South32 - Illawarra Metallurgical Coal

DENDROBIUM MINE

End of Panel Surface Water and Shallow Groundwater Assessment: Longwall 19 (Area 3A)

HGEO Pty Ltd
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Cover photo: Cordeaux River tributary location CR29_S1, looking upstream on 27/10/2016

QUALITY CONTROL

Process	Staff	Signature	Date
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Summary

This report summarises the observed, measured and estimated effects on hydrological features resulting from the extraction of Dendrobium Longwall 19. Longwall 19 is the fourth panel to be extracted from Dendrobium Area 3A, although the first since Longwall 8 in 2012. Extraction of Longwall 19 commenced on 20/06/2022 and was completed on 29/03/2023. Rainfall during Longwall 19 extraction was well above average, totalling 2979 mm during 2022 and 1982 mm in the calendar year to the end of the longwall (28/3/2022 – 29/3/2023). This follows similarly high rainfall in 2020 (1436 mm) and 2021 (1448 mm). As a result, stream flow, shallow groundwater levels and soil moisture across all catchments have generally been high compared with baseline conditions.

The Illawarra Metallurgical Coal Environmental Field Team (IMCEFT) conducts monitoring and inspections on landscape features including watercourses and swamps within Dendrobium Area 3A. This monitoring is conducted in accordance with the Dendrobium Area 3A Subsidence Management Plan (SMP) and monitoring and contingency plans contained therein. Trigger Action Response Plans (TARPs) contained in the SMP form the basis of the impact assessments in this report. A total of 63 new ground surface impacts attributed to the extraction of Longwall 19 were recorded, of which 6 were associated with watercourses or swamps. Fracturing was noted in watercourse WC14 and three new or reactivated occurrences of iron staining were noted in WC14, WC15 and adjacent to Wongawilli Creek.

Surface water quality

In general, stream salinity (EC) has decreased since 2020 and during the last four longwalls due to higher-than-average rainfall and significant increase in runoff compared with the preceding drought period (2017-2019). Similarly, Dissolved Oxygen (DO) has been generally elevated due to higher flows. No new water quality TARPs were triggered in the review period; however, water quality TARPs remain triggered at Lake Avon tributary site LA4_S1 for EC, pH and DO as a result of impacts related to Area 3B. Anomalous water quality effects are noted in streams that have been directly mined under by previous longwalls (e.g. WC21, SC10C, LA4, Donalds Castle Creek). Those effects include transient or persistent increases in EC, increases (or decreases) in pH and increases in dissolved metal concentrations such as Fe, Mn, Al and Zn.

Analysis of flow-corrected trends in water quality indicate increasing EC, sulphate and manganese at WC_FR6, despite generally declining EC in non-flow-corrected data. Flow-corrected trends in EC, pH, Mn, Zn and Al are evident at DCC_FR6. At Sandy Creek Rockbar 5, flow-corrected EC, sulphate, Fe, Mn and Zn remain above baseline levels due to upstream contributions from SC10C which was mined under by Longwalls 7 and 8.

Iron staining in creek beds is commonly associated with watercourses that have been directly mined beneath or are within the mining area of influence. Over the last three years, new or recurrent iron staining has been noted on Wongawilli Creek, WC21, LA5 and SC10C, WC14 and WC15. The increase in iron staining is partly related to increasing groundwater levels due to high rainfall. It is expected that the occurrence of iron seeps will decline as drier conditions return.

A gas release was observed in Wongawilli Creek at WC_Pool 50 on 18/1/2023. The release is intermittent to continuous and emanates from the base of a sandstone step on the western side of the pool with smaller gas bubbles from the centre of the pool. A gas sample was collected on 1/2/2023 for laboratory analysis, which indicated mostly carbon dioxide and very low levels of methane. Methane content was lower than that expected from strata or in-seam gas.

Stream flow

The following summary indicates that most headwater sites located above longwalls are affected by subsidence, with many sites showing Level 3 impacts and a mix of Level 1-2 impacts. Sites located downstream or offset from longwalls have lower levels of impact, with many of these sites not triggering the various assessments. As in previous assessments, sites without Level 3 for Assessment C are also subject to comparison against rainfall-runoff modelling (the old TARP method), and these are consistent with the comparison against Reference Sites (Assessment C), with the exception of Level 1 at WC12S1 and Level 2 at ND1S1.

Of most relevance to Longwall 19 (Area 3A), Sandy Creek tributary SC10C has not shown any further effect related to Longwall 19 extraction although still triggers Level 2-3 for two of the assessments, and despite continued signs of recovery. SC10 does not exhibit any sign of effects, and nor does downstream site SCL2 on Sandy Creek.

Table 1. Summary of Surface Water flow TARPs – Longwall 19

Site	Watercourse	Catchment Mined	Position of sub-catchment relative to mining	A) Low flow Q%ile outside Reference Site Q%ile	B) Change in cease-to-flow frequency (beyond natural)	C) Change in median flow, Q50 (beyond natural)	Comment
DC13S1	DC13	Yes	Above LWs	Level 3	Level 2	Level 3	Similar to LW14-18.
DCS2	Donalds Castle Creek	Yes	Above LWs	Level 3	Level 3	Level 3	Similar to LW14-18.
DCU	Donalds Castle Creek	Yes	Downstream	Not triggered	Level 1	Not triggered	Similar to LW14-18. Rainfall-runoff modelling supports this finding.
WC21S1	WC21	Yes	Above LWs	Level 3	Level 1	Level 3	Similar to LW14-18.
WC15S1	WC15	Yes	Above LWs	Level 3	Level 2	Level 3	Similar to LW15-18. * Flow monitoring method means that Method B assessment assess low flows, not true 'cease-to-flow'.
WC12S1	WC12	Yes	Above LWs	Not triggered	Not triggered	Not triggered	Similar to LW16-18. No discernible effect. Rainfall-runoff modelling suggests **Level 1** impact.
WWL	Wongawilli Creek	Yes	Downstream	Not triggered	Not triggered	Not triggered	Similar to LW14-18. Rainfall-runoff modelling supports this finding.
LA4S1	LA4	Yes	Above LWs	Level 3	Level 3	Level 3	Similar to LW14-17, with improved data availability. * Flow monitoring method means that Method B assessment assess low flows, not true 'cease-to-flow'.
LA3S1	LA3	Yes	Above LWs	Level 3	Level 3	Level 3	Similar to LW16-18.
LA2S1	LA2	Yes	Above LWs	Level 2	Not triggered	Level 3	Similar to LW18.
NDS1	ND1	Yes	Headwater	Not triggered	Not triggered	Not triggered	LW18 mined under part of ND1 tributaries. No discernible effects. However, rainfall-runoff modelling suggests **Level 2** impact.
NDCS1	Native Dog Greek	Yes	Offset	Not triggered	Not triggered	Not triggered	No discernible effect.
SC10CS1	SC10C	Yes	Above LWs	Not triggered	Level 2	Level 3	Although still Level 2&3 for two indicators, this site shows signs of recovery.

SC10S1	SC10	Yes	Above LWs	●●●● Not triggered	●●●● Not triggered	●●●● Not triggered	No discernible effect, as for previous LWs. Rainfall-runoff modelling supports this
SCL2 / GS 2122205	Sandy Ck	Yes	Downstream	●●●● Not triggered	●○○○Level 1	●●●●Not triggered	Minor effect on low flows, no other discernible effect. Rainfall-runoff modelling supports this

●●●●● = result of previous longwalls (LW14-18)

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Watercourse	Position of watercourse relative to mining	D) Surface flow observations		Comment
Wongawilli Creek	Between A3A andA3B	9 months / 11	Not triggered	Refer to Performance Measures
		2 months / 11	Catchment closed	Wet conditions leading to catchment closure mean this assessment unlikely to be triggered.

No change to catchment flow characteristics was identified at the Wongawilli Creek gauge downstream of Areas 3A and 3B (WWL). The TARP assessment methods indicate a continuation of modified low-flow characteristics at the downstream gauge of Donalds Castle Creek (DCU), which remains at TARP Level 1. Reductions in median flow (Q50) at sites upstream of DCU are obvious, and total approximately 70-80% of median flow at DCU, and so should be able to be detected at DCU, but no reduction in Q50 is apparent. No effects are apparent at Native Dog Creek NDCS1, although the short baseline record limits the reliability of this assessment.

While noting 'no change' was detected, it is acknowledged that the scale of impacts in headwater streams overlying longwalls (e.g. WC21, DC13) may be impossible to detect further downstream given natural variability, larger contributing (and un-mined) catchments downstream at WWL, as well as the inherent uncertainties of the assessment methods. However, the assessments of WWL and DCU appear to indicate that there is clear potential for returned or re-emergent flow that has been identified as lost from upstream headwater catchments.

Table 2. Summary of surface water flow Performance Measures– Longwall 19

Wongawilli Creek – minor environmental consequences	**This Performance Measure is met.**
Donalds Castle Creek – minor environmental consequences	**This Performance Measure is met.**
Lake Avon – negligible reduction in the quantity of surface water inflows to Lake Avon	**This Performance Measure is met.**
Cordeaux River – negligible reduction in the quantity of surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek	**This Performance Measure is met.**
Sandy Creek – minor environmental consequences	**This Performance Measure is met.**
Lake Cordeaux – negligible reduction in the quantity of surface water inflows to Lake Cordeaux	**This Performance Measure is met.**

Pool levels

Pools along Wongawilli Creek and Sandy Creek's tributary SC10 were observed to be full and flowing during the review period. No pools along these watercourses have become dry as a result of mining (No TARP triggers). Pool water levels at SC10_Pool29 appear to have declined from levels observed prior to 2016. Recent inspections have found no evidence for subsidence impacts at the SC10_Pool29, nor elsewhere along the watercourse. It is possible that movement of sediment and woody debris during floods may have affected the pools filling and outflow characteristics. At the downstream Pool 26a several declines in water level were noted from late 2023. The monitoring record is limited and it is not possible to determine if the observed fluctuations are related to mining or in response to drier conditions since late 2023. No other changes have been observed at the site that would indicate a mining affect. It is recommended that pool hydrographs be reviewed again in the next EOP report.

The upper reaches of WC14, at and upstream from Pool 16 were directly mined beneath by Longwall 19. Pool 16 ceased to flow and became dry following the passage of Longwall 19 beneath the site, as is common for watercourses directly mined beneath. Water levels and outflow status of the downstream Pool 3 remains unaffected.

Hydrology at Waterfall WF54

Detailed analysis of a potential change in hydrological behaviour at WF54 was investigated in late 2022 (Watershed HydroGeo, 2022). This found that some erroneous data was responsible for previous inference of a change in hydrology. The analysis has been repeated for the period to May-2023, and no change in hydrology at this site is apparent from the comparison with data from an upstream Reference Site.

Swamps

All reference swamp sites showed saturated conditions throughout the review period after three years of above average rainfall. The return to drier conditions in 2023 resulted in a slight decline in saturation levels at most locations.

Longwall 19 passed beneath, or within 400 m of Swamps 12, 15a, 15b, 34 and 148. A review of shallow groundwater hydrographs at swamp sites within the area of influence of Longwall 19 indicates mining subsidence effects at site 148_01 and a likely effect at site 15a_19, triggering additional swamp TARP Level 1 for Swamp 15a (one of five piezometers) and Level 3 for Swamp 148 (single piezometer). Mining related effects related to previous Area 3A longwalls are evident at Swamps 12 15b and 146 (>400m from Longwall 19), for which TARP Levels 3 remain.

A reassessment of swamp sites within the area of influence of Longwall 18 indicates that shallow groundwater levels at site 35b_01 are likely to have been affected by mining related fracturing and/or drawdown within the sandstone substrate. The impact results in a TARP Level 3 for Swamp 35b (single piezometer).

Soil moisture levels in reference swamps have been generally high since 2020. Within the zone of influence for Longwall 19, average soil moisture levels declined to below baseline levels at piezometers at swamp sites S148_01 and S15a_19, consistent with shallow groundwater triggers. Average soil moisture also dropped below the pre-Longwall 19 baseline at sites S15a_07 and S15a_15, corresponding to soil moisture TARP Levels 2 and 3 for Swamps 15a and 148, respectively.

1. Introduction

Illawarra Metallurgical Coal (IMC) operates the Dendrobium underground coal mine, located approximately 12 km west of Wollongong (NSW) in the Southern Coalfield. IMC is required under the conditions of mining approval to submit regular reviews of the local hydrological data, including water quantity and quality, for watercourses and water bodies above and adjacent to Dendrobium Mine.

Surface water monitoring has been undertaken by IMC since 2003. Field parameter measurements and sampling for more detailed laboratory chemical analyses were collected by the IMC Environmental Field Team (IMCEFT). Field observation sites include hydrographic gauging stations, shallow groundwater piezometers, soil moisture sensors and surface water sampling sites.

This End of Panel (EoP) assessment reviews hydrographic and water quality data for watercourses and sub catchments within the zone of mining influence of Longwall 19 in Area 3A and previously extracted longwalls in Area 3B. Data are assessed against baseline and impact criteria defined in the Trigger Action Response Plan (TARP) which forms part of the Subsidence Management Plan for Area 3A (South32, 2020a) and the Swamp and Watercourse management plans contained therein.

1.1 Reporting Objectives

This EoP surface water assessment report has been prepared to form part of IMC's EoP Review which satisfies Condition 3-9 of the Approval for Dendrobium Mine (DA 60-03-2001). The EoP Review:

- reports all subsidence effects (both individual and cumulative) for the longwall panel and compares subsidence effects with predictions;
- describes in detail all subsidence impacts (both individual and cumulative) for the panel;
- discusses the environmental consequences for watercourses, swamps, water yield, water quality, aquatic ecology, terrestrial ecology, groundwater, cliffs and steep slopes; and
- compares subsidence impacts and environmental consequences with predictions.

This report provides the following assessment for the EoP Review:

- Impacts to water flow, water levels and water quality in watercourses, including: Wongawilli Creek, Donalds Castle Creek, Sandy Creek, Native Dog Creek and relevant tributaries to these and to Avon Reservoir.
- Impact to flows at Waterfall 54.
- Impacts to shallow groundwater levels and soil moisture levels in mapped Coastal Upland Swamps within the mining area of influence, compared with reference swamps.

1.2 Longwall 19

Longwall mining at Dendrobium has been carried out in three designated areas: Area 1 (east of Lake Cordeaux), Area 2 (west of Lake Cordeaux), and Area 3 (between Lake Cordeaux and Lake Avon) which is divided into sub areas 3A, 3B and 3C. Mining in Area 3B was completed in May 2022, after which mining resumed in Area 3A with Longwall 19. Extraction of Longwall 19 commenced on 20/6/2022 and was completed on 29/3/2023. The longwall is located to the south of Longwall 8 which was completed in December 2012. Longwall 19 has a total length of 1651 m and a width of 305 m including first workings with a maximum cutting height of 3.9 m. The depth of cover ranges between 287 m and 369 m.

1.2.1 Catchment closures

During the last two calendar years, the Catchment has been closed numerous times (typically associated with high rainfall). Dates are reported below (Table 3), providing context to why infrastructure upgrades or equipment repairs have not occurred or been delayed, or why observation surveys may not have occurred in specific periods.

The dates include official Catchment closures as well as self-imposed entry restrictions, i.e. when the catchment remained officially open but the rainfall in 24 hours was more than 10 mm. South32 (IMC) do not archive all official WaterNSW notifications, so there may be some discrepancies in dates held by WaterNSW, mostly around weekends/public holidays; e.g. the catchment closed/opened on Friday and IMC recorded the date as the following Monday or similar.

Table 3. Catchment closure dates in 2022-23

Catchment closed	Catchment opened	Period (days) closed	Longwall
6/01/2022	24/01/2022	19	During Longwall 18 and start of Longwall 19
18/02/2022	8/06/2022	111	
4/07/2022	2/08/2022	30	During Longwall 19
5/09/2022	6/09/2022	2	
23/09/2022	23/09/2022	1	
28/09/2022	17/10/2022	20	
24/10/2022	4/11/2022	12	
14/11/2022	16/11/2022	3	
19/01/2023	19/01/2023	1	
23/01/2023	31/01/2023	9	
9/02/2023	10/02/2023	2	
22/02/2023	22/02/2023	1	
13/03/2023	15/03/2023	3	
24/03/2023	27/03/2023	4	
29/03/2023	6/04/2023	9	End of Longwall 19
14/04/2023	14/04/2023	1	
24/04/2023	24/04/2023	1	
8/05/2023	8/05/2023	1	

1.3 Feedback from agencies on previous assessment

WaterNSW provided feedback to DPIE in relation to Surface Water components of the Longwall 17 End of Panel Reporting in a letter dated 1/5/2022. WaterNSW noted that previous comments relating to Longwall 16 reporting had been adequately addressed in the previous End of Panel report. WaterNSW recommendations in relation to Surface Water are listed in Table 4.

Table 4. Comments on previous EOP assessment

Agency	Agency comment	Response
WaterNSW	Investigate a potential link between anomalous water quality results observed in the tributary of Banksia Ck (SC10C_Pool1) and increasing 3-year trends in sulphate and dissolved metal (manganese, zinc) concentrations at Sandy Creek (SCk_Rockbar5)	IMC has engaged HGEO to investigate a potential link between SC10C_POOL1 and SCk_ROCKBAR5. The investigation will include a monthly longitudinal survey from SC10C_POOL3 to SCk_ROCKBAR5 for a period of 6 months (pending catchment access). Water quality, water chemistry (major ions and metals) and visual observations will be collected at various pools along the stream. It is proposed that HGEO will complete a specialist report once results have been collated.
WaterNSW	Continue reviewing and improving stream flow monitoring and when uncertainty results are reported, include a brief discussion of results.	Flow site upgrades are progressing as approved by Activity Approval D2021/29912 and D2021/130997. Site installs have commenced. On 30 August and 1 September 2022 work was completed at site WC20S2 and LC6S1, respectively. Work proposed for 2021 and 2022 were delayed due to COVID and extensive catchment closures. Flow sites experienced damage due to the flood events in 2022. IMC has completed repairsto these sites. However the proposed upgrade to SC10S1 monitoring site (that commenced immediately prior to heavy rainfall in early 2022 and the extended Catchment closure period that followed) has not progressed because it would have further affected the ability to use this site in a BACI context. However, it is possible that the reliability of that site has been affected by those works commencing (a notch was cut in the control). A measurement uncertainty analysis is included in this report (charts included in Appendix C).
BCD	BCD questioned the claim that "*no changes in flow characteristics were detected at WC12S1 which is close to LW 16 and 17, noting that that rainfall runoff modelling shows an apparent mild change (Level 1).*" The model used is unlikely to be able to detect change less than about 1 ML/day so the suggestion of a 'mild change' is probably indicative of water loss.	A longer response was provided in January 2023. In summary, the agency's comment that the "*model used is unlikely to be able to detect change less than about 1 ML/day*" is strange given that flow in WC12 rarely rises above 1 ML/d, and the method comparing Reference Sites vs other Assessment Sites often indicates changes in flow <<1 ML/d. Furthermore, the assessment carried out in the EOP reports acknowledges that a reduction in flow may be present, but not detectable given natural variability or method accuracy.
BCD	BCD questioned the statement [re: ND1] that "comparison against reference sites did not indicate an impact, however comparison against rainfall-runoff modelling suggested a significant decline in flow occurring in the latter half of LW 18. This finding will be reviewed in future."	A longer response was provided in January 2023. However, the most important thing is that flow have been assessed/reviewed again, as stated in the Longwall 18 EOP report. The assessments using comparison against Reference Sites presented in this current EOP report suggests that flow at ND1S1 remains unaffected (within the bounds of natural variability and method accuracy), although the rainfall-runoff modelling again suggests an impact is present (noting difficulty in calibrating such a model for this catchment).
BCD	BCD is concerned about the lack of Quality Assurance/Quality Control for	IMC have been transparent about data quality, the reasons for this occurring, and practical processes to attempt to reduce uncertainty.

	flow gauging and measurements in the streams at Dendrobium.	
BCD	BCD is concerned that many impacts on streamflow are described often at a Level 3 TARP exceedance status.	Impacts on flows in headwater streams located above or near to Longwalls are expected. As noted, downgradient streams and monitoring sites are not significant (TARP Level 0 or 1).
BCD	BCD questioned the claims of no loss of flow in Wongawilli Creek when error rates in the gauging/flow estimates at WWL are up to 600%, and where there are pools that have been completely drained;	Various assessments have stated that a reduction of flow to Wongawilli Creek is likely to occur (as predicted by modelling for SMP assessments) but is sufficiently low to be difficult to detect except in very dry conditions (e.g. 2017-19). Pool 50 (previously named 43a) did dry out (rather than draining through fractures), however groundwater levels have recovered sufficiently to support baseflow inputs to this pool (Section 5.6.2).
BCD	BCD state that these impacts (above) appear to breach the performance measures in place for Wongawilli Creek and Donald's Castle Creek	The EOP reports include clear assessment of the various flow-related Performance Measures (e.g. Section 5.5 in this current report).
	Statements made provides inadequate details and no plot of data: "*Initial analysis suggests that the relationship between WF54 pool levels and those at WWU has changed since mid-December 2021.*"	A detailed review ("Dendrobium Mine – Investigation Report WF54; Watershed HydroGeo, 2022) was completed in December 2022. This has been submitted to DPE and agencies via the planning portal.

