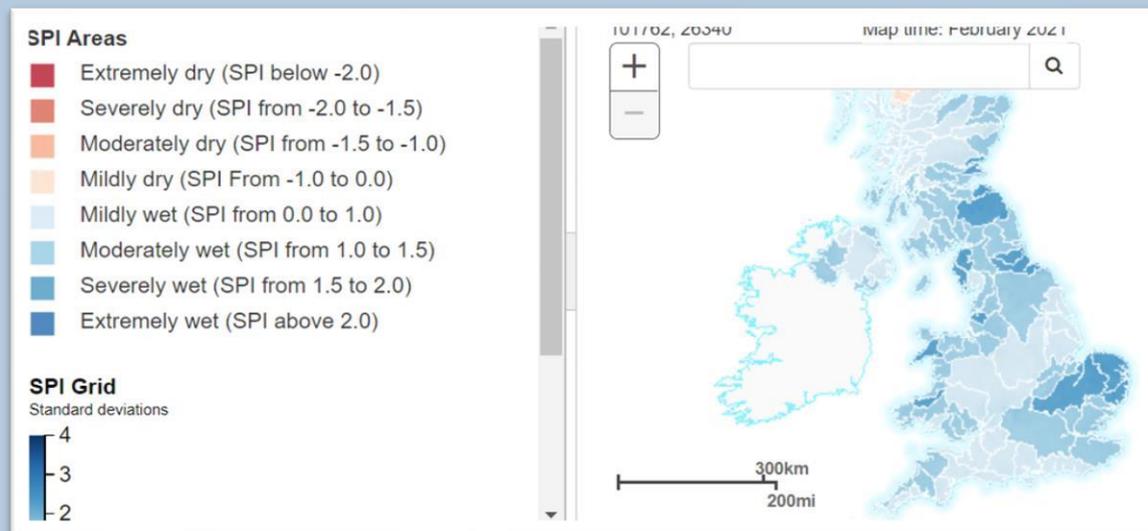
The historical rainfall data provided by PW is for Havant rain gauge and is therefore a point source dataset. The latest guidance by the EA on Exceptional Shortage of rainfall (EA DRAFT Guidance, Exceptional Shortage of

Rain, 2021), was provided following the calculation of SPIs for this work. Due to the fact that no aerial datasets were analysed, SPI results have been compared to SPI data calculated by the UKCEH³ drought portal to assess the suitability of point vs areal rainfall in calculating SPI (Section 2.2). Suitability of the point dataset is important in the justification of periods of 'exceptional shortage of rainfall' required to prepare for drought permit applications. The text box below provides a short description of the UKCEH portal and datasets.

UKCEH Drought Portal

The UK Centre of Ecology and Hydrology (UKCEH) have developed the UK Drought Portal, a tool to help visualise current meteorological drought status across the UK, and to put the current situation in a long-term context.

UK CEH have produced the Portal primarily as a near-real-time tool to aid the monitoring and early warning of drought and as a way of allowing users to explore past drought characteristics in an area of interest. This, used alongside other Hydrological Summaries produced by the National Hydrological Monitoring Programme, the Water Situation Reports produced by the Environment Agency and similar products developed by Natural Resources Wales (NRW) and the Scottish Environment Protection Agency (SEPA) are intended to provide real time, updated information on drought status for the UK.



The derived SPI values are initially calculated on a 5km grid, based on rainfall data from the UK Met Office¹. The 5km rainfall is aggregated up to river basins from CEH's Integrated Hydrological Units (IHU) dataset, at two different scales to represent the impacts over wider areas. The portal enables the user to visualise SPI data but also allows for downloading of derived SPI's for specific locations up to the year 2015. For PW, the SPI records for the Hampshire Coastal catchments is the more appropriate location available in the portal to represent the area.

We have compared SPI data for Havant with SPI records for the Hampshire Coastal catchments published by UKCEH (Figure 4, Figure and Figure 6). The UKCEH data is provided from 1961 – 2015, whilst the Havant data covers the period 1886 – 2019.

The results generally indicate a good fit for all three durations (SPI-6, SPI-12, SPI-24) between the SPI calculated using the rain gauge and the SPI calculated by UKCEH for the Hampshire Coastal catchments. Differences observed may be attributed to the different length of the datasets. The Havant rain gauge has

³ [EIP | Droughts \(ceh.ac.uk\)](https://ceh.ac.uk)

been used for a long time and it provides a longer dataset to Portsmouth Water for rainfall monitoring. In the future, however, it is suggested, that the use of aerial rainfall data is examined. This is one of the suggestions noted in the EA ESoR guidance.