In a more recent email to IMC, dated 22/8/2022, WaterNSW expressed concern with the number of new impacts reported in Area 3B associated with longwalls 16 to 18, including in Lake Avon tributary LA2 and Wongawilli Creek Pool 14, Pool 42, Waterfall 54 and water quality impacts. WaterNSW requested that IMC prepare a specialist report on the cumulative impacts on Wongawilli Creek due to extracted, approved, and proposed longwalls in Dendrobium Area 3. This report was prepared by HGEO (2023a) .

Hgeo

2. Surface water and groundwater management

This section outlines the network of monitoring infrastructure and sites operated by IMC at and around the Dendrobium Mine. Further details of monitoring sites and procedures are outlined in the Dendrobium Area 3A Watercourse Impact Monitoring Management and Contingency Plan (South32, 2021a).

2.1 Surface Water Monitoring

Monitoring includes a selection of sites downstream and within the mining area, as well as sites located away from the mining area to provide control sites and act as a comparison to impact sites. Pools within streams are monitored monthly before and following mining and weekly (when site access available) during active subsidence, and in response to any observed impacts. Surface water monitoring sites fall into four categories:

- **Flow gauge sites** at which stream flow is monitored at a calibrated gauge or weir.
- **Water chemistry sites** at which samples are collected for laboratory analysis (DOC, Na, K, Ca, Mg, Filt. SO_4, Cl, T. Alk., Total Fe, Mn, Al, Filt. Cu, Ni, Zn, Si), in addition to water observations, field parameters.
- **Water field parameter sites** at which water quality field parameters are measured (pH, Electrical Conductivity (EC), temperature, Dissolved Oxygen (DO), Oxygen Reduction Potential (ORP), in addition to water observations.
- **Water observation sites** at which pool water levels and flow status are noted and photographs taken upstream and downstream.

At a subset of sites, data loggers are installed in pools to allow monitoring of pool water level and temperature at hourly intervals. The monitoring of water quality parameters provides a means of detecting and assessing the effects of streambed fracturing or induction of ferruginous springs.

Figure 1 shows the location of surface water monitoring and sampling sites in relation to the extracted and planned longwall panels. Figure 2 shows the locations of hydrographic gauging stations which extend beyond the mining lease.

A summary of water flow monitoring sites in Areas 3A and 3B is presented in Table 5 and a full list of all installations is included in Appendix B. Several more sites have been installed or are planned in Area 3C in advance of operations commencing there.

Table 5. Surface Water Flow Monitoring Sites in Area 3A and 3B

Area	Site	Installation	Catchment	Easting (MGA z56)	Northing	Catchment area (km2)
A3B	WWU	Natural control; Stainless Steel housing; Diver logger	Wongawilli Creek	290808	6189716	3.211
A3B	WWL	Natural control; Stainless Steel housing; Diver logger	Wongawilli Creek	290975	6197526	20.079
A3B	WWL_A	Installed August 2019. Weir and half pipe; PVC housing; Orpheus logger	Wongawilli Creek	290962	6197370	19.602
A3B	WC21S1	Natural control; Stainless Steel housing; Diver logger	Wongawilli Creek	290529	6194255	2.434
A3B	WC15S1	Natural control; PVC housing; Diver logger	Wongawilli Creek	290754	6192239	1.192

Area	Site	Installation	Catchment	Easting (MGA z56)	Northing	Catchment area (km2)
A3B	WC12S1	Weir and half pipe flume; Polypipe housing; Orpheus logger	Wongawilli Creek	290964	6191459	0.38
A3B	LA2S1	Weir and half pipe flume; Polypipe housing; Orpheus logger	Lake Avon	288364	6191364	0.824
A3B	LA3S1	Weir and half pipe flume; Polypipe housing; Orpheus logger	Lake Avon	288385	6191548	0.375
A3B	LA4S1	Modified control; Stainless Steel housing; Diver logger	Lake Avon	288134	6192565	0.817
A3B	NDT1S1	Weir and half pipe flume; Polypipe housing; Orpheus logger	Lake Avon/Native Dog Creek	288607	6190491	1.13
A3B	NDCS1	Weir and half pipe flume; Polypipe housing; Orpheus logger	Native Dog Creek	288473	6190484	3.75
A3B	DC13S1	Natural control; PVC housing; Diver logger	Donalds Castle Creek	289401	6194605	1.638
A3B	DCS2	Natural control; PVC housing; Diver logger	Donalds Castle Creek	289502	6194572	1.084
A3B	DCU	Natural control; Stainless Steel housing; Diver logger	Donalds Castle Creek	289407	6195577	6.219
A3A	SC10S1	Natural control; Stainless Steel housing; Diver logger	Sandy Creek	293608	6192516	2.771
A3A	SC10CS1	Natural control; Stainless Steel housing; Diver logger	Sandy Creek	293358	6192433	0.817
A3A	SCL2	Modified control; Stainless Steel housing; Diver logger	Sandy Creek	293819	6192648	7.029
A3A,C	LC5S1	Reference site until Area 3C is mined. Weir and half pipe flume; Polypipe housing; Orpheus logger	Lake Cordeaux	293043	6195327	1.861
Ref	CR36S1	Weir and half pipe flume; Polypipe housing; Orpheus logger	Cordeaux River	291482	6197652	1.75
Ref	O'Hares Ck at Wedderburn			300411	6217387	73.0

2.1.1 Improvements to monitoring network in reporting period

Type of change / improvement	Description of recent change	Reference / comment
New surface water gauging sites	None in Area 3A, and one in Area 3B. New sites approved, and some installed in A3C.	NDCS1 on Native Dog Creek was installed in late 2021, and is analysed here for the first time. Figure B1 (Appendix B) shows the network.
Upgrade of existing sites	None during recent EOP period	It was originally proposed that site SC10S1 would be upgraded in early 2022. This commenced but was interrupted by long period of Catchment closure, and then not progressed further due to Longwall 19 commencing.
Gauge rating curves	More gaugings taken at most sites. Rating curves updated at most sites.	Details from ALS (consultants) can be requested via IMC. Methods to estimate uncertainty in surface water flow estimation has been developed by Enviromon (consultant), and is being rolled out to all sites. See Appendix C5 for sites assessed thus far.
Pool monitoring sites	Installation of additional water level data loggers in key pools.	Additional water level loggers installed in pools in Wongawilli Ck (more relevant to Area 3C).
Revision of assessment methods	Surface flow TARPs (Assessments A-D) not change since agreement in early 2020.	Section 0, WIMMCP (IMC, 2020a) and Watershed HydroGeo, 2019a.

	IAPUM requested that old method (comparison of rainfall-runoff modelling) be re-instated.	Section 2.1.3. Peer-review of methods planned for early 2022.
WWL vs WWL_A correlation	No change. Enviromon analysed the common period of WWL and WWL_A records in order to allow cessation of monitoring at WWL. Due to the shorter record at WWL_A and uncertainties at WWL it is recommended to continue to rely on data from WWL until the end of Area 3A (Longwall 19), and use WWL_A thereafter.	See separate document (Enviromon, 2021).

2.1.2 Surface water flow data update

IMC's contract hydrographers, ALS, provided the most recent flow data for assessment for sites in and around Areas 3A and 3B (details in Table C1 of Appendix C). This has been augmented by flow data from sites managed by WaterNSW, specifically one of the primary reference flow gauges (O'Hares Creek at Wedderburn) and for WaterNSW's Sandy Creek gauging station (GS 2122205). The WaterNSW Sandy Creek gauging station is co-located with IMC's SCL2 gauging site, but has a longer record and, based on comments from ALS, relies on higher accuracy monitoring equipment.

This data was then assessed based on the quality of records provided before some further processing was conducted. A discussion of this assessment is provided below. As is standard, data is available to agencies on request.

2.1.3 Re-rating of flow records

ALS updates the rating curves of flow monitoring sites as new manual gaugings are taken and added to the dataset that correlates 'stage' (water level at a monitoring site) and flow at the site. In recent times, WaterNSW has granted limited access to the Special Area during wetter periods in order to improve the moderate/high flow sections of the rating curves. This has meant that historical records of estimated flow can change when a rating curve is updated.

Hydrographers ALS took over the contract for flow monitoring at Dendrobium on 11/05/2016. ALS provide the record of daily flow for each IMC site based on the latest rating curve and the historical record of stage (level) at each site. ALS do not provide re-rated data from before their contract date, i.e. before 11/05/2016.

Table 6. Stream gauges that have been re-rated in 2022-23

DATE	A3A/B GAUGES RE-RATED	OTHER GAUGES RE-RATED
June 2022	SCL2, WC21S1, DCU	DC8

It is apparent from review of previous data obtained from WaterNSW for O'Hares Creek (WaterNSW site 213200) that a similar re-rating process occurs periodically in WaterNSW data.

There are two implications of the re-rating process:

1. Estimates of flow included in previous EOP reports may be different to that reported in the current (or future) EOP report. For example, median flow for sub-catchment WWU for the period May-2016 to June-2020 was 0.068 ML/d in the EOP for Longwall 15 but was revised to 0.202 ML/d EOP for Longwall 16 due to changes to the rating curve.
2. For gauging sites that commenced operation before the contract date of ALS (11/05/2016), time-series data prior to that date need to be adjusted to account for re-rating. This pre-processing step

was accomplished by comparing the ‘old’ (pre-ALS) flow data and the new rating curve in order to derive a flow record that is based on a consistent rating curve across the entire record.

2.1.4 Data quality assessment

An analysis of the data received from ALS was performed to assess the reliability and continuity of data collected at each flow gauge. The data quality code recorded by ALS for flow measurements was used for this purpose. A summary of these data quality codes has been provided in Table C2 of Appendix C, alongside the data quality assessment of each flow gauge.

Each daily flow recorded is the average flow determined from multiple sub-daily (typically 15-minute interval) stage measurements. The Hydstra database maintained by ALS will assign the 'worst' data quality code from any of the sub-daily records to the aggregated or averaged daily record. It is for this reason that Hydstra will sometimes assign quality code 140 ("Level below cease-to-flow") to days where there is a small, non-zero average flow.

For each flow gauge the percentage of available daily flow measurements was calculated. This value indicates the number of measurements that exist between the first date of data collection and the last available date. From this the percentage of ‘suspect’ data was calculated. Based on the ALS quality codes, suspect data refers to any flow data with a code that falls between 104 and 255. A summary of the data quality assessment for each flow gauge is included in Table C3 and C4 of Appendix C.

Data processing was then undertaken for flow data where entries were blank or entered as text and these could be confidently infilled. These entries were associated with the following quality codes:

- 151 (“data not yet available”): associated with comments of ‘rating exceeded’, commonly following high regional rainfall events;
- 161 (“poor quality data from debris affecting sensor”): occurred only at flow gauge WWU for the period 23/01/2019 to 27/02/2019;
- 205 (“data lost”): associated with comments such as ‘logger dead’, ‘data lost’;
- 255 (“no data exists”): associated with comments of ‘rating exceeded’, ‘logger dead’.

For these entries an infilling procedure was used to estimate the flow value, if the record could be confidently estimated (e.g. flows were consistent through time and compared to other gauging stations, especially at higher flows when the “rating exceeded” flag was assigned. Flow estimates were calculated using either the average flow from the preceding and following days, or the flow recorded at another gauged sub-catchment for the same day, scaled by catchment size. The percentage of infilled data is recorded for the relevant gauges in Appendix C. The results of processing, with comparison against ‘raw’ data are illustrated on charts in Appendix C.

2.1.5 Catchments and watercourses within mining influence of Longwall 19

Surface watercourses and catchments mined beneath by Longwall 19 are listed in Table 7.

Table 7. Surface water features within area of mining influence

Catchment / location	Approximate dates	Monitoring sites (level and chemistry)	
		Upstream	Downstream
Wongawilli Creek	Longwall 19 finished at 184 m from the main channel of Wongawilli Creek on 29/3/2023. Approximately 900 m of channel length is within 400 m of the longwall.	Sites upstream of WC_Pool 78	Sites downstream ofWC_Pool 56
WC13	The upper slopes of the WC13 catchment are within 400 m of Longwall 19. The mapped watercourses are all beyond 400 m from the longwall.	-	All sites on WC13
WC14	The upper reaches of WC14 were mined beneath by Longwall 19 between 25/12/2022 and 12/2/2023. Watercourses upstream of Pool 16 flow across the longwall footprint.	-	WC14_Pool 3
WC15	Longwall 19 approached within 325 m of the confluence of WC15 and Wongawilli Creek in March 2023.	-	WC15_Pool 2
WC17	The watercourse was directly mined beneath by Longwalls 7 and 8 in 2011 and 2012. Longwall 19 passed within 355 m of the watercourse; 280 m of the watercourse passes within 400 m the longwall.	-	All locations downstream of WC17_Pool 4
SC10C	Almost the entire watercourse was mined beneath by Longwall 8 in 2012. Most of the watercourse is also within 400 m of Longwall 19; the upper mapped watercourse is within 105 m of the longwall.	-	SC10C_Pool 1 (All sites are within area of influence from Longwall 19, 7 and 8)
SC10	Longwall 8 mined beneath a small portion of SC10 in late 2012. Longwall 19 started within 30 m of the main channel on 20/6/2022; a length of 1.13 km of the watercourse is within 400 m of Longwall 19.	SC10_Pool 34	All locations downstream of SC10_Pool 31 (most sites within area of influence from Area 3A)

2.2 Shallow Groundwater Monitoring

Figure 2 shows Longwall 19 in relation to the locations of shallow groundwater monitoring sites in Areas 3B and 3A. Typically, these sites are piezometers approximately 1 - 3 m deep that monitor groundwater levels within the swamp deposits located around the Dendrobium area. IMC maintains a network of shallow groundwater monitoring sites at swamps within the area of mining influence (400 m), referred to as “impact” sites, as well as “reference” sites installed within swamps that are located well outside the influence of mining (currently Swamps 2, 7, 22, 25, 33, 84, 85, 86, 87 and 88).

Figure 2 also shows swamp areas: broadly mapped by NSW Office of Environment and Heritage (OEH) and refined through site-scale mapping for IMC carried out by Biosis and Niche Environment and Heritage. Note that the TARP assessment relates only to those piezometers that are located within swamp sub-communities mapped as Banksia Thicket, Sedgeland-heath complex and Tea Tree Thicket; being listed as Costal Upland Swamp Endangered Ecological Community (EEC). Piezometers located within other areas, such as fringing Eucalypt Woodland, are excluded from the TARP assessment as per the advice from OEH (17/01/2014).

The following swamps and piezometers are located within 400 m of Longwall 19:

- Swamp 12: Piezometer 12_04
- Swamp 15a: Piezometers 15a_07, 12, 15, 18 and 19

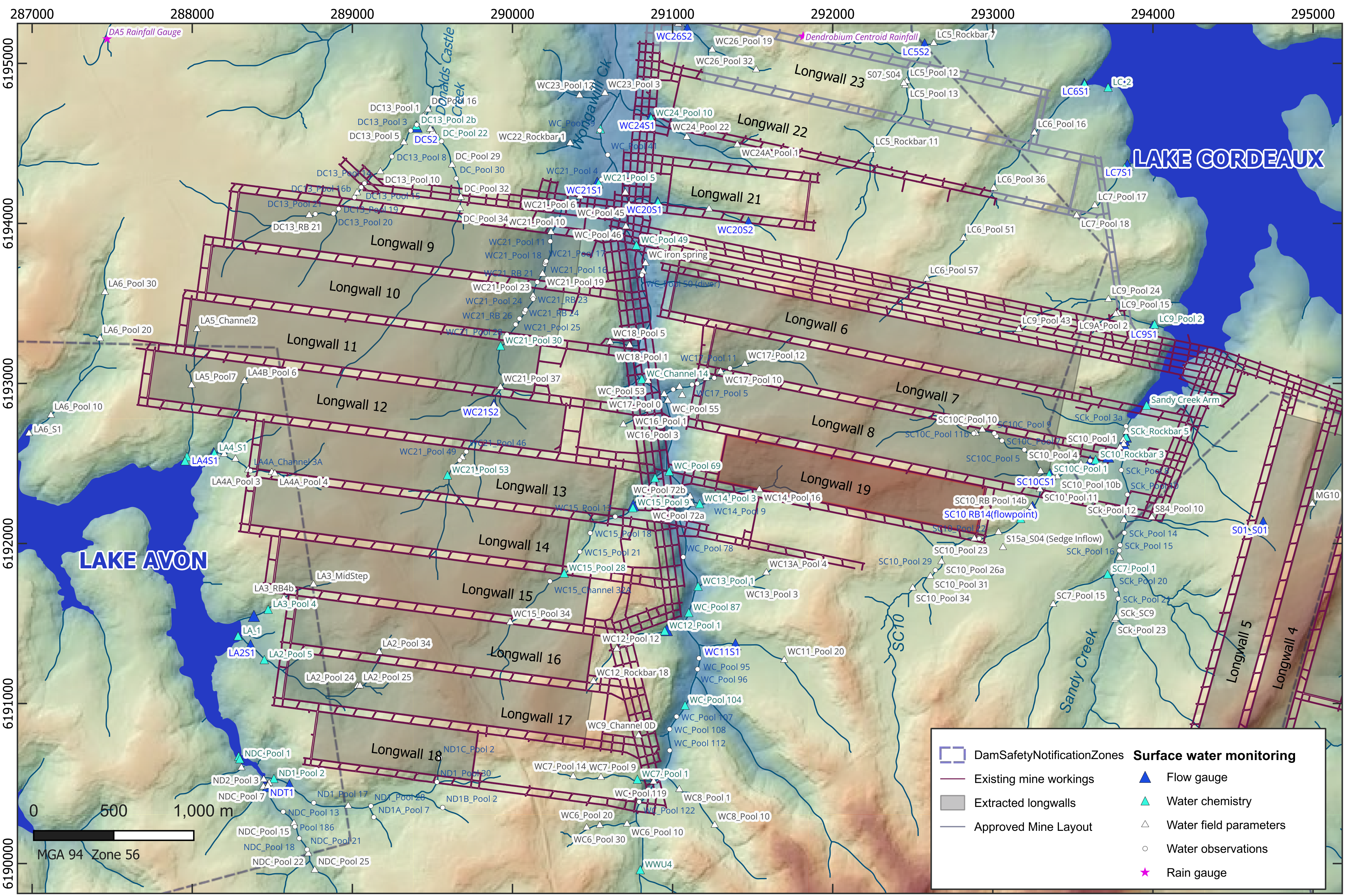
- Swamp 15b: Piezometers 15b_H1, H2, H3, 39
- Swamp 148: Piezometer 148_01
- Swamp 34: Piezometer 34_01

Shallow groundwater monitoring data are presented and discussed in Section 6.

2.3 Soil moisture monitoring

Soil moisture profiles are monitored at most swamps, with sensor arrays typically positioned near shallow piezometers (where possible). Where possible the monitoring arrays are numbered according to the corresponding piezometer (if present) with the addition of an 'S' prefix. At most locations, sensors are installed up to a maximum depth of 1.2 m.

Soil moisture is measured using Sentek sensors which monitor changes in the dielectric constant within a cylinder of soil extending to a radial distance of 10 cm from the access tube. Soil moisture is reported as mm water per 100 mm soil depth (or volumetric % water) at each monitored depth (Sentek, 2017). The most recent installations are equipped with automated data loggers set to record moisture levels every hour. The remaining installations are recorded manually during scheduled site visits.



Hgeo

Dendrobium End of Panel Surface Water Assessment

Surface water monitoring sites

Figure 1

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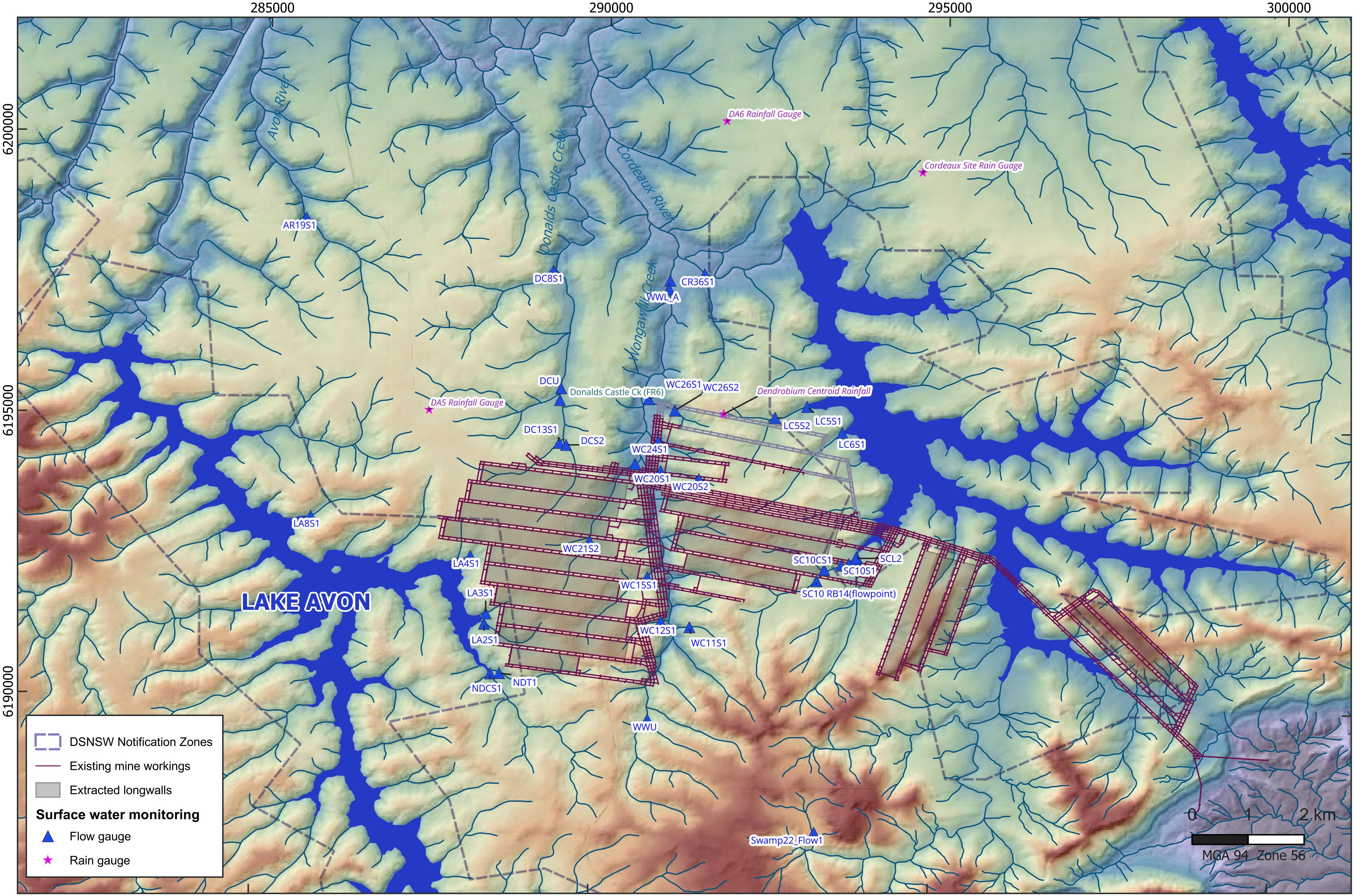

Hgeo

Dendrobium Mine End of Panel Surface Water Assessment

Hydrographic gauging stations

Figure 2

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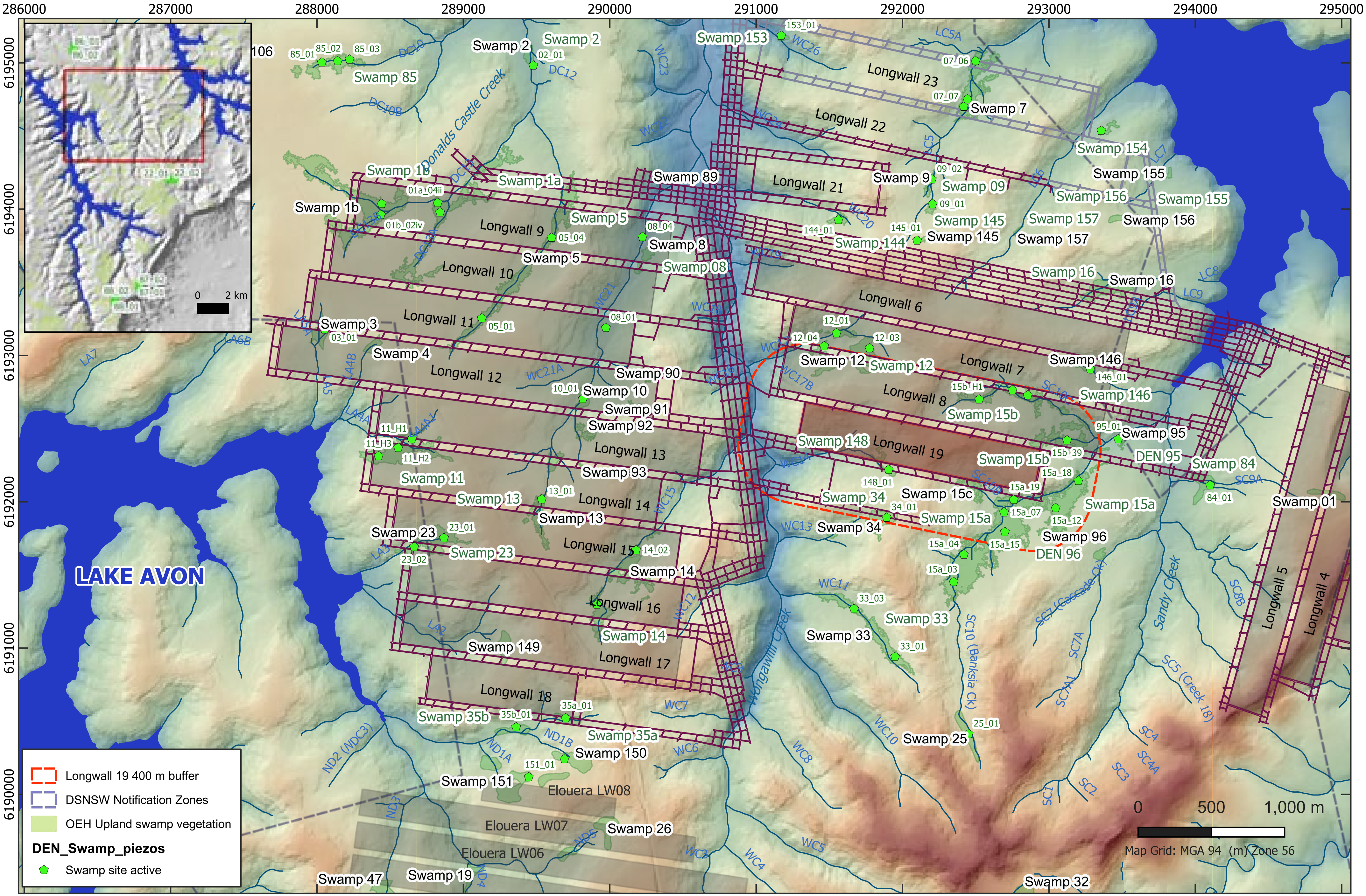

Dendrobium Mine End of Panel Surface Water Assessment

Swamp monitoring sites

Figure 3

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2.4 Weather conditions during the assessment period

Rainfall data are collected from several gauging stations across the mining lease. Weather observations at Dendrobium over the last 10 years are summarized in Figure 4. Potential evapotranspiration (EVT) is calculated from SILO data (DSITI, 2011) for Dendrobium, using the FAO Penman-Monteith formula (Allen et al., 1998). The average annual rainfall for Dendrobium is 1142 mm (2002 – 2022) based on data from site rainfall gauges. Rainfall events occur year-round but tend to be more frequent in the summer and early autumn months. It is common for a substantial proportion of the annual rainfall to be delivered in a small number of large rainfall events, during which significant surface water runoff and groundwater recharge is generated. Evapotranspiration varies seasonally in line with temperature and solar radiation, peaking during the summer months.

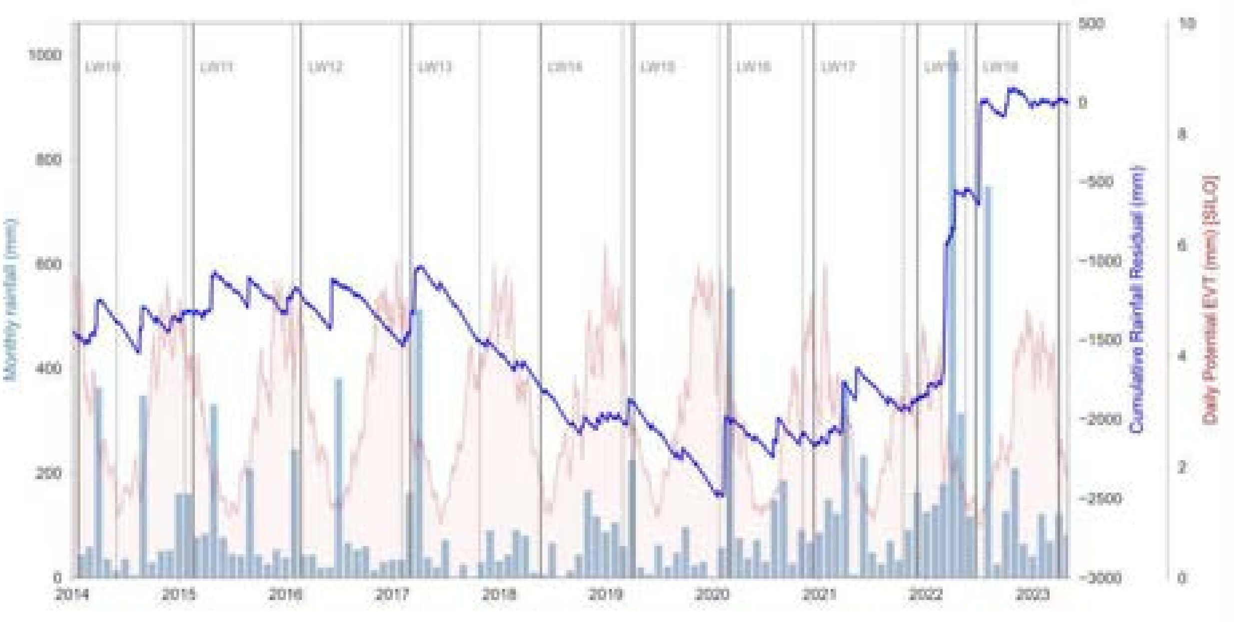


Figure 4. Rainfall and potential evapotranspiration (EVT) at Area 3 for the reporting period

Rainfall during Longwall 19 extraction was well above average, totalling 2979 mm during 2022 and 1982 mm in the calendar year to the end of the longwall (28/3/2022 – 29/3/2023). This follows similarly high rainfall in 2020 (1436 mm) and 2021 (1448 mm) due to sustained La Nina conditions over that period. As a result, there has been a full recovery in stream flow, shallow groundwater levels and soil moisture across all catchments since the severe drought of 2017-2019.

Soil moisture levels derived from the Australian Water Resources Assessment Landscape model (AWRA-L) are through the Bureau of Meteorology (BOM) Australian Water Outlook site. A timeseries of estimated soil moisture storage for the Woronora Plateau in the vicinity of Dendrobium Mine is shown in Figure 5. Soil moisture storage declined to record low levels during the 2017-2019 drought. Due to the higher-than-average rainfall between 2020 and 2022, soil moisture levels have been sustained at their highest levels since mining started at Dendrobium.

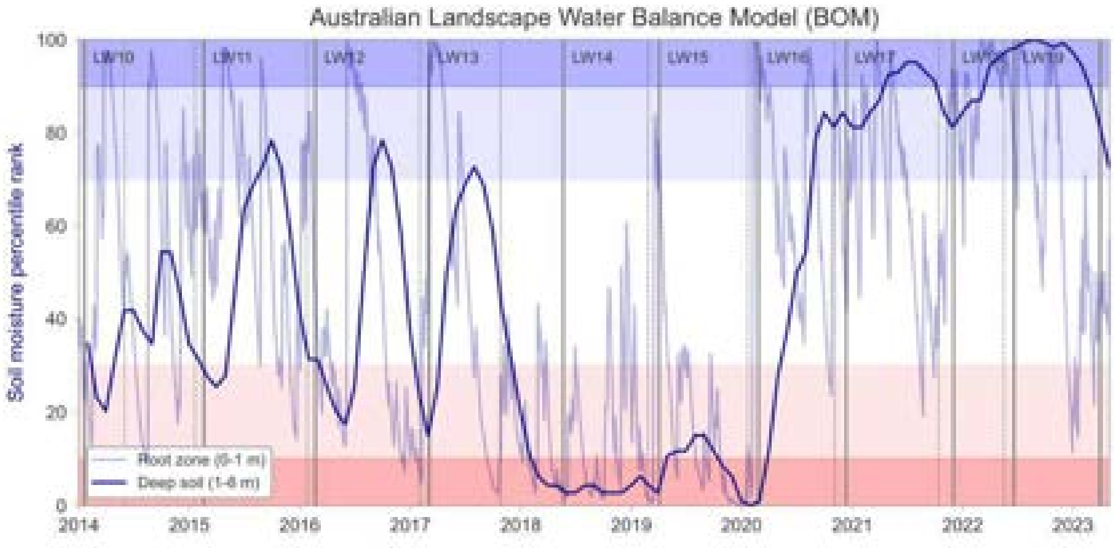


Figure 5. Calculated soil moisture from the AWRA Landscape Model

3. Longwall subsidence effects

Figure 6 presents the total subsidence predicted by MSEC (2020a) above Area 3A longwalls in including Longwall 19. This shows that Wongawilli Creek and Lake Cordeaux are outside the main area of subsidence. The upper reaches of tributary WC14 overlaps Longwall 19 (See Figure 1 for tributary locations).

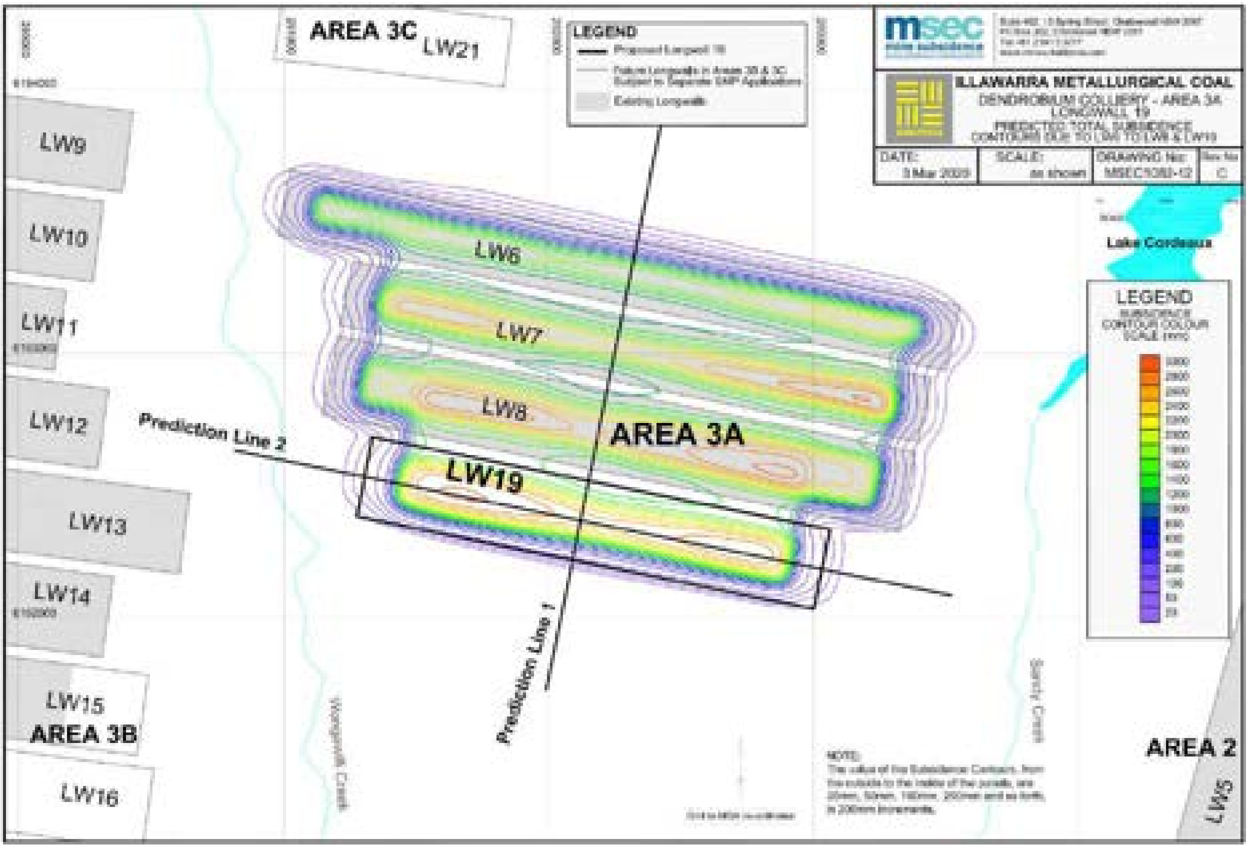


Figure 6. Predicted Subsidence above Area 3B (from MSEC, 2020)

3.1 Measured subsidence

Observed mine subsidence movements due to the extraction of Longwall 19 were reviewed by MSEC (2023). Mine subsidence effects were measured using the Wongawilli Creek closure lines, Avon Dam 3D monitoring points, creek and tributary cross lines including Sandy Creek waterfall closure lines, swamp cross lines and airborne laser scans and 330 kV transmission lines. The review concluded that:

- *It is considered, therefore, that the observed surface impacts on the natural and built features, due to the mining of LW19, are consistent with the MSEC assessments provided in Report No. MSEC1082* (MSEC, 2020a) *which supported the SMP Application for LW19.*

3.2 Observed surface impacts

Observed subsidence impacts on the landscape, including surface fracturing and iron staining are monitored by the IMCEFT and reported separately in the EoP Landscape Report (South32, 2023). A total of 63 new ground surface impacts attributed to the extraction of Longwall 19 were recorded (Figure 7). Of those, 6 were associated with watercourses or swamps and are listed in (Table 8). One impact first reported in relation to Longwall 8 was updated to record additional rock fracturing in the WC14 watercourse (LW8_003).