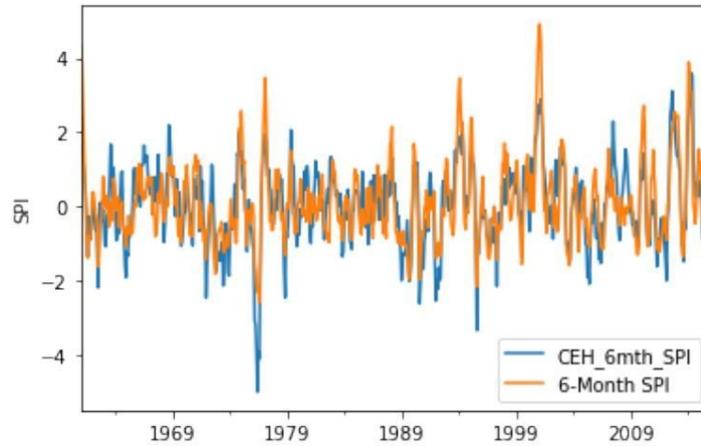


Figure 4. 6-month Rainfall calculated SPI compared to CEH data for 'Hampshire Coastal Catchments'

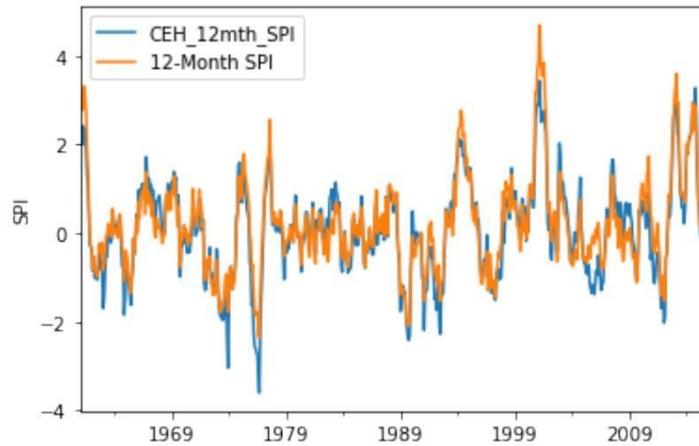


Figure 5. 12-month Rainfall calculated SPI compared to CEH data for 'Hampshire Coastal Catchments'

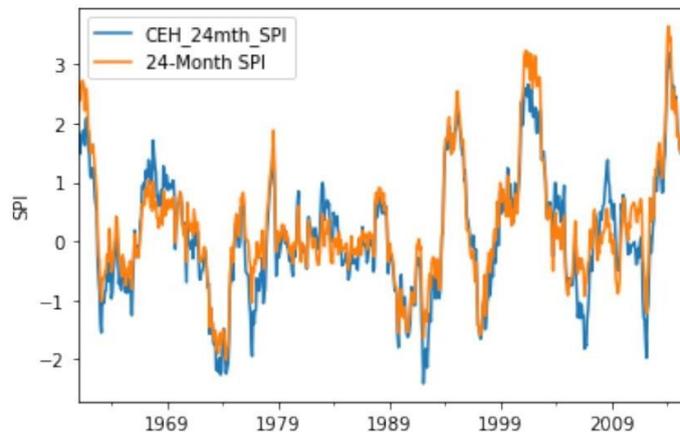


Figure 6. 24-month Rainfall calculated SPI compared to CEH data for 'Hampshire Coastal Catchments'

2.3. SPI Indices

The classification system shown in Table 1 is adopted to indicate drought status for Portsmouth Water, and linked to the existing groundwater trigger levels currently used by Portsmouth Water as follows:

Trigger	Drought status	Levels of restrictions
SPI < -1	Moderately Dry	L1
SPI < -1.5	Severely Dry	L2
SPI < -2	Extremely dry	L3

To assess whether the identification of SPI indices could potentially benefit PW’s drought management, particularly in providing increased notice period and early warning of moving into a drought, or worsening drought conditions, the use of SPI indices against historical droughts has been investigated. Example figures for selected drought years are included in 3.Appendix A. The SPI indices are plotted for a selection of drought years and the timings for crossing those are noted and compared to the timings that groundwater level triggers are crossed. These plots indicate that the SPI indices offer some additional early warning, although this varies between the different SPI periods. It is noticed that SPI-6 and SPI-12 provide a few months additional warning mostly on the L1 and L2 triggers being crossed, whilst SPI-24 fails to provide additional warning on L1 and provides minimal warning on L2. However, SPI-24 seems to provide better early warning for groundwater levels crossing L3.