Table 8. Reported subsidence impacts to stream beds during Longwall 19

Site ID	Watercourse	Date Observed	Description	Tarp Level
LW8_003	WC14	29/1/2020 17/4/2023	Update. Rock fracturing with associated rockfall and fragmentation	1
LW19_003	WC14	16/08/2022	Iron Staining: Increase in iron staining on tributary WC14; First described following Longwall 8	2
LW19_029	Wongawilli Creek	18/1/2023	Small gas releases in WC_Pool 50. See Section 4.5.	1
LW19_043	WC14	17/04/2023	Rock Fracturing: Multiple varying sized rock fractures across WC 14_rockbar7 19.4 m x 10.2 m in area. No flow at time of inspection. >20 rock fractures ranging from the ones measured through to hairline cracks throughout the rockbar.	2
LW19_044	Wongawilli Creek	19/04/2023	Iron Staining: Iron spring appearing from beneath a rock flowing downhill on eastern slope of valley (faces west) approximately 50m south east of WC_Pool59. Iron Spring not flowing in to Wongawilli Creek. Length of spring estimated to be about 20m long.	1
LW19_045	WC15	26/04/2023	Iron Staining: Iron Staining appears at base of WC15_Step2 and flows into WC15_Pool2, extent approximately 1.4m long and 0.6m wide	1
LW19_051	WC14 / Swamp 148	4/05/2023	Rock Fracturing: Rock fracturing across the base of the downstream end of Channel 7 within swamp 148. Fracturing is parallel & perpendicular to the stream. There is no current surface flow or seepage of water. The main fracturing is 1.150m long, 0.060m wide and 1.270m deep.	1

Iron staining was observed to extend from tributary SC10C downstream to Sandy Creek (Rockbar 5 and Sandy Creek waterfall) in May 2022, prior to Longwall 19. Iron staining was first reported in SC10C (Pool 3) on 11/3/2013 following Longwall 8 (impact LW8_158) and after a period of high rainfall. Iron staining was again reported at Pool 3 and extending downstream to SCK_Rockbar5 on 3/9/2020, following high rainfall. The occurrence and reactivation of iron staining in 2020 triggered a Level 2 TARP within the Area 3A WIMMCP. The iron staining is a Longwall 8 impact reactivated prior to Longwall 19 and is therefore not included as a Longwall 19 impact. The TARP level related to the iron staining from SC10C to Sandy Creek remains at Level 2. This impact and associated water quality effects are discussed further in Sections 4.3 and 4.4.

3.3 Specialist advice in relation to observed impacts.

Subsidence impacts of TARP Level 2 or above require specialist advice in relation to possible Corrective Management Actions (CMAs), reporting and/or monitoring. Advice in relation to subsidence impacts to watercourses is as follows:

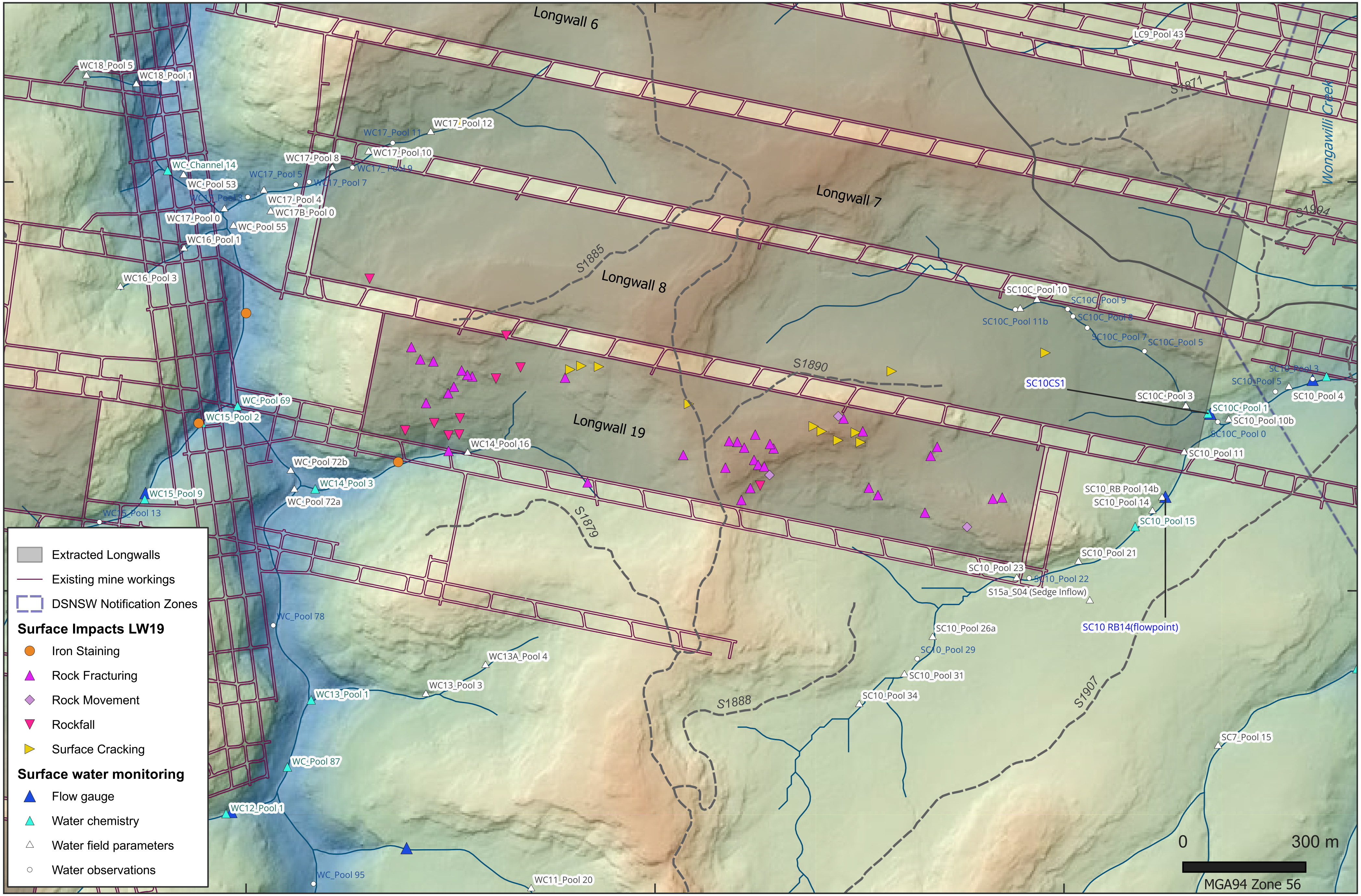
- **LW19_003**: The observed increase in iron staining on the WC14 watercourse, 50 m from the edge of the longwall footprint, is in line with predicted subsidence effects associated with Longwall 19, being above, or within 400 m of, the extracted longwall. Current routine monitoring is adequate, and no additional actions are recommended.
- **LW19_043**: Multiple varying sized rock fractures were observed within the WC14 watercourse. The fractures are located within the longwall footprint (including first workings). Surface fracturing with possible flow diversion is expected to occur in watercourses that overlie extracted longwalls,

as has been observed in other water courses that have been mined beneath (e.g., WC21, SC10C). The observed impacts are therefore in line with predictions. Current routine monitoring is adequate, and no additional actions are recommended.

3.4 Valley closure at Waterfall 54

The mine subsidence effects for Waterfall 54 (WF54) along Wongawilli Creek have been measured by IMC using 2D survey techniques. Survey lines were established prior to the commencement of Longwall 16. MSEC (2022) noted a period of valley closure movement between August and September 2021, towards the end of Longwall 17. As a precautionary measure, Longwall 17 finished approximately 105 m short of the approved finishing location to minimise further closure at the waterfall.

A rockfall was identified at Waterfall 54 along Wongawilli Creek after the completion of Longwall 18. A review of historical photographs found that the rockfall occurred between 6 and 28 October 2021 during (or soon after) the mining of Longwall 17. Assessment of pool water levels above Waterfall 54 as at the end of Longwall 19 is presented in Section 5.6.7.



Dendrobium Mine End of Panel Surface Water Assessment

Observed surface impact sites

Figure 7

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4. Assessment of surface water quality effects

During the 5-month reporting period between the start of Longwall 19 (20/6/2022) and one month after the end of Longwall 19 (29/4/2023), monitoring was carried out at 196 surface water sites. Sites were monitored on an approximately weekly or monthly basis, as per the Watercourse Impact Monitoring Management and Contingency Plan (WIMMCP).

Trigger values for water quality field parameters are defined in the Area 3A WIMMCP Attachment 1 (South32, 2020a). Trigger thresholds (TARPs) have been defined for three locations downstream of the mining area for which there is adequate high-quality baseline information (Wongawilli Creek (at Fire Road 6 [FR6]), Sandy Creek (at Rockbar 5) and Lake Cordeaux (Sandy Creek Arm). The TARPs are based on the field parameters pH, EC and DO and defined by the value three standard deviations (SD) from the baseline mean (mean plus 3SD for EC and mean minus 3SD for pH and Dissolved Oxygen). TARP levels are defined as follows:

- Level 1: One exceedance within six months
- Level 2: Two non-consecutive exceedances within six months
- Level 3: Three exceedances within six months
- Exceeding prediction: Mining results in two consecutive exceedances during the monitoring period. Predicted impacts are summarised in the WIMMCP.

TARP triggers for the monitoring period are summarised in Table 9. No water quality TARPs were triggered during the review period; however, water quality TARPs remain triggered at Lake Avon tributary site LA4_S1 for EC, pH and DO as a result of impacts related to Area 3B.

Table 9. Summary of Water Quality TARPs for the monitoring period

DATE	CATCHMENT / LOCATION	PARAMETER	VALUE	TARP	TRIGGER LEVEL
-	-	-	-	-	None triggered

Assessment of surface water quality effects, including TARP triggers is presented by catchment (watercourse) in the following subsections.

In addition to the surface water TARPs, the mining consent contains conditions related to surface water quality and flow as outlined in Table 10

Table 10. Assessment of performance against mining consent conditions

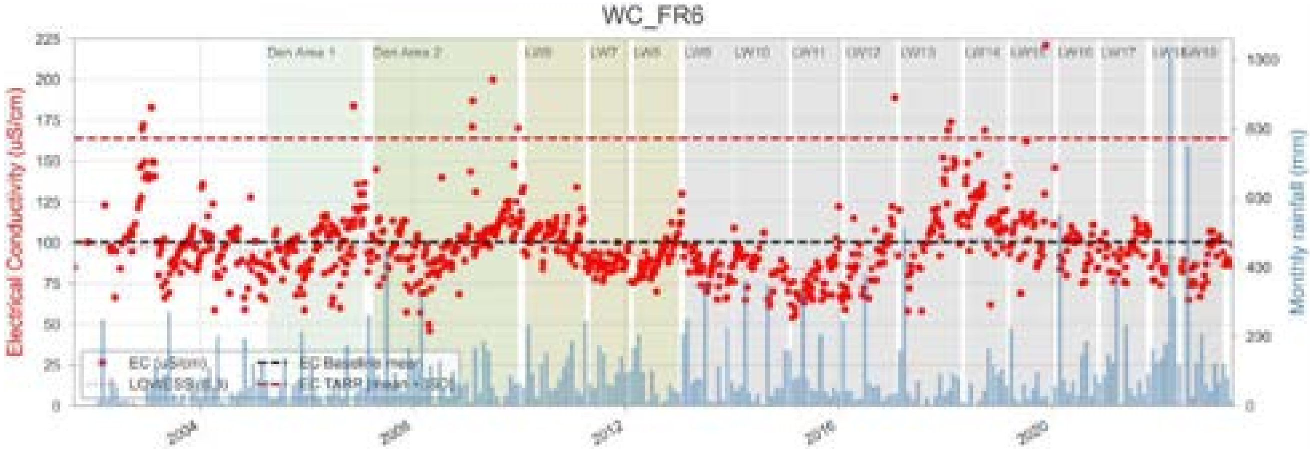
Condition	Addressed
Condition 2, Schedule 3: The applicant must ensure that underground mining operations do not cause subsidence impacts at Sandy Creek and Wongawilli Creek other than minor impacts (such as minor fracturing gas, release iron staining and other impacts on water flows, water levels and water quality) to the satisfaction of the Secretary.	Sections 4 and 5 of this report
Condition 3, Schedule 3: Operations will not result in reduction (other than negligible reduction) in the quality or qualtity of surface water or groundwater flows* to Lake Cordeaux or Lake Avon or surface water inflow to the Cordeaux River at the confluence with Wongawilli Creek.	Sections 4.1 and 0 of this report

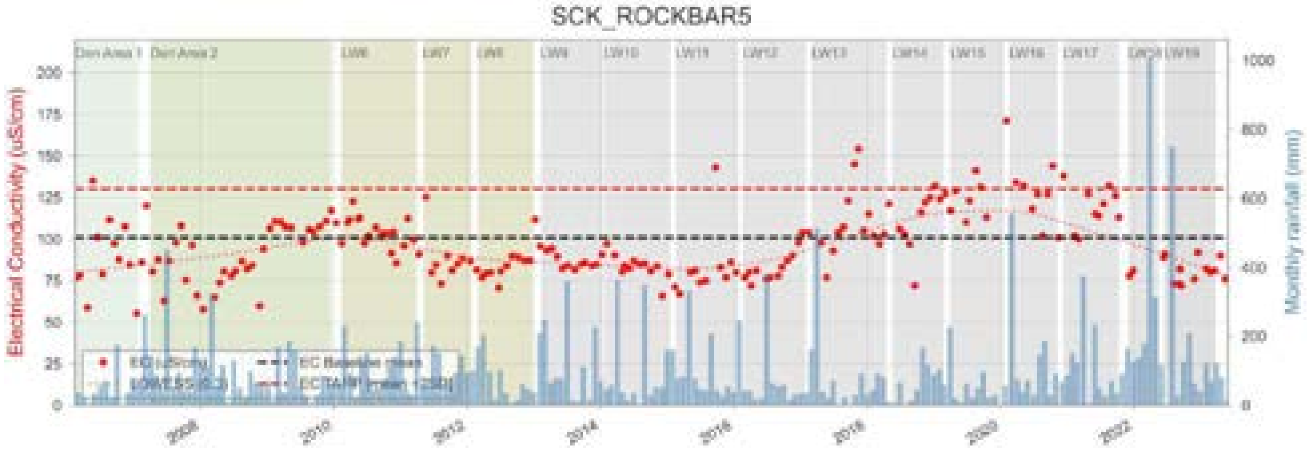
Notes: Groundwater flows and quality are reported in the End of Panel groundwater assessment report.

4.1 Overview of surface water quality

Hydrographs of stream field parameters (EC, pH and DO) are presented in Appendix A for 146 observation sites and hydrographs of dissolved sulfate, Fe, Mn, Al, Si and Zn are presented for 60 sites at which sampling, and laboratory analysis are carried out. Due to the large volume of data, water quality trends (qualitative) for the review period are summarised for representative sites and sites at which significant or noteworthy trends are apparent in Table 11. A quantitative analysis of water quality trends is presented in Section 0, below.

In general, stream salinity (EC) has decreased since 2020 and during the last four longwalls due to higher-than-average rainfall and significant increase in runoff compared with the preceding drought period (2017-2019). The decreasing trend follows slightly more saline conditions at most locations during the drought which resulted in low flows and evaporative concentration of salts. Timeseries of EC at the Area 3A TARP sites are shown in Figure 8 as examples. Similarly, DO has trended higher or remained stable over the reporting period due to high stream flows.





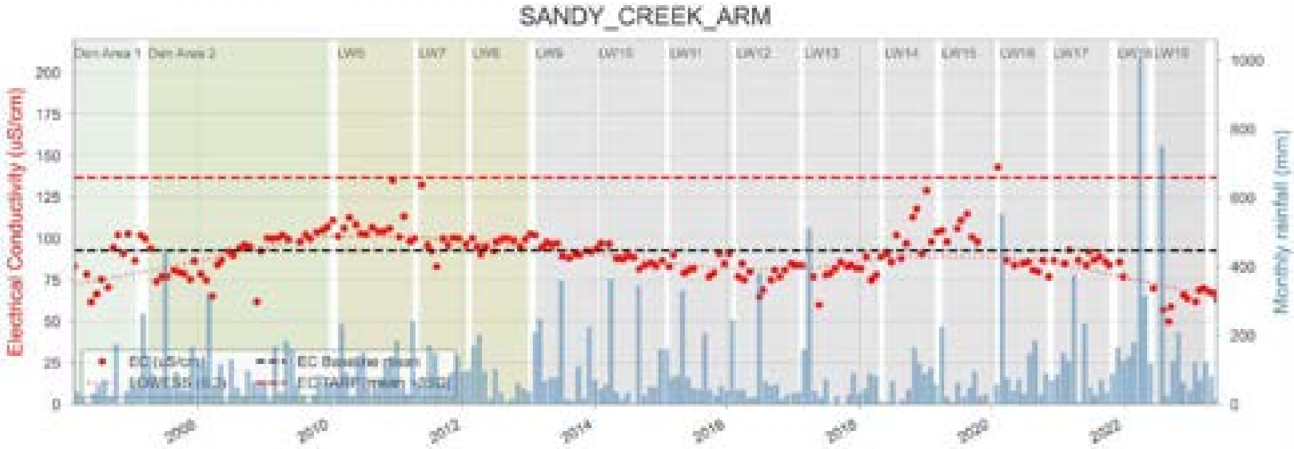


Figure 8. Timeseries of water Electrical Conductivity at TARP sites.

Anomalous water quality effects are noted in streams that have been directly mined under by previous longwalls (e.g. WC21, SC10C, LA4, DCC). Those effects include transient or persistent increases in EC, increases (or decreases) in pH and increases in dissolved metal concentrations such as Fe, Mn, Al and Zn. Iron staining in creek beds is commonly associated with watercourses that have been directly mined beneath or are within the mining area of influence.

Table 11. Summary of surface water quality observations and trends

Catchment	Field parameters (EC, pH and DO)	Dissolved metals
Wongawilli Creek	**WC_FR6 TARP: None in review period** **Iron staining**: Iron staining reported between Pool 50 and RB12 in August 2021, associate with iron spring. Staining still apparent at Pool 50 as of June 2023. Elevated Fe concentration at Pool 49 and 38, declining to baseline by Pool 20.	WC_FR6: Mn increasing trend since 2019. No other adverse trends WC_Pool38,49: Dissolved Fe, Mn declined from peak in 2021 (associated with iron staining event), but remain slightly elevated (See Section 4.4.2)
Wongawilli Creek tributaries	WC14: Iron staining reappeared at Pool 10 during Longwall 19. EC, pH and DO remain within baseline range at Pool 3. WC15: Minor iron staining at Step 2 (April 2023) WC21: Slight increase in EC and increase in pH at Pool 5 after Longwall 10. Fracturing / Loss of flow upstream.	WC7: No adverse trends (decline in metals) WC12: No adverse trends WC15: At Pool 2, Zn decreased to near baseline during LW19. WC21_Pool5: Increasing Fe,Mn and SO4 since early 2020; remains elevated compared with baseline.
Donalds Castle Creek	Decline in EC and pH and increase in DO from 2020. No significant trends further downstream (at DCL3). Upstream at DC13_Pool2B return to baseline EC, pH and DO after elevated EC and declined in pH, DO from 2018-2023. **DCC_FR6 TARP: None in review period**	DCC_FR6: Increase in Sulfate, Zn, Al and Mn after Longwall 14; Decline since 2020. Trends not evident further downstream at DCL3. Upstream sites: DC13_Pool2B and DC_Pool22; Transient increases in Fe, Mn, Al, Zn after Longwall 13; Declined to near baseline levels from 2020.
Lake Avon tributaries	LA4_S1: Fracturing / loss of flow after Longwall 13; EC slightly higher and pH, DO lower than baseline since flow returned in 2020. **LA4_S1 TARP: Exceeding Predictions for EC & pH**; **Level 1 for DO**. These TARPS remain triggered as at the end of Longwall 19. LA3: iron staining observed following completion of Longwall 18. EC, pH and DO within baseline range.	LA4_S1: Dissolved Fe, Mn, Al, Zn and Si remain elevated above baseline after flow returned in 2020. LA2: No adverse trends. LA3: No adverse trends; Metal concentrations have declined since 2019.
Native Dog Creek	Native Dog Creek NDT1 (Pools 2, 23): EC, pH and DO within baseline range; no adverse trends.	ND1_Pool2: No adverse trends
Avon River	No adverse trends	AR19_S1: Decrease in dissolved metals Fe, Mn and Al since 2018.
Sandy Creek	SCk_Rockbar5: EC and DO within baseline range; pH slightly higher than baseline (~6.3); no adverse trends. SC10: EC returned to baseline since 2020. pH slightly higher than baseline (~6.5); DO within baseline range. SC10C: EC has declined to ~200 uS/cm since 2019 but remains above baseline of ~100 uS/cm. pH increased to ~6.2 from low of ~3.2 in 2017. DO remains slightly below baseline; **SCk_Rockbar5 TARP: None in review period**	SCk_Rockbar5: Increase in Fe, Mn from 2020 (to ~2.0 and 0.8 mg/L); small increase in Zn from 2016 (to ~0.05 mg/L). Fe Mn and Zn remain above baseline. SC10_Rockbar3: Increase in Fe, Mn from 2019; small increase in Zn from 2016. Concentrations declined in 2023. SC10C_Pool1: Increase in Fe, Mn, Al, Zn, Si and sulfate following Longwall 8. Declining trends since 2020. Fe and Mn remain above baseline.
Cordeaux River	No Adverse trends	CR_S1 and CR_S2: Slight increase in Fe, Mn, Al and Si from 2020-22.
Reservoirs	Lake Avon (LA5_S2): No adverse trends. Lake Cordeaux (SANDY CREEK ARM): No adverse trends **Lake Cordeaux (Sandy Creek Arm) TARP: None in review period**	Lake Avon (LA5_S2): No adverse trends. SANDY_CREEK_ARM: Small spike in concentrations of Fe and Mn associated with 2017-2019 drought. Possible increase in Fe and Al since 2020.

4.2 Quantitative assessment of water quality trends

WaterNSW endorsed the recommendation of the Independent Advisory Panel for Underground Mining (IAPUM) that "*A method of quantifying and reporting trends in key water quality indicators (both concentrations and loads) should be trialled in addition to applying the proposed water quality TARPs.*"

A methodology for trend analysis was developed and trialled at two monitoring locations on Wongawilli Creek and Donalds Castle Creek (HGEO, 2021a). The methodology was reviewed and considered appropriate by WaterNSW. Trend analysis is carried out as follows:

- Generate a flow-corrected residual timeseries by applying the LOWESS smoother to concentration versus stream discharge data.
- For each specified time period, calculate the Mann-Kendall test statistic for significance at the 5% significance level; the Theil-Sen slope; and compare the mean concentration during the period with the baseline period using the non-parametric Mann-Whitney U rank sum test statistic.
- Trend analysis should be carried out on field EC, pH and DO, and sulphate, dissolved Fe, Mn, Al, Zn.
- Tabulate and discuss significant trends, including comparison with control site(s). Trend analysis should be carried out for monitoring sites with associated flow gauges on the major 3rd order streams: sites WC_FR6, DCC_FR6, SCk_Rockbar5 and an appropriate control site (O'Hares Creek, or WWU4).

4.2.1 Trend analysis results

Flow-corrected water quality time series and tabulated results are included in Appendix A2. A summary table, highlighting results of statistical significance is provided in Table 12. The trend analysis results reflect the qualitative assessment presented in the previous section, with the following being statistically significant:

- At WC_FR6, an increasing trend in EC is identified in flow-corrected data, despite non-flow-corrected data showing a generally decreasing trend (Figure 8). Increasing trend are also noted for sulphate and Mn. The mean flow-corrected concentrations are also significantly higher than that of the baseline. No similar trends are apparent in the upstream control site (WWU4). Note that no TARP was triggered for EC, pH nor DO for the review period.
- At DCC_FR6, flow-corrected data show increasing trends for EC, Mn, Zn and Al and a decreasing trend in pH. Over the past 1-year and 3-yer periods, EC, sulphate, Fe, Mn, Zn and Al are elevated compared with baseline (flow-corrected); whereas pH is lower than baseline. Again, no TARP was triggered for EC, pH nor DO for the review period.
- At SCk_Rockbar5, there are no statistically significant trends identified over the last 1- and 3-year periods. This is in contrast to the LOWESS trends apparent in the flow-corrected timeseries plots in Appendix A2 which reflect increases that occurred prior to the 3-year trend window (sulphate, Fe, Mn, Zn). It is apparent that flow-corrected EC, sulphate and dissolved metals Fe, Mn and Zn are above the baseline. These trends reflect contributions from tributary SC10C which was mined under by Longwall 8. No TARP was triggered for EC, pH nor DO for the review period.

Table 12. Summary of flow-corrected water quality trends (as of April 2023)

Parameter	WC_FR6	DCC_FR6	SCK_Rockbar5	WWU4 (Control)
EC (uS/cm)	↗↗ (1 yr, 3 yr) ▲ (1 yr) TARP Level 0	↗↗ (1 yr, 3 yr) ▲ (1 yr) TARP Level 0 (A3B)	→ ▲▲ (1 yr, 3 yr) TARP Level 0	↗ (3 yr) ■
pH (field)	→■ TARP Level 0	↘ (1 yr) ▼ (3 yr) TARP Level 0 (A3B)	→■ TARP Level 0	→■
DO (%)	→■ TARP Level 0	→■ TARP Level 0 (A3B)	→■ TARP Level 0	→■
SO4 mg/L)	↗ (3 yr) ▲▲ (1 yr, 3yr)	→ ▲ (1 yr)	→ ▲▲ (1 yr, 3 yr)	→■
Fe (Dissolved, mg/L)	→■	→ ▲▲ (1 yr, 3yr)	→ ▲▲ (1 yr, 3 yr)	→■
Mn (Dissolved, mg/L)	↗ (3 yr) ▲▲ (1 yr, 3yr)	↗↗ (1 yr, 3 yr) ▲▲ (1 yr, 3yr)	→ ▲▲ (1 yr, 3 yr)	↗ (1 yr) ■
Zn (Dissolved, mg/L)	→ ▲ (1 yr)	↗↗ (1 yr, 3 yr) ▲▲ (1 yr, 3yr)	→ ▲▲ (1 yr, 3 yr)	→■
Al (Dissolved, mg/L)	→■	↗ (3 yr) ▲▲ (1 yr, 3yr)	→■	→■

Note: **Mann-Kendall nonparametric test for ordinal trend** (flow-corrected concentration); ↗ Increasing trend; ↘ Decreasing trend (pH, DO) → No significant adverse trend; **Mann-Whitney U test for difference in means**; ▲ Above baseline mean; ▼ Below baseline mean (pH, DO); ■ No significant adverse change in mean (All at 95% significance Level).

Note that the above results highlight that the trend analysis approach is highly sensitive for identifying flow-corrected trends over the last 1-year and 3-year periods, when such trends may not be apparent in the non-flow-corrected data or when TARP levels are not triggered (as was the case in this assessment). As with SCk_Rockbar5, the trend analysis can produce apparently conflicting or non-intuitive results, depending on the technique and time-period chosen. The Mann-Kendall trend analysis identifies trends only over the specified 1-year and 3-year periods, whereas the Locally weighted regression trend (LOWESS – blue line) smooths over short- and medium-term fluctuations and reflects the longer-term trends. Results should therefore be interpreted with reference to both the flow-corrected and non-corrected hydrographs.

4.3 Sandy Creek

In May 2022, WaterNSW (via DPE) requested that IMC *Investigate a potential link between anomalous water quality results observed in the tributary of Banksia Ck (SC10C_Pool1) and increasing 3-year trends in sulphate and dissolved metal (manganese, zinc) concentrations at Sandy Creek (SCk_Rockbar5).*

IMC carried out a longitudinal sampling survey along the affected reaches of the watercourse over a period of 6 months from September 2022 to February 2023. The results are presented in a report by HGEO (2023b), dated March 2023; the main conclusions of which are summarised below:

Water samples were collected at seven sites between SC10C_POOL3 to SCk_ROCKBAR5, and two additional control sites located upstream of the observed water quality effects. Visual inspections were carried out at monthly intervals (weather permitting), and water samples were analysed for major ions and dissolved metals. The results showed that:

- All solutes generally decrease systematically with distance downstream from SC10 Pool 3 to SCk_Rockbar5. The trend is consistent for all sampling events (e.g., Figure 9).
- At the downstream sampling site SCK Rockbar 5, solute concentrations are up to an order of magnitude less than at the up-stream site SC10C Pool 3 but remain above the pre-mining baseline 90th percentile values.
- There are apparent step-changes in concentration corresponding with the confluence of SC10C with SC10 and the confluence of SC10 with Sandy Creek. Those step changes are consistent with dilution of solutes from an up-stream source at those confluences.
- In general, the most recent samples returned the lowest solute concentrations. However, there is no consistent trend of decreasing concentration over time over all sites and all solutes. This is to be expected over the relatively short survey period.

It is expected that metal concentration in Sandy Creek will continue to decline in line with decreasing metal concentrations in SC10C and SC10, and if dryer weather conditions resume in late 2023 as predicted by the Bureau of Meteorology. Recent samples from SCK_Rockbar5 suggest this is the case. It is expected the elevated metal concentrations in Sandy Creek will not have a measurable effect on water quality in Cordeaux Reservoir due to extreme dilution in the reservoir. Timeseries plots of metal concentrations in the Sandy Creek Arm of Cordeaux Reservoir show that some metals (iron and aluminium) may be slightly elevated since 2020 (Figure 10), noting that this period coincides with high rainfall and high runoff from all Lake Cordeaux catchments. It is recommended that water quality in Sandy Creek and at Sandy Creek Arm be reassessed in November 2023, or in the next End of panel Report.

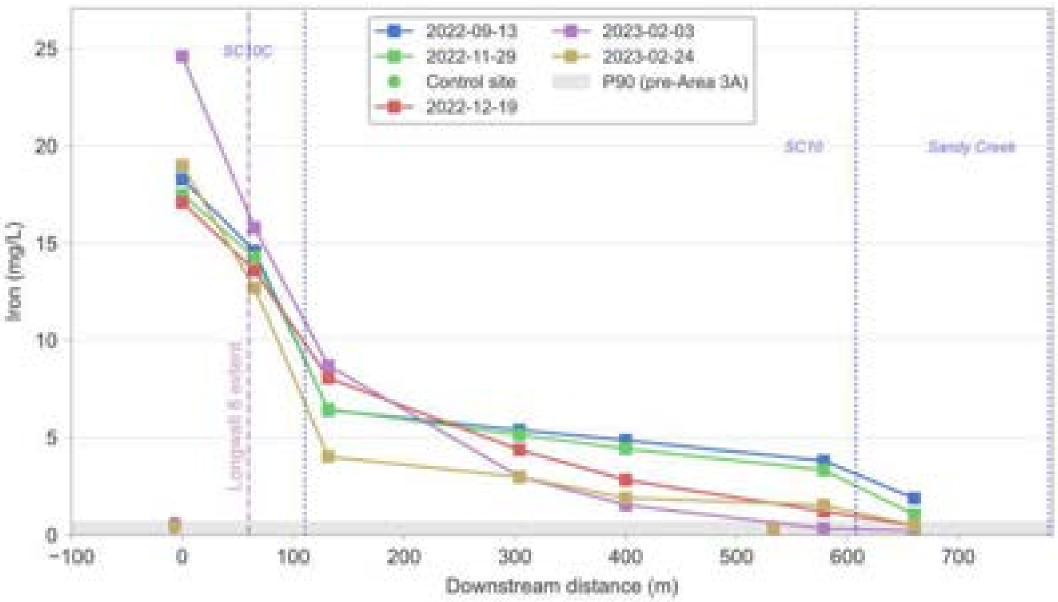


Figure 9. Dissolved iron concentration versus distance downstream of SC10C Pool 3

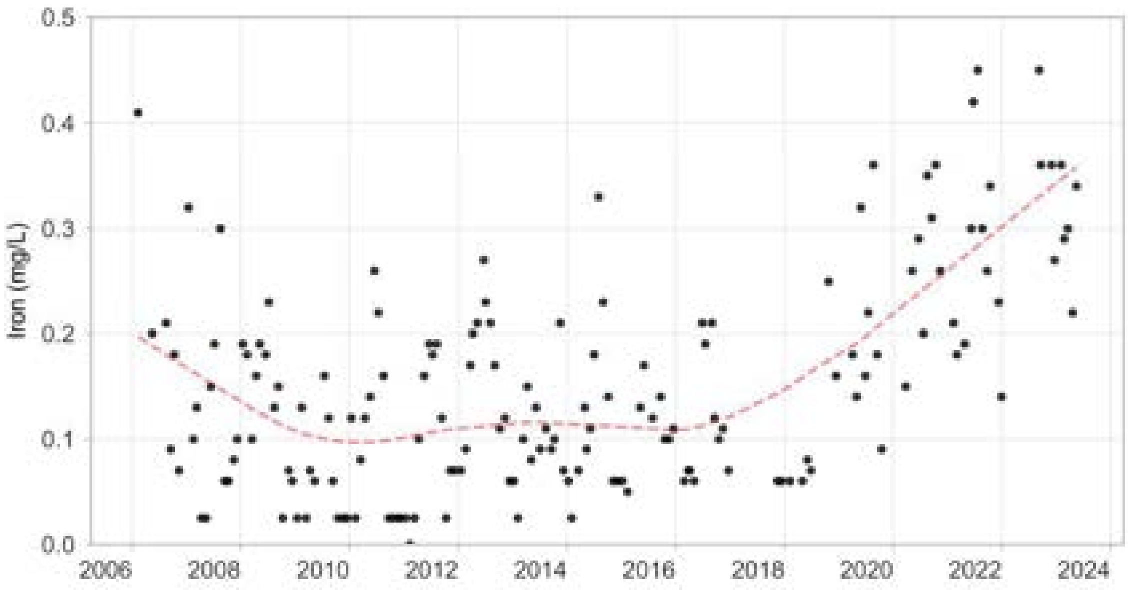


Figure 10. Dissolved iron concentration at Sandy Creek Arm of Lake Cordeaux

4.4 Iron staining

Since 2020, new or recurrent iron staining has been noted on Wongawilli Creek (see Section 4.4.2), WC21, LA5 and SC10C. During Longwall 19, rock fracturing and reactivation of iron staining were reported on WC14, the upper reaches of which were mined beneath by Longwall 19 and on WC15. Iron staining has also been observed in natural catchments on the Woronora Plateau that are located outside mining influence and has generally increased due to high rainfall and rising water tables since 2020.

4.4.1 Iron staining in Sandy Creek

Iron staining was first reported in SC10C (Pool 3) on 11 March 2013 after Longwall 8 mined beneath the watercourse (Impact reference LW8_158). The iron staining corresponds to the first detection of high dissolved Fe (13/3/2013; 15.6 mg/L) and followed two months of high rainfall. Iron staining was also observed downstream of the SC10 and SC10C confluence following the extraction of Longwall 8.

Iron staining persisted at SC10C_Pool3 through to 2020, generally localised to SC10C and SC10. Following high rainfall in 2020 the iron staining was reported by IMC as an update to impact LW8_158 (Report date 19/10/2020), extending downstream into Sandy Creek and to SCk_Rockbar5. As of June 2023 there is evidence for residual iron staining at SCK_Rockbar5 and at Sandy Creek Waterfall; however there appears to be little iron being currently deposited at those locations and the water generally appears clear and free of suspended iron floc. No iron staining was observed within Lake Cordeaux (Sandy Creek Arm) beyond the base of the waterfall. Reactivations of iron springs and iron staining in the last three years is likely associated with high rainfall resulting in rising water tables and increased flow through natural and mining-induced fracture networks. It is expected that, as drier conditions return, the extent and severity of iron staining will reduce further.

The occurrence and reactivation of iron staining in 2020 triggered a Level 2 TARP within the Area 3A (Longwalls 6 to 8) WIMMCP (*Increase in iron staining for >2 consecutive months in Sandy Creek*). The TARP level related to the iron staining from SC10C to Sandy Creek remains at Level 2.

4.4.2 Iron-staining in Wongawilli Creek

In August 2021, an increase in iron staining was observed along reaches of Wongawilli Creek adjacent to Areas 3A and 3B during routine monitoring. The most noticeable iron-staining effects extended from WC_Pool 50 to Pool 2. The source of the iron staining was identified as a pre-existing but reactivated spring located on the valley slope of Wongawilli Creek, approximately 35m to the east and upslope from WC_Pool 50. The observations corresponded to a Level 3 trigger according to the Dendrobium Area 3B Watercourse Impact Monitoring, Management and Contingency Plan (WIMMCP) and were reported by IMC on 9/8/2021.

A review of monitoring data concluded that the appearance of iron staining along Wongawilli Creek in August 2021 was caused by increasing groundwater levels and reactivation of slope springs in response to high rainfall and groundwater recharge events in March and May 2021 (and generally high rainfall since 2020) (HGEO, 2021b). Spring discharge is likely facilitated by fracturing associated with mine subsidence; however discharge via natural fractures is also possible (and was observed during baseline monitoring). It should also be noted that increased Iron staining has been observed in natural catchments on the Woronora Plateau that are located outside mining influence. Discharge from the slope spring resulted in elevated concentrations of dissolved iron above the baseline P95 level in Wongawilli Creek Pools 49 and 38 (Figure 11).

As of April 2023, dissolved iron concentrations remained elevated relative to baseline at Pools 49 and 38, decreasing downstream to baseline levels by Pool 20 (Figure 11). It is expected that dissolved iron concentrations will continue to decline as the fracture systems through which groundwater is discharging, age and weather. A return to drier weather conditions will also likely result in reduced discharge from the slope spring to Wongawilli Creek.

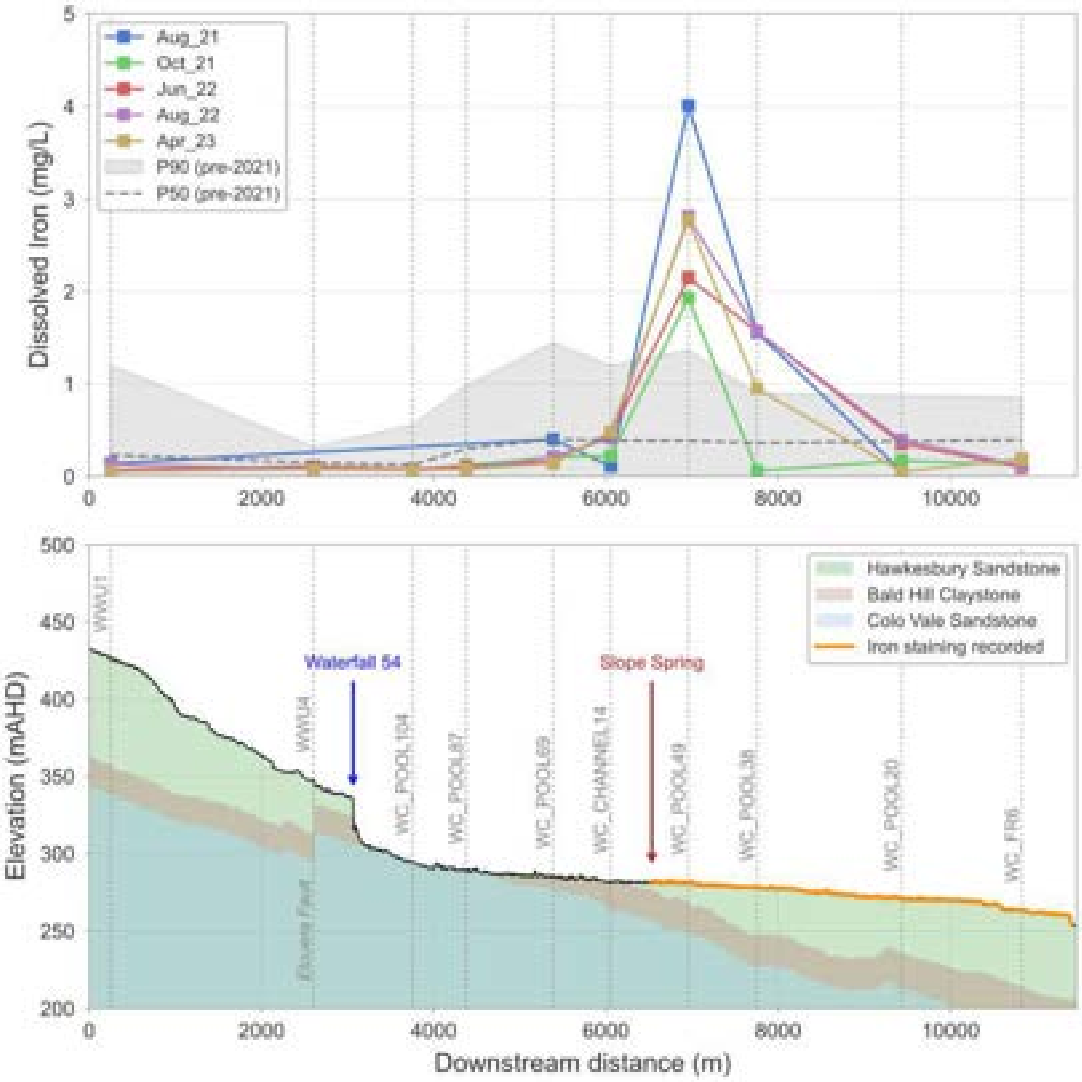


Figure 11. Dissolved iron concentration in Wongawilli Creek

4.5 Gas emissions at Wongawilli Creek, Pool 50

The IMCEFT reported a gas release in Wongawilli Creek at WC_Pool 50 on 18/1/2023. The release was observed originating from the base of a sandstone step on the western side of the pool. The emission was observed to be intermittent with smaller gas bubbles from the centre of the pool. Follow-up inspections were carried out on 1/2/2023 and 26/4/2023. The gas release was found to be more consistent in the last inspection.