3. Conclusions and Recommendations

The Standard Precipitation Index has been calculated for rainfall data from the Havant rain gauge for the period 1886 – 2019. SPI has been calculated for 6-, 12- and 24-month durations and in each case successfully captures key droughts in the historic record. SPI is proposed to act as an indicator of ‘exceptional shortage of rainfall’ required by Portsmouth Water in the event of a Drought Permit application. The SPI indices calculated have been linked to L1-L3 levels of restriction based on the existing groundwater trigger levels currently used by Portsmouth Water. The indices provide some additional early warning with respect to the groundwater level triggers.

SPI results based on the Havant rain gauge point source have been compared to UKCEH results based on areal rainfall for the Hampshire Coastal catchments. The generally good fit observed between the two datasets indicates that currently PW could use the point source data in determining SPI until the use of aerial rainfall data is examined. It is recommended that for the next Drought Plan, the use of the EA aerial rainfall data is explored further.

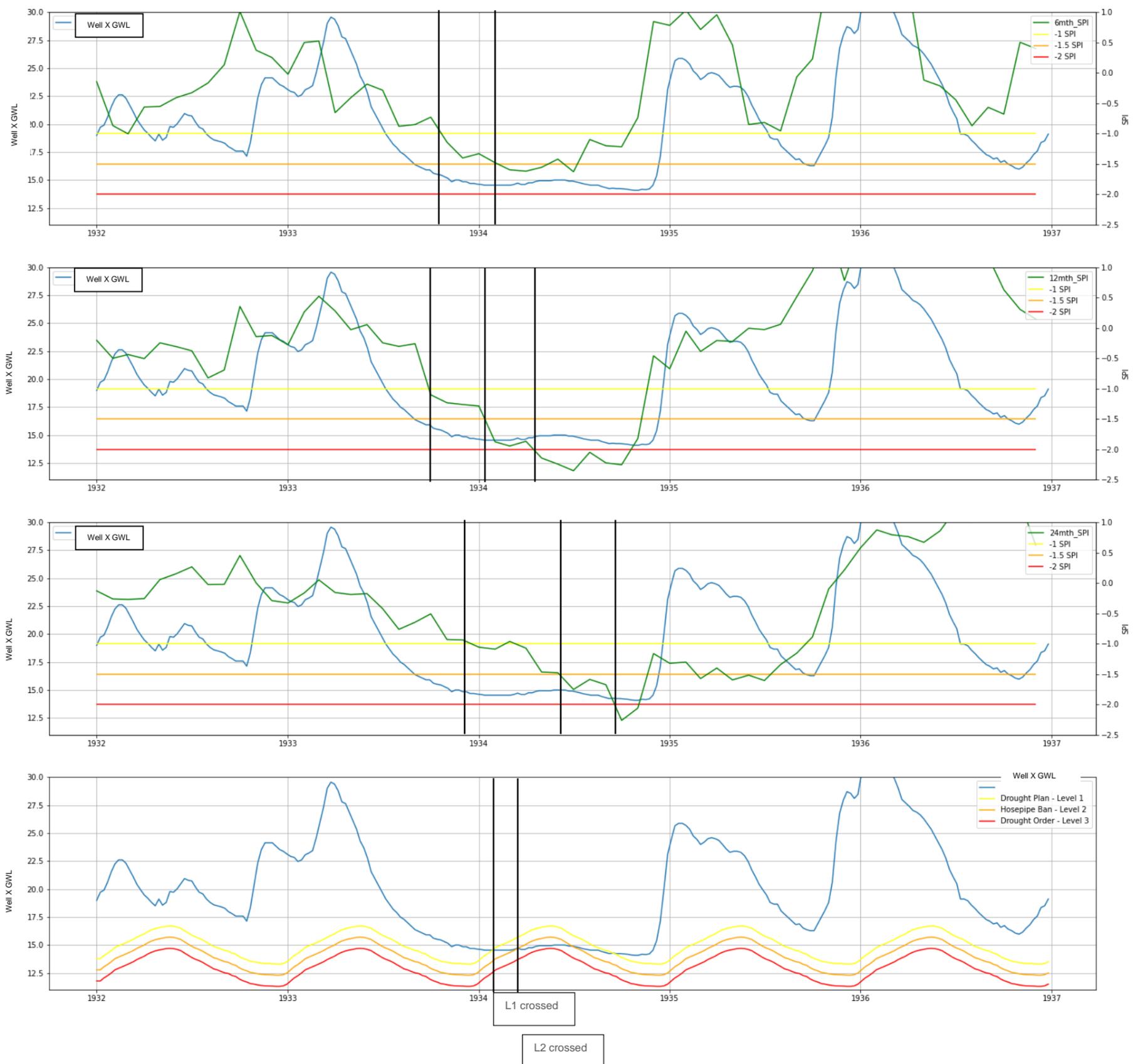
Portsmouth Water are updating their groundwater level triggers for WRMP24. It is recommended that a study is carried out, to understand if SPIs could also be used as triggers, linking to Portsmouth Water’s Levels of service and estimated return periods. River flow triggers for the River Itchen could also be looked at as potential additional triggers to the existing ones.