A gas sample was collected on 1/2/2023 for laboratory analysis, which indicated mostly carbon dioxide and very low levels of methane. Methane content was lower than that expected from strata or in-seam gas.

A water sample collected from WC_Pool50 on 26/4/2023 was analysed for dissolved gasses. Dissolved methane was present at a concentration of 43 µg/L and ethane was below detection (<10 µg/L). Methane and ethane are naturally present in groundwater, with concentrations generally increasing with depth. At Dendrobium groundwater samples have a median of 175 µg/L and a mean of 3,836 µg/L (700 samples), Ethane is present at much lower concentrations with a median value on groundwater of <10 μg/L and a mean of 341 μg/L (329 samples). The observed concentration of methane and ethane in Pool50 is therefore low compared with typical groundwater samples.

Methane occurs naturally in streams and wetlands and is produced by microbial activity during decomposition of organic matter (amongst other processes). Most methane is lost to the atmosphere, but low concentrations may be present in natural streams. It is not known to be harmful to aquatic life under natural conditions and the ANZECC Guidelines for Fresh and Marine water Quality have no Default Guideline Values (DGV) for methane. Methane and ethane are not typically analysed in surface water samples and therefore there is no local baseline or reference level for comparison. However, the low observed concentration of methane in water at WC_Pool50 is not considered to represent a risk to aquatic ecosystems along the watercourse.

With reference to water quality timeseries plots provided in Appendix 2, there are no anomalous trends in field parameters at the nearest downstream water quality sampling site (WC_Pool49). As discussed in Section 4.4.2, dissolved iron and manganese have trended higher at WC_Pool49 since 2020, which is related to the reactivation of the slope-spring immediately upstream of the location.

5. Assessment of surface water flow effects

5.1 Surface Water Flow TARPs

The surface water flow assessment and relevant TARPs have been modified from those used previously for Area 3B End of Panel reports. Consultation with agencies during 2018-2019 led to agreement of new TARPs in early 2020, as outlined in the WIMMCP (South32, 2021a).

This assessment of surface water flow in this End of Panel report relies on comparison against flows at Reference Sites, as recommended by the IEPMC (IEPMC, 2019, 2018). The revised and agreed assessment methods are described in more detail in (Watershed HydroGeo, 2019a). Other recommendations of the IEPMC are addressed in this assessment, as listed in Table 13.

Table 13. Recommendations of the IEPMC (2018) (revised as IEPMC, 2019a)

RECOMMENDATION / COMMENT	RESPONSE / ACTION
Assessment of impacts to be made against the full post-mining period, not longwall by longwall.	**Implemented.** Assessment of effects is now reported for the complete post-mining period at each site, rather than for each longwall. This provides an assessment of cumulative effects.
The EOP reports to provide more information on the data sources for rainfall, evaporation and the monitoring sites.	**Implemented.** This is presented Appendix B and C, noting that rainfall and evaporation are not required for assessment against Reference Sites.
Document the specific sources of rainfall and evaporation data used in the rainfall-runoff modelling.	**Implemented.** The rainfall and evaporation data sources are documented in Appendix B, noting that rainfall and evaporation are not required for assessment against Reference Sites.
Discussion of flow monitoring errors and their impact on assessing compliance should be published and peer reviewed.	**Implemented** (On-going). IMC are progressing with a review of gauging station accuracy. This report has been issued (EnviroMon, 2019) but will be extended in the near future to include other sites. See Appendix C (Section C5) for charts.
Use techniques to supplement the rainfall-runoff modelling. This has been done in some EOP reports, including for LW11 but has been excluded from the LW12 and LW13 EOP reports	**Implemented**. The use of Reference Sites, as documented in WatershedHG (2019a) and agreed by agencies, is now adopted for this assessment. Additional Reference Sites are potentially available for future areas (Area 3C).
There is no validation on flow measurements from outside the calibration period.	**Not yet implemented:** The use of Reference Sites as the basis for assessment was agreed by agencies in the approved WIMCCP. More recent feedback by IAPUM recommended that comparison against rainfall-runoff modelling should be re-instated (Section 1.3). This has been done so for a limited number of sites (Section 5.3.1), and if deemed necessary can be expanded in future.
Given the criticality of low flows for this project, attempts to improve the low flow modelling should continue, and should be reported and peer reviewed.	**Not yet implemented:** Peer review to occur in the near future, following discussion with IAPUM in 2022.

The agreed Assessments A, B, and C are respectively focussed on assessing:

- general hydrological behaviour compared with Reference Sites,
- the frequency and duration of ecologically-significant cease-to-flow events compared with Reference Sites; and

- changes to median flow compared with Reference Sites which is now the agreed measure of the water resource availability in each sub-catchment.

A further assessment, Assessment D is specific to Wongawilli Creek, relies on comparison of qualitative flow data from gauging stations and semi-quantitative field observations by IMCEFT along the "middle reach" of Wongawilli Creek, which has been shown in the recent past (e.g. in Watershed HydroGeo, (2018)) to be subject to baseflow loss due to depressurisation of groundwater systems as a result of mining activity.

5.2 Performance Measures

Performance Measures have also been agreed and are documented in the WIMMCP. These are outlined in Table 14. The assessment of these is presented in Section 0.

Table 14. Area 3A Surface flow Performance Measures

DOMAIN	PERFORMANCE MEASURE	AGREED MEASURE
Areas 3A and 3B	Wongawilli Creek – minor environmental consequences	Assessment Methods C and D, to be compared against predictions made in contemporary groundwater modelling conducted to the satisfaction of the Secretary to assess whether effects that cannot be explained by natural variability "exceed prediction".
Area 3A	Sandy Creek – minor environmental consequences	Assessment Method C to be compared against predictions made in contemporary groundwater modelling conducted to the satisfaction of the Secretary to assess whether effects that cannot be explained by natural variability "exceed prediction".
Area 3A	Lake Cordeaux – negligible reduction in the quantity of surface water inflows to Lake Cordeaux	Surface water inflows calculation = [Impacts at gauged catchments (SCL2 + LC5 + LC6) + estimated impacts at ungauged but undermined catchments (e.g. LC9, LC4)] / [total inflow to LC].
Area 3B	Lake Avon – negligible reduction in the quantity of surface water inflows to Lake Avon	Surface water inflows calculation = [Impacts at gauged catchments (LA2 + LA3 + LA4 + NDT1) + estimated impacts at ungauged but undermined catchments (e.g. LA5)] / [total inflow to LA].
Areas 3A and 3B	Cordeaux River – negligible reduction in the quantity of surface water inflow to the Cordeaux River at Wongawilli Creek	Flow reduction as determined from measured flow gauging station WWL_A (or WWL, whichever gauge is being used).

5.3 Assessment for Longwall 19

The following sections present the analysis and results of the agreed Assessments A, B, and C for each sub-catchment relevant to Areas 3A and 3B. This is followed by Assessment D for the mid-reach of Wongawilli Creek and then followed by assessment against the agreed Performance Measures. The detail and criteria for each assessment are outlined in the WIMMCP (South32, 2021a), as described in Section 5.1.

At the gauged sub-catchments around Areas 3A and 3B, the assessment consists of a three-step approach (A, B, and C as listed below) to identify and assess any changes in hydrology at the assessment sites in relation to the agreed reference sites. A fourth assessment (D) is carried out for Wongawilli Creek.

The four assessment methods are as follows:

- Change in flow exceedance ("Q%ile") behaviour compared to Reference Sites. In essence, this aims to quantify an otherwise visual or qualitative assessment of flow behaviour (compared to normalised Reference Site flow). This test is a broad indicator of hydrological behaviour.

Greater proportion of time with lower flow than expected based on Reference Q%	Trigger level (Inference)
Proportion of time increased by < 10%	Not triggered – no evidence of impact (or impact below detection)
Proportion of time increased by >= 10%	Level 1
Proportion of time increased by >= 15%	Level 2
Proportion of time increased by >= 20%	Level 3

- Relative change in the frequency of cease-to-flow days compared to that at Reference Sites. This assessment is focussed on changes that are likely to be significant to ecological values.

Greater proportion (%) of time that cease-to-flow conditions occur	Inference
<= "natural variability" + 5%	No evidence of impact (or impact below detection)
> "natural variability" + 5%	Level 1
> "natural variability" + 10%	Level 2
> "natural variability" + 20%	Level 3

- Relative change in median flow ("Q50") compared to Reference Site flows. This assessment is focussed on a measure of the water resource potential of each sub-catchment, noting that 'average' flow is not used due to the high uncertainty associated with high flows. The uncertainty is typically less at moderate flows– see charts in Appendix C5, and the calculation of median flow is much less sensitive to uncertainties; and

Relative change in Q50	Inference
<= "natural variability" + 10%	No evidence of impact (or impact below detection)
> "natural variability" + 10%	Level 1
> "natural variability" + 15%	Level 2
> "natural variability" + 20%	Level 3

Note that this is calculated as a % reduction compared to measured pre-mining Q50 at the assessment site. It is proposed that this be changed to % reduction from 'expected Q50'.

- Assess whether observed dry pools and 'cease-to-flow' conditions along Wongawilli Creek between WWU and WWL gauging stations are anomalies, and indicative of mining-related drawdown along that valley (as described in Watershed HydroGeo, 2018).

Observations of no flow	Inference
Observation that the subject Creek has ceased to flow at spatially consecutive observation sites.	Level 2 → Carry out Assessment D.

If any of these indicate an impact is likely to have occurred, then the EOP will describe the Impact as it relates to one or more of the broad hydrological behaviours, a reduction in the water resource Indicator, or an effect that could modify or impact upon the ecological values of the stream.
Assessment against surface water flow TARPs

The following sub-sections (Sections 5.3.1 to 5.3.11) summarise the TARP Assessments A, B and C for each relevant sub-catchment using the criteria outlined in the previous section. A secondary check for sites that do not trigger Level 3 for Assessment C is presented in Section 5.3.17.

TARP Assessment D for flow conditions along Wongawilli Creek is presented in Section 5.4.

5.3.1 DC13S1 – tributary of Donalds Castle Creek

This tributary lies across the centre of several Area 3B panels. The catchment to DC13S1 was first mined under at the commencement of Longwall 9, and again by Longwalls 10 and 11. Longwalls 12 to 18 did not directly mine under this sub-catchment, and Longwall 19 is approximately 3 km away.

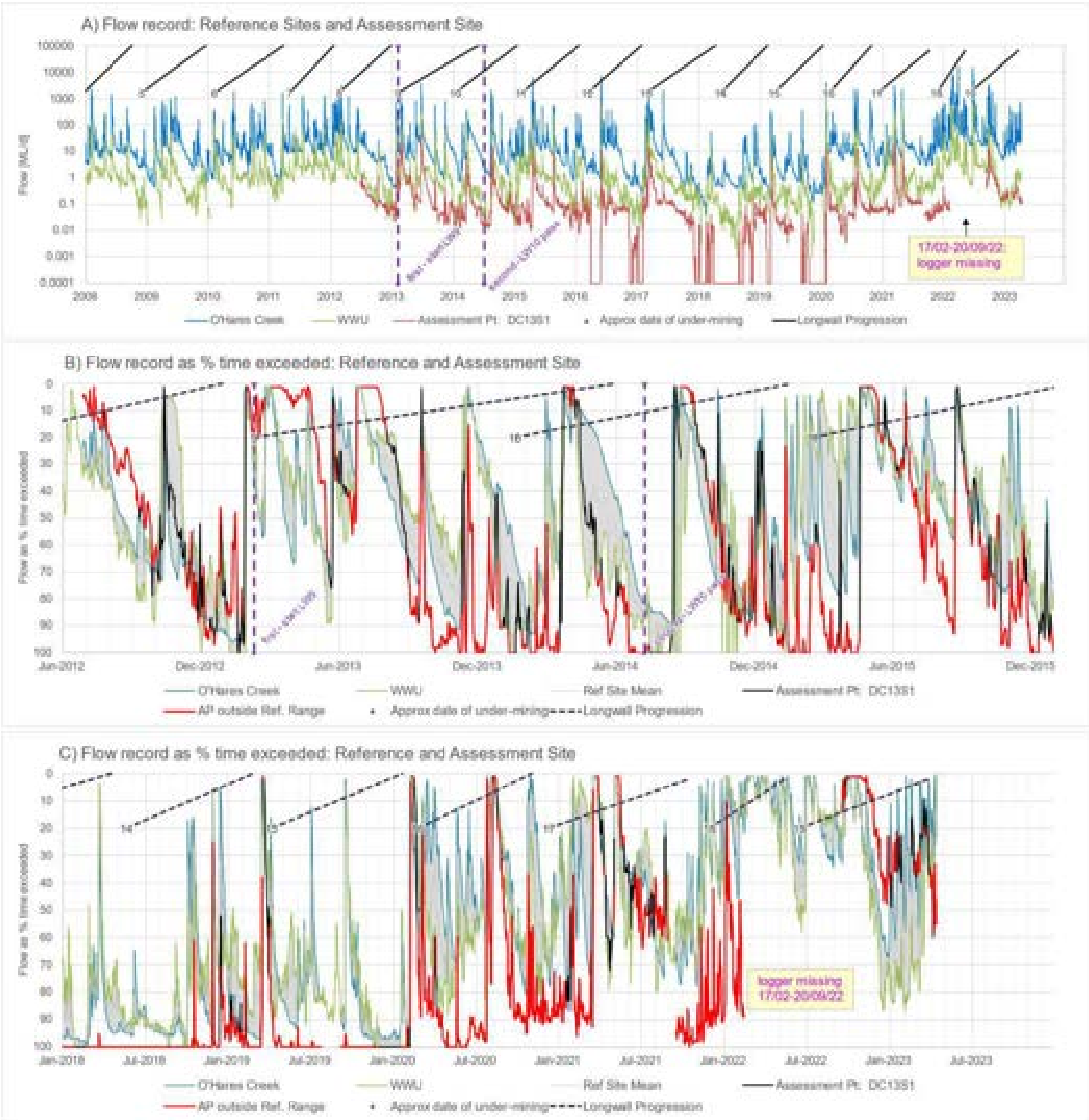


Figure 12. DC13S1 vs Reference Sites A) flows; B) and C) flow duration statistics [Q%iles]

Figures B and C (above) show the Q%ile hydrograph for the DC13 Assessment Point versus the Q%ile hydrographs for the Reference Sites, O'Hares Creek and WWU. For this assessment 'natural variability' is defined as the range between the Q%ile for the Reference Sites on each day.

Table 15. Flow assessments A, B and C for the sub-catchment to DC13S1

DC13S1		Pre-mining	Post-mining	
		to start LW9	end LW19 + 30days	
		27/06/2012	10/02/2013	
		9/02/2013	28/04/2023	
Method A:	Assessment of flow variability:			
Period	Compared to Reference Sites, gauge is at: Lower flow (higher Q%ile)		Higher flow (lower Q%ile)	
Pre-mining	11%		60%	of the time
Post-mining	67%		14%	of the time
Change	**56%**		-46%	of the time
			Assessment A:	Level 3
Method B:	Change in cease-to-flow frequency:			
	Cease to flow as % of daily record during		pre- and post- mining periods	
Site	Pre-mining		Post-mining	Change
O'Hares Creek	0.0%		0.0%	0.0%
WWU	10.1%		4.2%	-5.9%
Average Ref. Site change (= natural variability):				-2.9%
DC13S1	0.0%		13.2%	13.2%
	no. of cease-to-flow days increased:			**16.2%**
			Assessment B:	Level 2
Method C:	Change to median flow (Q50):			
Reference Site Q50 [ML/d]		Q50 (pre-)	Q50 (post-)	% Change
O'Hares Creek		5.46	7.73	41%
WWU		0.40	0.45	13%
Natural variability		Min	Mean	Max
from 2 x Ref. Sites		13%	27%	41%
Assessment Site Q50 [ML/d]		Q50 (pre-)	Q50 (post-)	% Change
DC13S1		0.126	0.060	-52%
'Expected' post-mining Q50 at		Min	Mean	Max
DC13s1		0.141	0.159	0.178
Change beyond natural		Min	Mean	Max
% change (of pre-mining Q50)		-64.8%	**-79.2%**	-93.6%
% change (of 'expected' Q50)		-58%	**-62%**	-66%
ML/d change from natural		-0.081	**-0.099**	-0.118
			Assessment C:	Level 3

5.3.2 DCS2 – Donalds Castle Creek

The upper reach of Donalds Castle Creek lies across several Area 3B panels. This sub-catchment was first mined under by Longwall 9 (July 2013), then by Longwalls 10-12. Longwall 13 passed within 250 m of the creek in May-2017. Longwalls 14-18 and 19 did not mine directly under this catchment.

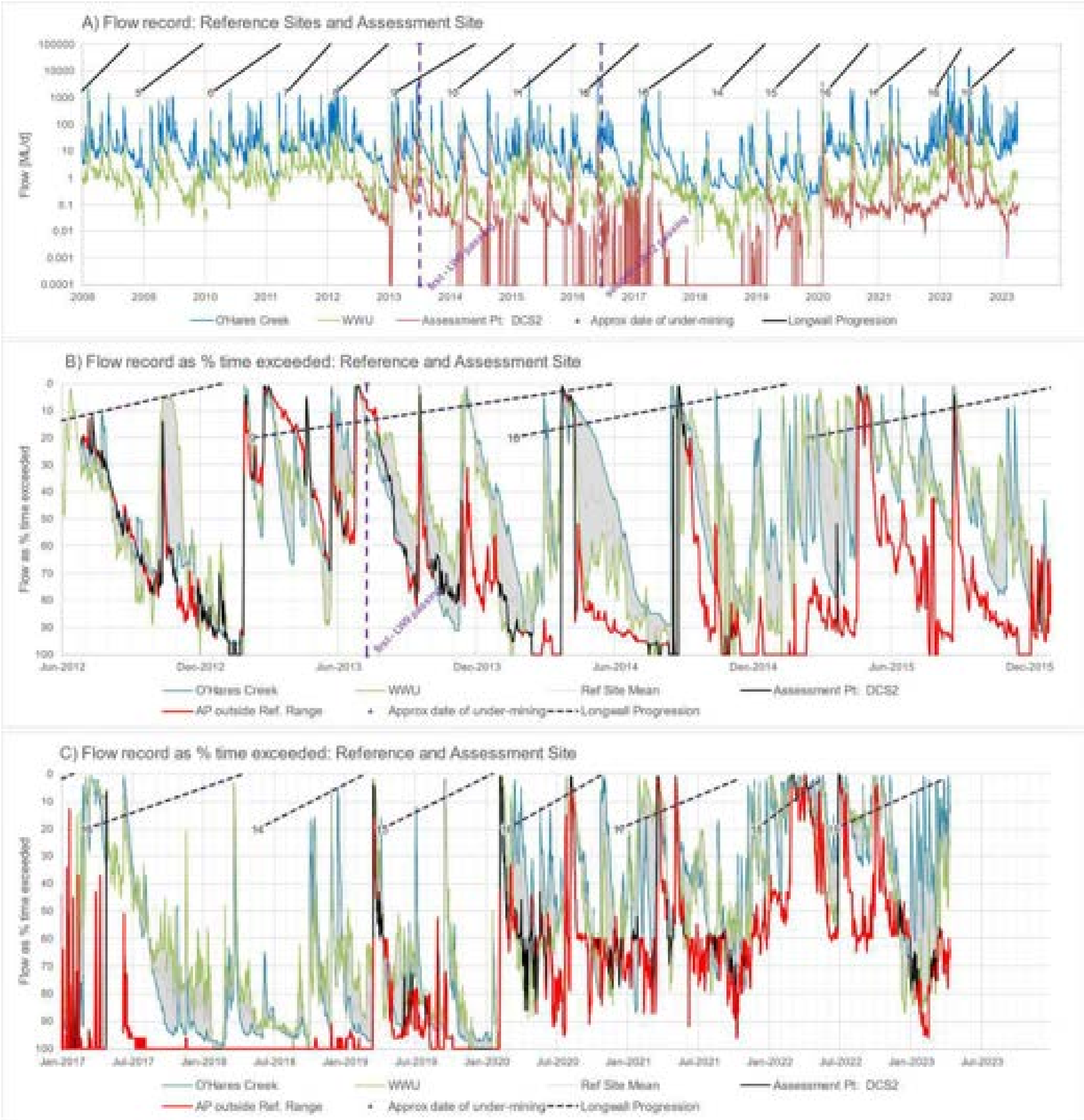


Figure 13. DCS2 vs Reference Sites A) flows; B) and C) flow duration statistics [Q%iles]

Figures B and C (above) show the Q%ile hydrograph for the DCS2 Assessment Point versus the Q%ile hydrographs for the Reference Sites, O'Hares Creek and WWU. For this assessment 'natural variability' is defined as the range between the Q%ile for the Reference Sites on each day.

Table 16. Flow assessments A, B and C for the sub-catchment to DCS2

DCS2	Pre-mining	Post-mining	
	to LW9 passing	end LW19 + 30days	
	27/06/2012	11/07/2013	
	10/07/2013	28/04/2023	
Method A:	**Assessment of flow variability:**		
Period	Compared to Reference Sites, gauge is at: Lower flow (higher Q%ile)		Higher flow (lower Q%ile)
Pre-mining	24%	36%	of the time
Post-mining	78%	5%	of the time
Change	**54%**	-30%	of the time
		Assessment A:	Level 3
Method B:	**Change in cease-to-flow frequency:**		
	Cease to flow as % of daily record during	pre- and post- mining periods	
Site	Pre-mining	Post-mining	Change
O’Hares Creek	0.0%	0.0%	0.0%
WWU	6.1%	4.4%	-1.7%
		Average Ref. Site change (= natural variability):	-0.8%
DCS2	2.9%	32.4%	29.5%
		no. of cease-to-flow days increased:	**30.3%**
		Assessment B:	Level 3
Method C:	**Change to median flow (Q50)**		
Reference Site Q50 [ML/d]	Q50 (pre-)	Q50 (post-)	% Change
O’Hares Creek	8.52	8.21	-4%
WWU	0.82	0.44	-46%
Natural variability	Min	Mean	Max
from 2 x Ref. Sites	-46%	-25%	-4%
Assessment Site Q50 [ML/d]	Q50 (pre-)	Q50 (post-)	% Change
DCS2	0.164	0.031	-81%
‘Expected’ post-mining Q50 at	Min	Mean	Max
DCS2	0.088	0.123	0.158
Change beyond natural	Min	Mean	Max
% change (of pre-mining Q50)	-34.9%	**-56.2%**	-77.5%
% change (of ‘expected’ Q50)	-65%	**-75%**	-80%
ML/d change from natural	-0.057	**-0.092**	-0.127
		Assessment C:	Level 3

5.3.3 DCU – Donalds Castle Creek

This catchment incorporates the headwater sub-catchments DC13 and DCS2 was mined under at the commencement of Longwall 9, again by Longwalls 10-12, and marginally by Longwall 13. Longwalls 14-19 are beyond it (to the south and SE). About 60% of the DCU catchment is not mined under.

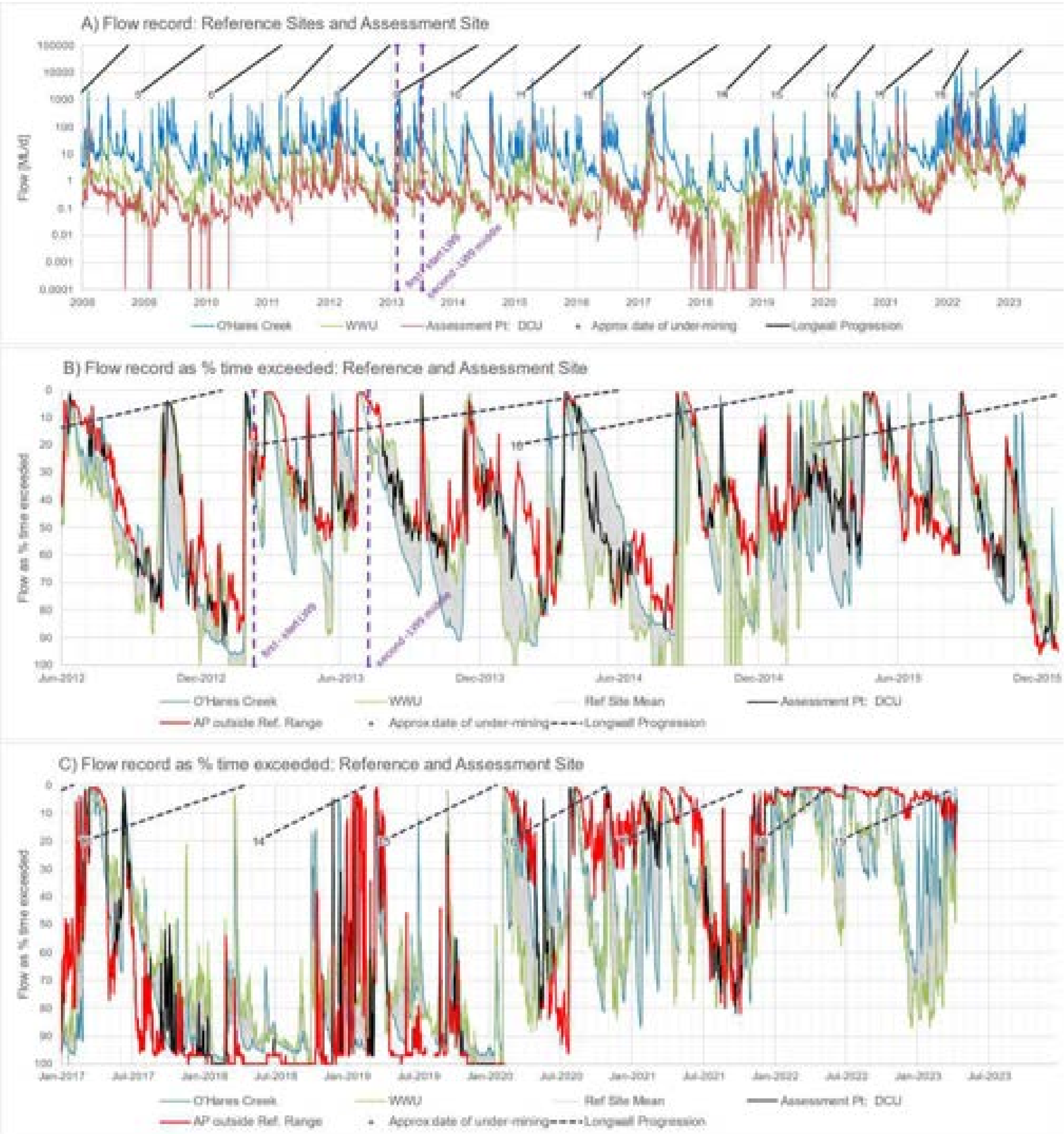


Figure 14. Comparison of DCU against Reference Sites A) flows; B) and C) flow duration statistics [Q%iles]

Figures B and C (above) show the Q%ile hydrograph for the DCU Assessment Point versus the Q%ile hydrographs for the Reference Sites, O'Hares Creek and WWU. For this assessment 'natural variability' is defined as the range between the Q%ile for the Reference Sites on each day.

Table 17. Flow assessments A, B and C for the sub-catchment to DCU

DCU	Pre-mining	Post-mining	
	to LW9 passing	end LW19 + 30 days	
	27/06/2012	10/02/2013	
	9/02/2013	28/04/2023	

Method A:	Assessment of flow variability:		
Period	Compared to Reference Sites, gauge is at: Lower flow (higher Q%ile)	Higher flow (lower Q%ile)	
Pre-mining	45%	28%	of the time
Post-mining	32%	43%	of the time
Change	**-13%**	15%	of the time
		Assessment A:	Not triggered

Method B:	Change in cease-to-flow frequency:		
	Cease to flow as % of daily record during	pre- and post- mining periods	
Site	Pre-mining	Post-mining	Change
O'Hares Creek	0.0%	0.0%	0.0%
WWU	5.2%	4.2%	-1.0%
		Average Ref. Site change (= natural variability):	-0.5%
DCU	1.8%	8.4%	6.6%
		no. of cease-to-flow days increased:	**7.1%**
		Assessment B:	Level 1

Method C:	Change to median flow (Q50)		
Reference Site Q50 [ML/d]	Q50 (pre-)	Q50 (post-)	% Change
O'Hares Creek	11.64	8.62	-26%
WWU	1.03	0.48	-53%
Natural variability	Min	Mean	Max
from 2 x Ref. Sites	-53%	-40%	-26%
Assessment Site Q50 [ML/d]	Q50 (pre-)	Q50 (post-)	% Change
DCU	0.217	0.245	+13%
'Expected' post-mining Q50 at	Min	Mean	Max
DCU	0.102	0.131	0.161
Change beyond natural	Min	Mean	Max
% change (of pre-mining Q50)	+66.0%	**+52.4%**	+38.8%
% change (of 'expected' Q50)	141%	**87%**	52%
ML/d change from natural	+0.143	**+0.114**	+0.084
		Assessment C:	Not triggered

5.3.4 WC12S1 – Wongawilli Creek tributary

The end of Longwall 15 skirted the north-western edge of this sub-catchment and to within 250 m of the watercourse itself. Longwall 16 mined within 40 m of WC12, and Longwall 17 mined under this watercourse. Longwalls 18-19 did not mine under this sub-catchment (Longwall 19 is 1 km away).

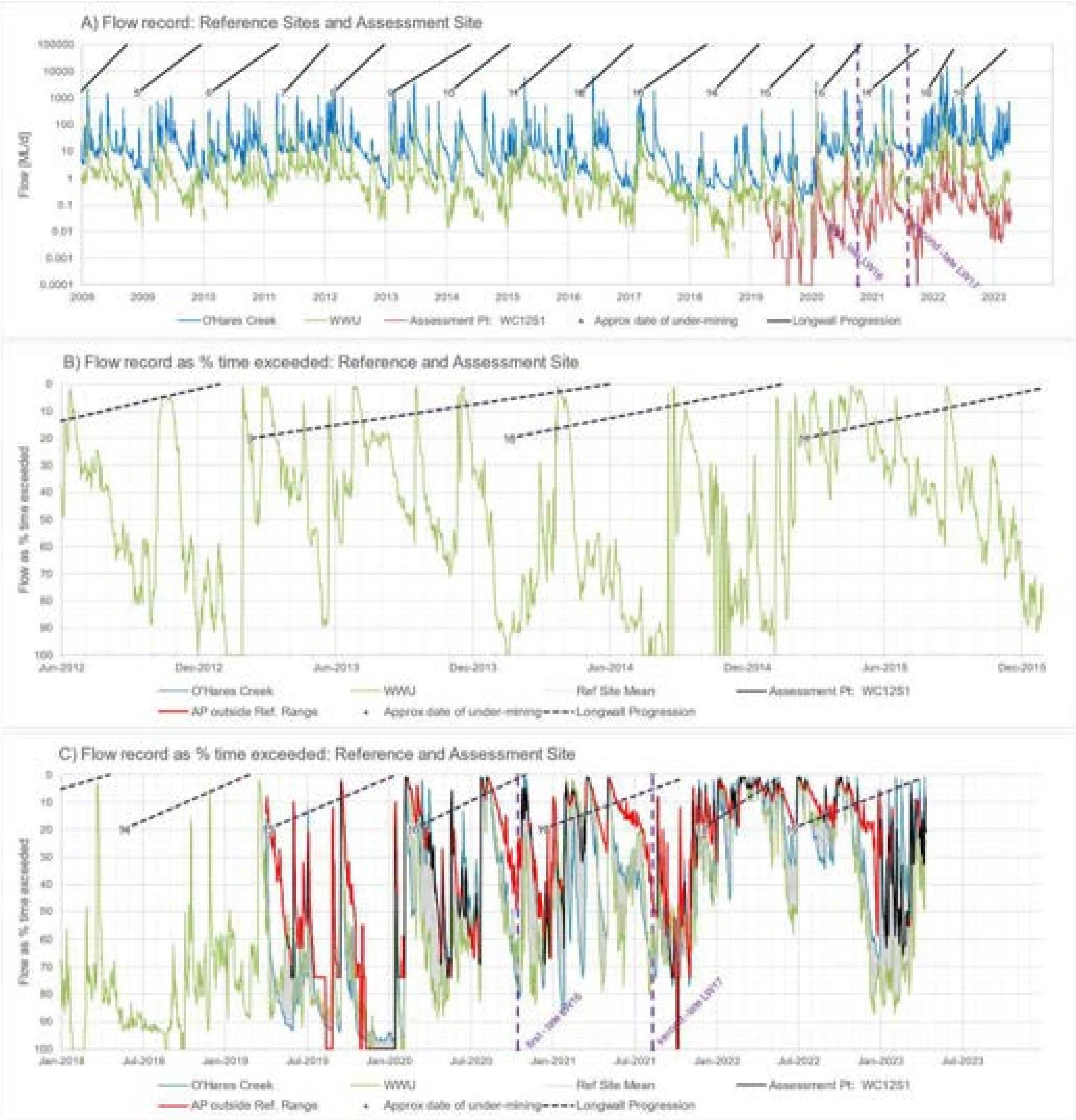


Figure 15. WC12S1 vs Reference Sites A) flows; B) and C) flow duration statistics [Q%iles]

Figures B and C (above) show the Q%ile hydrograph for the WC12S1 Assessment Point versus the Q%ile hydrographs for the Reference Sites, O'Hares Creek and WWU. For this assessment 'natural variability' is defined as the range between the Q%ile for the Reference Sites on each day.

Table 18. Flow assessments A, B and C for the sub-catchment to WC12S1

WC12S1	Pre-mining	Post-mining	
	to late LW16	end LW19 + 30 days	
	5/04/2019	19/10/2020	
	18/10/2020	28/04/2023	
Method A:	Assessment of flow variability:		
Period	Compared to Reference Sites, gauge is at: Lower flow (higher Q%ile)		Higher flow (lower Q%ile)
Pre-mining	10%	59%	of the time
Post-mining	5%	62%	of the time
Change	**-5%**	2%	of the time
		Assessment A:	Not triggered
Method B:	Change in cease-to-flow frequency:		
	Cease to flow as % of daily record during	pre- and post- mining periods	
Site	Pre-mining	Post-mining	Change
O'Hares Creek	0.0%	0.0%	0.0%
WWU	11.0%	0.0%	-11.0%
		Average Ref. Site change (= natural variability):	-5.5%
WC12S1	14.7%	0.4%	-14.3%
		no. of cease-to-flow days increased:	**-8.8%**
		Assessment B:	Not triggered
Method C:	Change to median flow (Q50)		
Reference Site Q50 [ML/d]	Q50 (pre-)	Q50 (post-)	% Change
O'Hares Creek	5.05	19.18	280%
WWU	0.23	1.17	404%
Natural variability	Min	Mean	Max
from 2 x Ref. Sites	280%	342%	404%
Assessment Site Q50 [ML/d]	Q50 (pre-)	Q50 (post-)	% Change
WC12S1	0.009	0.068	656%
'Expected' post-mining Q50 at	Min	Mean	Max
WC12S1	0.034	0.040	0.045
Change beyond natural	Min	Mean	Max
% change (of pre-mining Q50)	+375%	**+313%**	+251%
% change (of 'expected' Q50)	99%	**71%**	50%
ML/d change from natural	+0.034	**+0.028**	+0.023
		Assessment C:	Not triggered

5.3.5 WC15S1 – Wongawilli Creek tributary

Longwall 12 came within 100 m of the sub-catchment. Longwall 13 mined within 20 m of this watercourse, and directly under the WC15A tributary). Longwall 14 approached to 40 m. Longwalls 15-17 mined under WC15. Longwall 18 is 170 m away, and Longwall 19 is >550 m away.

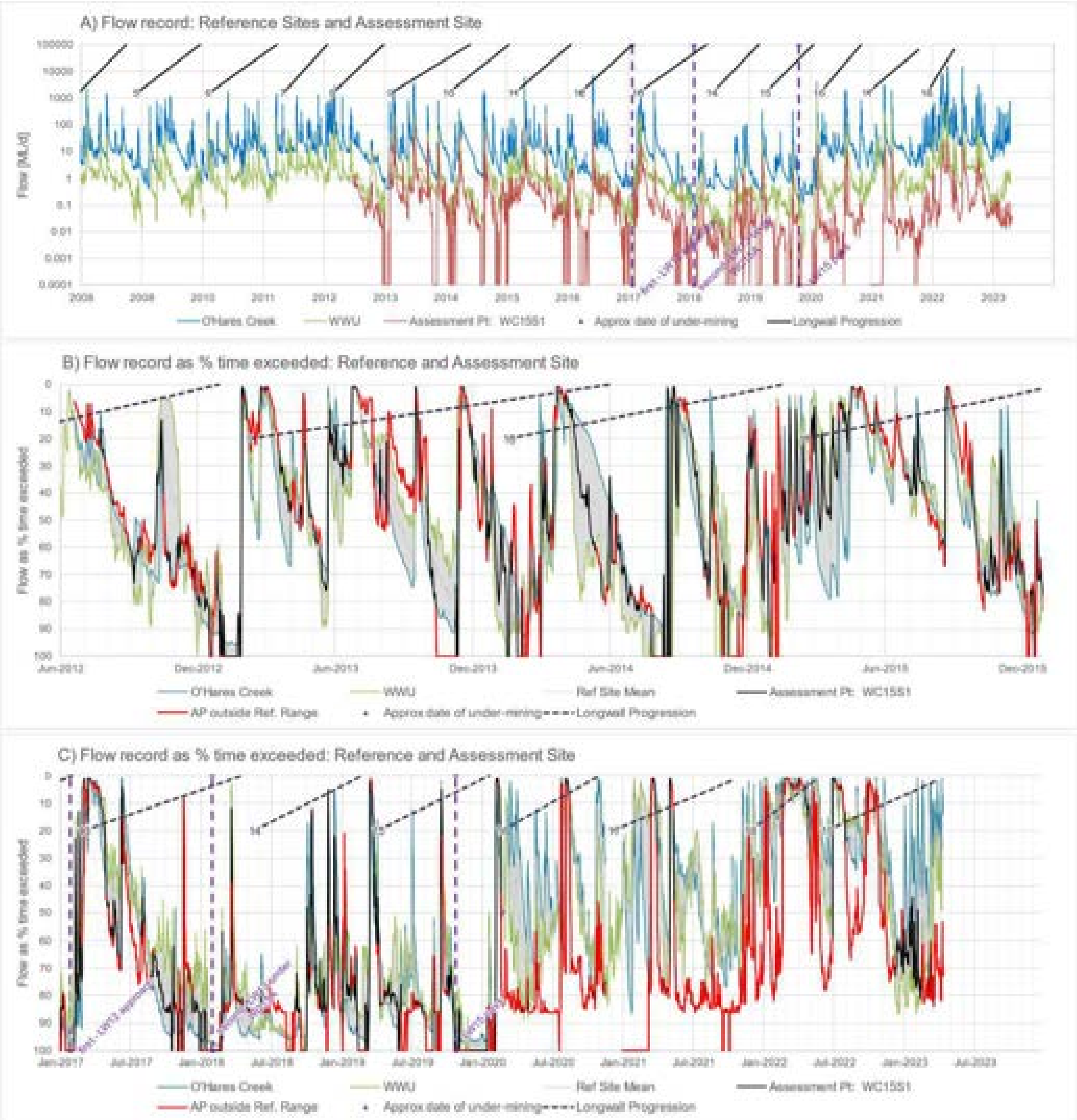


Figure 16. Comparison of WC15S1 against Reference Sites A) flows; B) and C) flow duration statistics [Q%iles]

Figures B and C (above) show the Q%ile hydrograph for the WC15S1 Assessment Point versus the Q%ile hydrographs for the Reference Sites, O'Hares Creek and WWU. For this assessment 'natural variability' is defined as the range between the Q%ile for the Reference Sites on each day.