Appendix A. SPI indices for selected drought years.

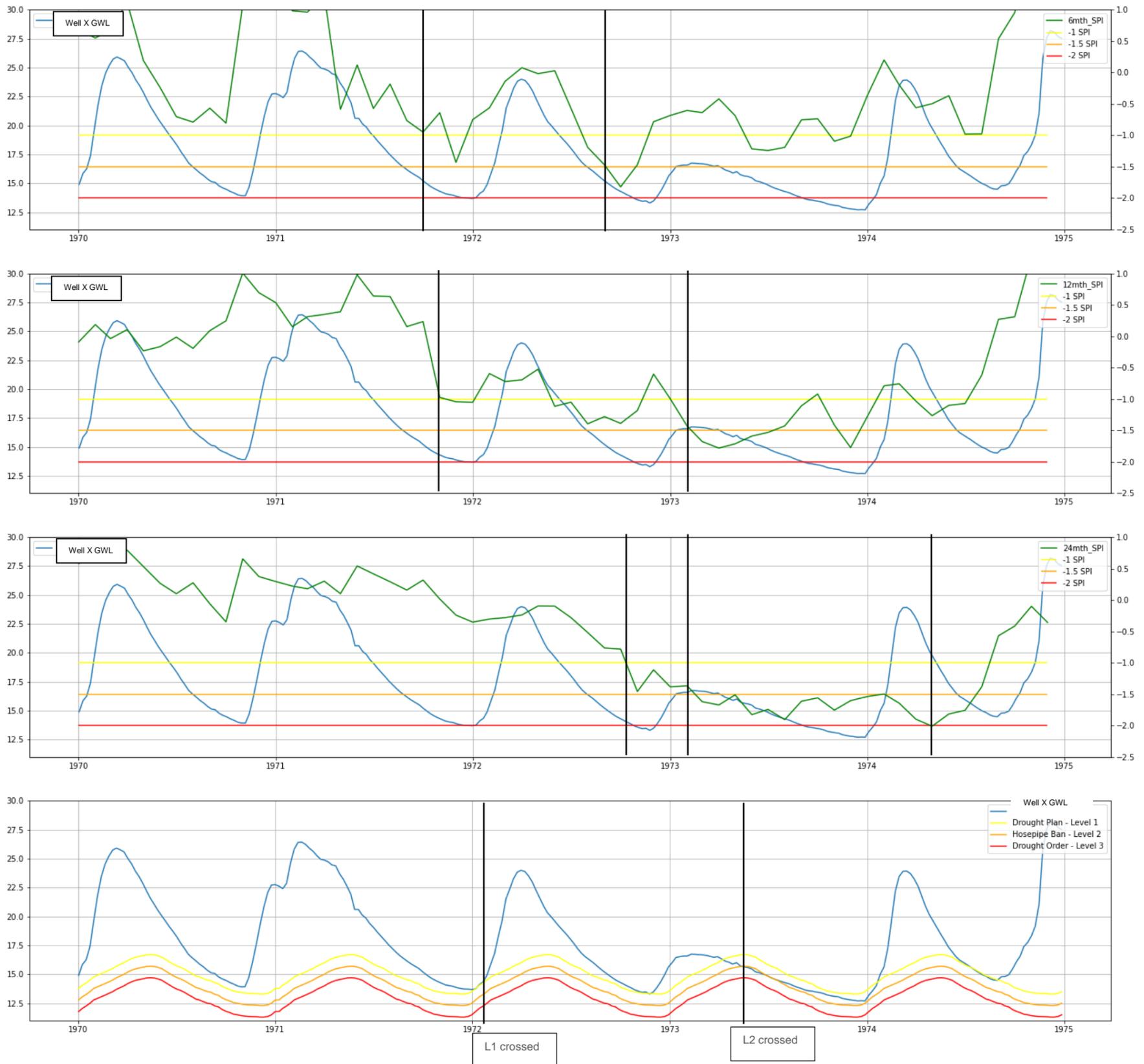
Plots of Well X groundwater levels, and SPI levels are shown for the following drought years: 1934, 1973, 1975, 1976 and 1990. For the SPI indices the following plots (with Well X groundwater level shown on each plot) are shown:

- 6mth_SPI, -1 SPI, -1.5 SPI, and -2 SPI
- 12mth_SPI, -1 SPI, -1.5 SPI, and -2 SPI
- 24mth_SPI, -1 SPI, -1.5 SPI, and -2 SPI
- Drought Plan – Level 1, TUBs (Hosepipe Ban) – Level 2, Drought Order – Level 3

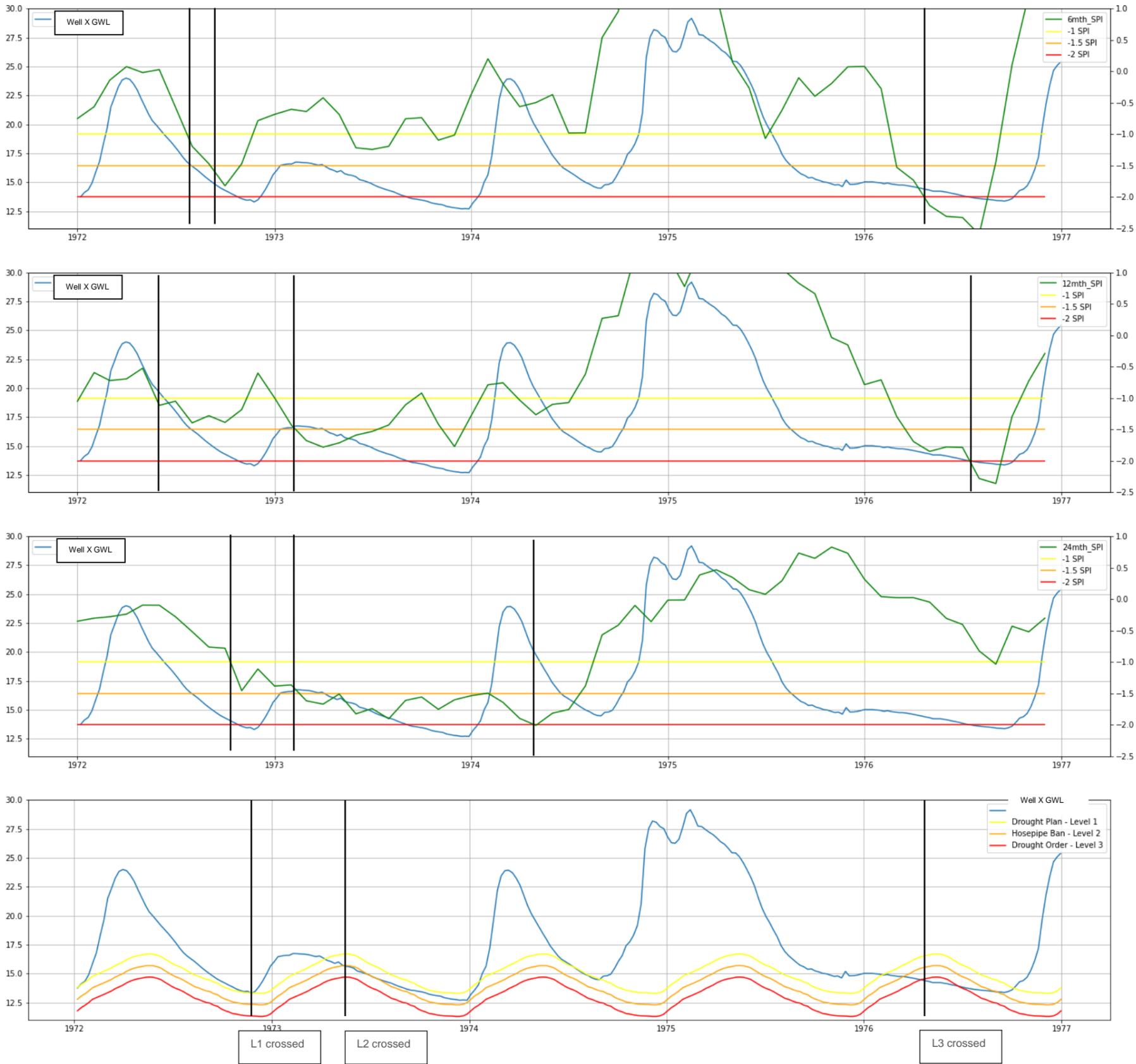
A.1. Drought Year 1934



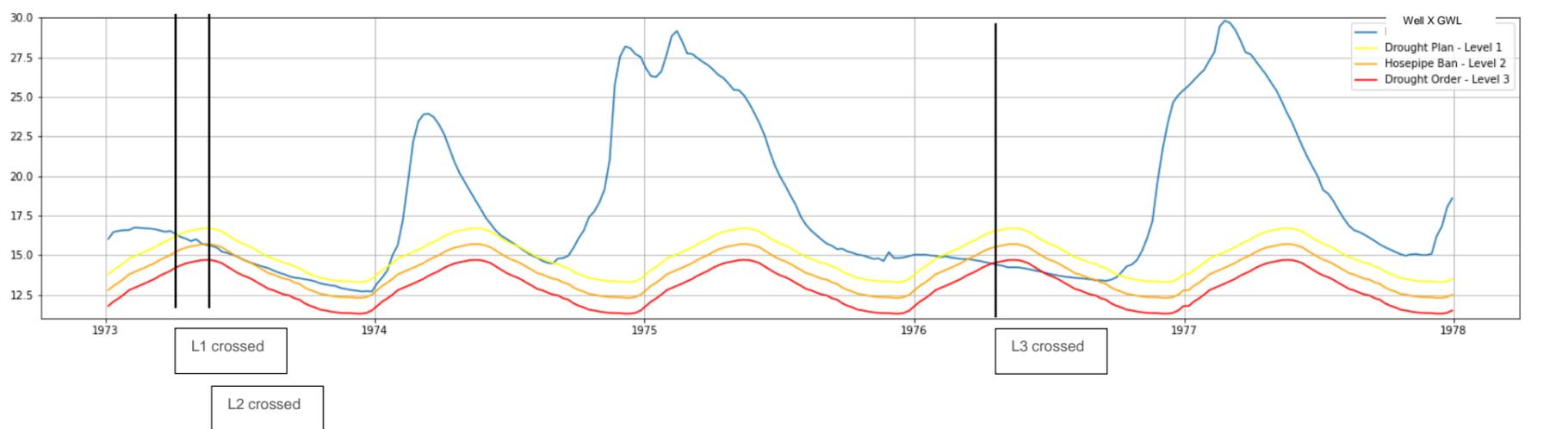
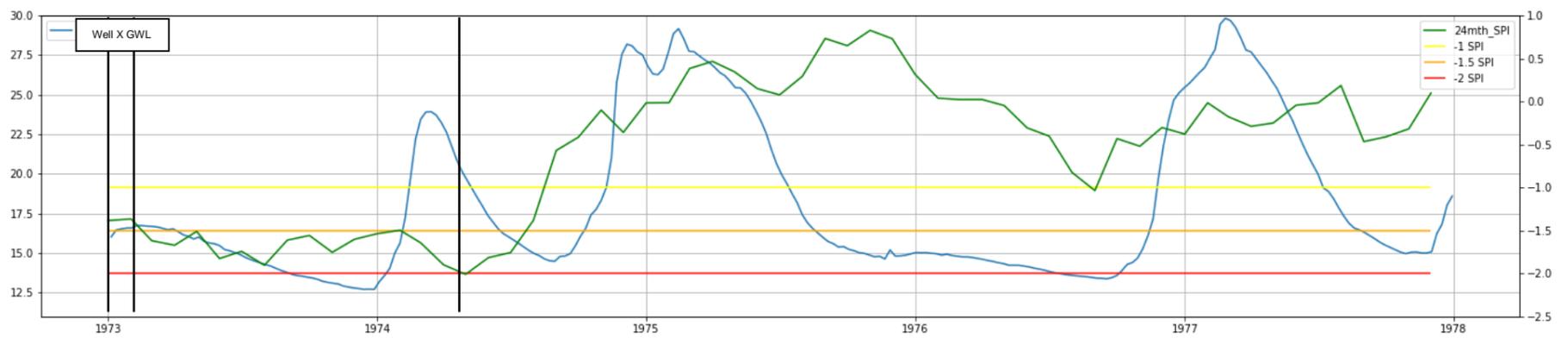
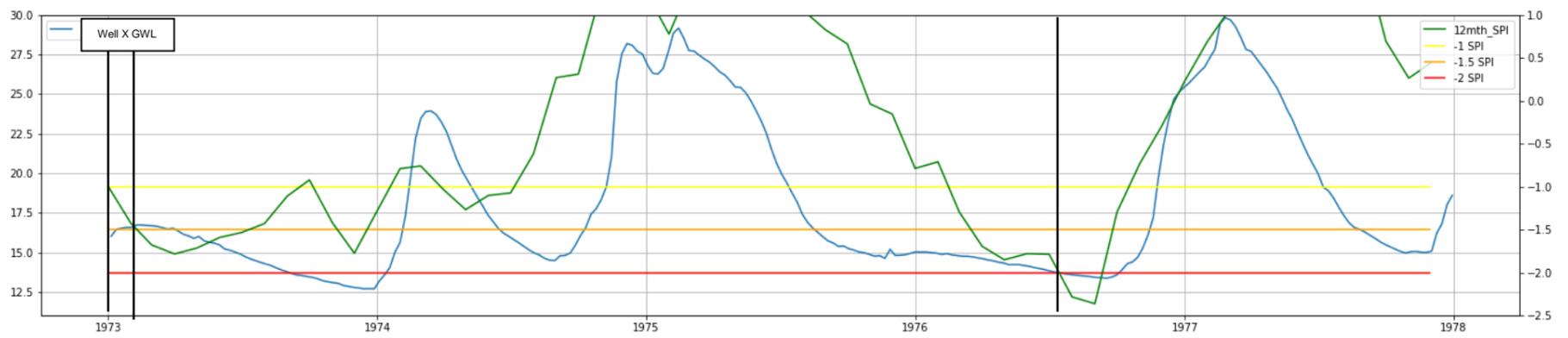
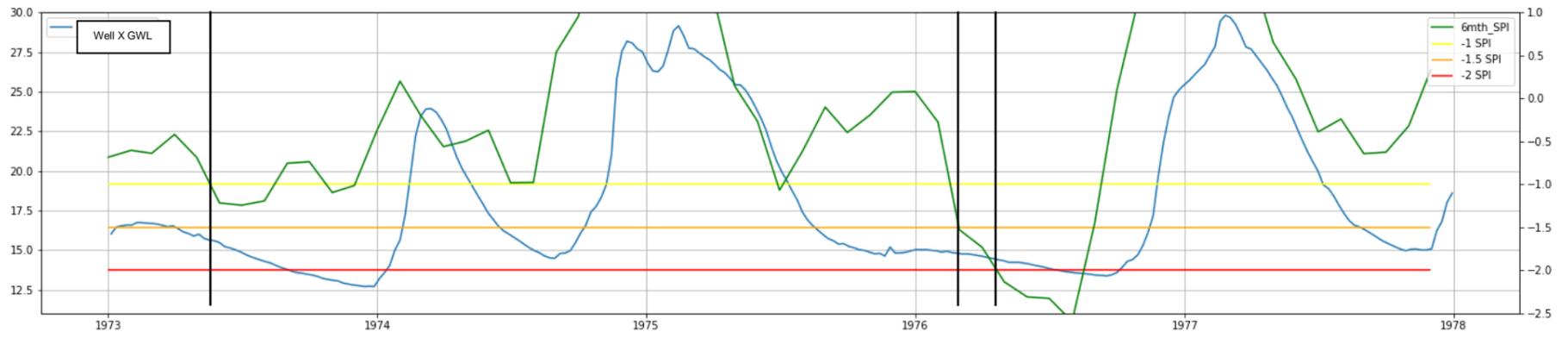
A.2. Drought Year 1973



A.1 Drought Year 1975



A.1 Drought Year 1976



A.1 Drought Year 12