Table 19. Flow assessments A, B and C for the sub-catchment to WC15S1

WC15s1		Pre-mining	Post-mining	
		to LW12 approach	end LW19 + 30 days	
		20/06/2012	29/01/2017	
		28/01/2017	28/04/2023	
Method A:	Assessment of flow variability:			
Period		Compared to Reference Sites, gauge is at: Lower flow (higher Q%ile)		Higher flow (lower Q%ile)
Pre-mining		21%	39%	of the time
Post-mining		59%	11%	of the time
Change		**38%**	-29%	of the time
			Assessment A:	Level 3
Method B:	Change in cease-to-flow frequency:		(this assessment uses **0.005 ML/d** as 'cease-to-flow')	
		Cease to flow as % of daily record during	pre- and post- mining periods	
Site		Pre-mining	Post-mining	Change
O'Hares Creek		0.0%	4.4%	4.4%
WWU		5.0%	6.4%	1.4%
			Average Ref. Site change (= natural variability):	2.9%
WC15S1		13.0%	26.0%	13.0%
			no. of cease-to-flow days increased:	**10.1%**
			Assessment B:	↑ to Level 2
Method C:	Change to median flow (Q50)			
Reference Site Q50 [ML/d]		Q50 (pre-)	Q50 (post-)	% Change
O'Hares Creek		8.44	8.14	-4%
WWU		0.58	0.42	-27%
Natural variability		Min	Mean	Max
from 2 x Ref. Sites		-27%	-15%	-4%
Assessment Site Q50 [ML/d]		Q50 (pre-)	Q50 (post-)	% Change
WC15s1		0.150	0.023	-85%
'Expected' post-mining Q50 at		Min	Mean	Max
WC15s1		0.109	0.127	0.145
Change beyond natural		Min	Mean	Max
% change (of pre-mining Q50)		-57.3%	**-69.2%**	-81.1%
% change (of 'expected' Q50)		-79%	**-82%**	-84%
ML/d change from natural		-0.086	**-0.104**	-0.122
			Assessment C:	Level 3

5.3.6 WC21S1 – Wongawilli Creek tributary

WC21, a tributary to Wongawilli Creek, was mined under late in Longwall 9, and has since been mined under by Longwalls 10-15. Longwalls 16-18 are located south of this sub-catchment, and Longwall 19 is 1.5 km to the east. A period of data in 2022 is missing, but the logger is now replaced.

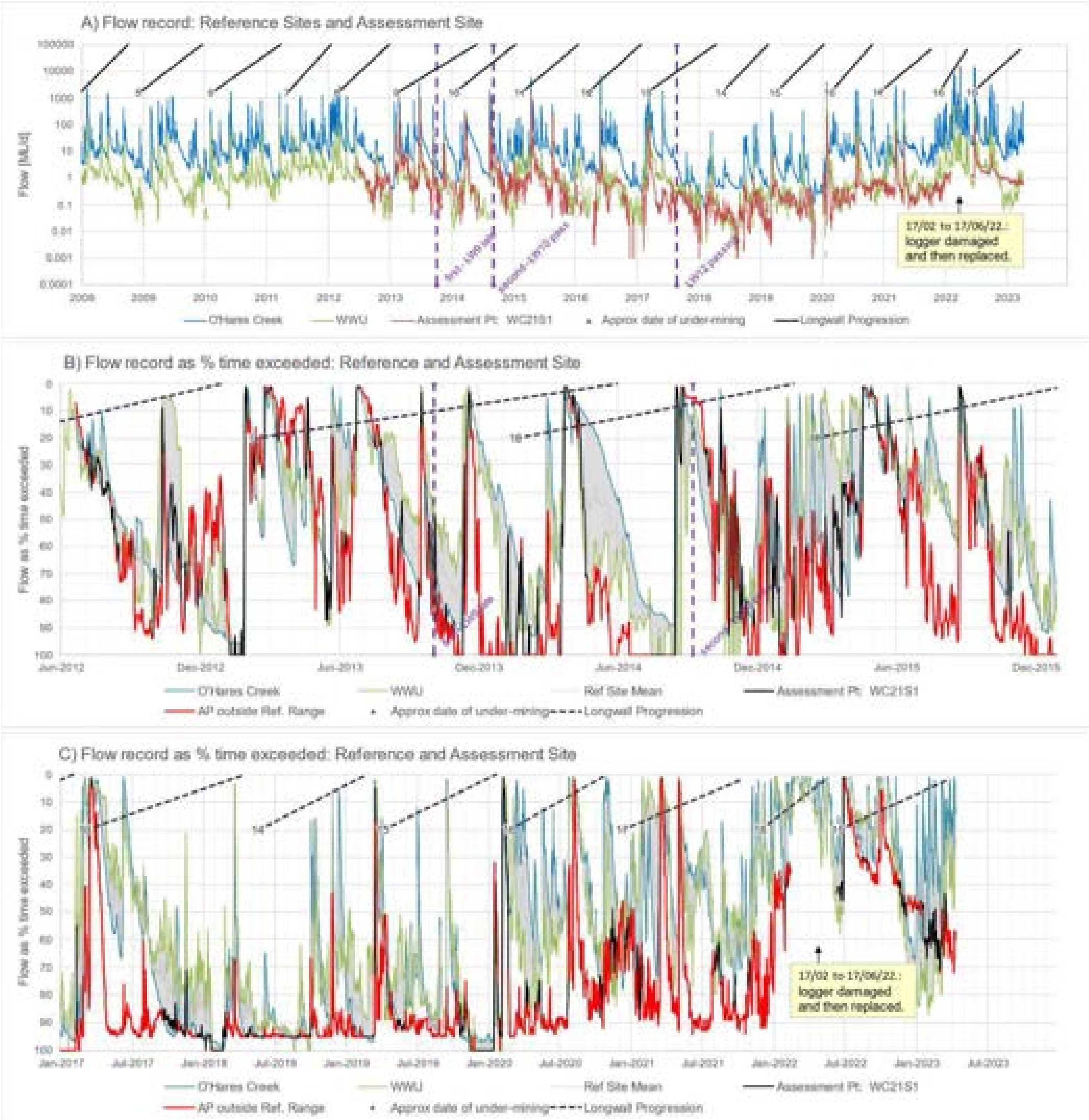


Figure 17. WC21S1 vs Reference Sites A) flows; B) and C) flow duration statistics [Q%iles]

Figures B and C show the Q%ile hydrograph for the WC21S1 Assessment Point versus the Q%ile hydrographs for the Reference Sites, O'Hares Creek and WWU. For this assessment 'natural variability' is defined as the range between the Q%ile for the Reference Sites on each day.

Table 20. Flow assessments A, B and C for the sub-catchment to WC21S1

WC21S1		Pre-mining	Post-mining	
		to LW9 late	end LW19 + 30 days	
		20/06/2012	6/10/2013	
		5/10/2013	28/04/2023	
Method A:	Assessment of flow variability:			
Period	Compared to Reference Sites, gauge is at: Lower flow (higher Q%ile)		Higher flow (lower Q%ile)	
Pre-mining		38%	36%	of the time
Post-mining		71%	6%	of the time
Change		**33%**	-30%	of the time
			Assessment A:	Level 3
Method B:	Change in cease-to-flow frequency:			
	Cease to flow as % of daily record during		pre- and post- mining periods	
Site		Pre-mining	Post-mining	Change
O'Hares Creek		0.0%	0.0%	0.0%
WWU		4.9%	4.5%	0.3%
			Average Ref. Site change (= natural variability):	-0.2%
WC21S1		3.6%	12.4%	8.8%
			no. of cease-to-flow days increased:	9.0%
			Assessment B:	Level 1
Method C:	Change to median flow (Q50)			
Reference Site Q50 [ML/d]		Q50 (pre-)	Q50 (post-)	% Change
O'Hares Creek		8.86	7.62	-14%
WWU		0.90	0.41	-55%
Natural variability		Min	Mean	Max
from 2 x Ref. Sites		-55%	-34%	-14%
Assessment Site Q50 [ML/d]		Q50 (pre-)	Q50 (post-)	% Change
WC21S1		0.960	0.255	-73%
'Expected' post-mining Q50 at		Min	Mean	Max
WC21S1		0.435	0.630	0.825
Change beyond natural		Min	Mean	Max
% change (of pre-mining Q50)		-18.8%	**-39.1%**	-59.4%
% change (of 'expected' Q50)		-41%	**-60%**	-69%
ML/d change from natural		-0.180	**-0.375**	-0.570
			Assessment C:	Level 3

Note: The rating curve at this site has been revised recently, resulting in significantly higher flows (pre- and post-mining), and therefore greater losses (in ML/d) at median flow. Watershed HydroGeo considers the revised flows too high, on a flow per catchment area (i.e. mm/d/m^2) basis, compared to other sites in this area.

5.3.7 WWL – Wongawilli Creek (lower)

Wongawilli Creek lies between Areas 3A and 3B. The watercourse is not directly mined under by longwalls, but some of its tributaries (e.g. WC21, WC15 etc.) have been mined under by Area 3A and 3B longwalls 6-17 and recently by Longwall 19. Watercourse impacts, e.g. cracking at a single pool, have been identified in the past. Longwall 18 is outside the catchment to WWL.

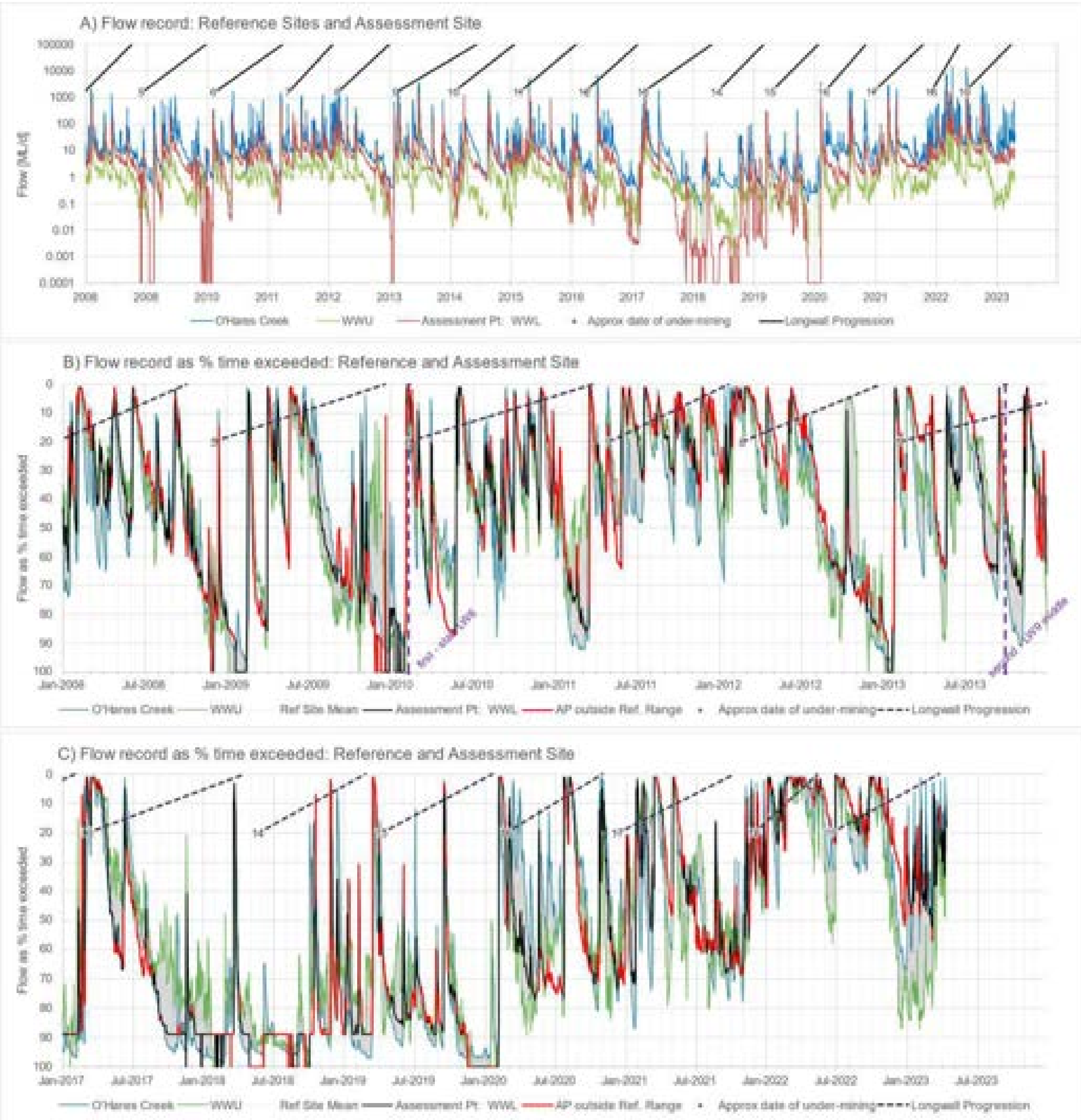


Figure 18. WWL vs Reference Sites A) flows; B) and C) flow duration statistics [Q%iles]

Figures B and C (above) show the Q%ile hydrograph for the WWL Assessment Point versus the Q%ile hydrographs for the Reference Sites, O'Hares Creek and WWU. For this assessment 'natural variability' is defined as the range between the Q%ile for the Reference Sites on each day.

Table 21. Flow assessments A, B and C for the sub-catchment to WWL

WWL	Pre-mining	Post-mining	
	to start LW6	end LW19 + 30 days	
	1/01/2008	10/02/2010	
	9/02/2010	28/04/2023	
Method A:	Assessment of flow variability:		
Period	Compared to Reference Sites, gauge is at: Lower flow (higher Q%ile)		Higher flow (lower Q%ile)
Pre-mining	18%	29%	of the time
Post-mining	18%	37%	of the time
Change	**0%**	9%	of the time
		Assessment A:	Not triggered
Method B:	Change in cease-to-flow frequency:		
	Cease to flow as % of daily record during	pre- and post- mining periods	
Site	Pre-mining	Post-mining	Change
O'Hares Creek	0.0%	0.0%	0.0%
WWU	9.7%	3.7%	-6.0%
		Average Ref. Site change (= natural variability):	-3.0%
WWL	9.1%	3.6%	-5.5%
		no. of cease-to-flow days increased:	**-2.5%**
		Assessment B:	Not triggered
Method C:	Change to median flow (Q50)		
Reference Site Q50 [ML/d]	Q50 (pre-)	Q50 (post-)	% Change
O'Hares Creek	9.50	10.08	+6%
WWU	0.75	0.66	-11%
Natural variability	Min	Mean	Max
from 2 x Ref. Sites	-11%	-3%	+6%
Assessment Site Q50 [ML/d]	Q50 (pre-)	Q50 (post-)	% Change
WWL	3.372	3.552	+6%
'Expected' post-mining Q50 at	Min	Mean	Max
WWL	2.988	3.283	3.579
Change beyond natural	Min	Mean	Max
% change (of pre-mining Q50)	+16.7%	**+8.0%**	-0.8%
% change (of 'expected' Q50)	19%	**8%**	-1%
ML/d change from natural	+0.564	**+0.269**	-0.027
		Assessment C:	Not triggered

5.3.8 LA4S1 – Lake Avon tributary

LA4, a tributary to Lake Avon, lies above the western ends of Longwalls 11-14, but was not mined under by Longwalls 15-18. Longwall 19 is 2 km away. The gauging site was directly impacted by Longwall 13 with fracturing and flow diversion.

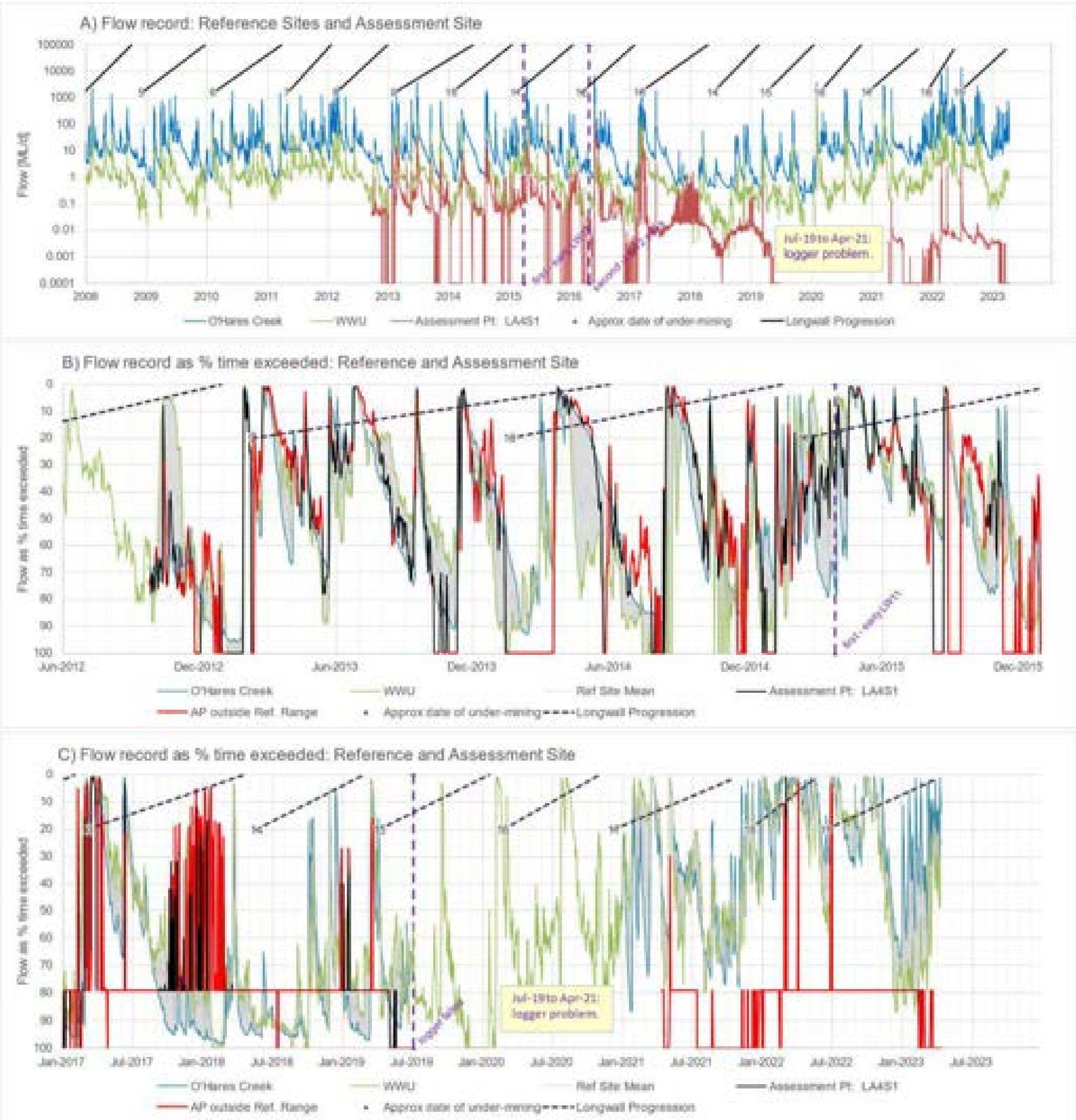


Figure 19. Comparison of LA4S1 against Reference Sites A) flows; B) and C) flow duration statistics [Q%iles]

Figures B and C show the Q%ile hydrograph for the LA4S1 Assessment Point versus the Q%ile hydrographs for the Reference Sites, O'Hares Creek and WWU. For this assessment 'natural variability' is defined as the range between the Q%ile for the Reference Sites on each day.

Table 22. Flow assessments A, B and C for the sub-catchment to LA4S1

LA4S1		Pre-mining	Post-mining	
		to early LW11	end LW19 + 30 days	
		24/09/2012	2/04/2015	
		1/04/2015	28/04/2023	
Method A:	Assessment of flow variability:			
Period		Compared to Reference Sites, gauge is at: Lower flow (higher Q%ile)		Higher flow (lower Q%ile)
Pre-mining		26%	32%	of the time
Post-mining		56%	24%	of the time
Change		**+31%**	-8%	of the time
			Assessment A:	Level 3
Method B:	Change in cease-to-flow frequency:		**(this assessment uses 0.02 ML/d as 'cease-to-flow')**	
		Cease to flow as % of daily record during	pre- and post- mining periods	
Site		Pre-mining	Post-mining	Change
O'Hares Creek		14.5%	21.1%	+6.6%
WWU		19.6%	10.4%	-9.2%
			Average Ref. Site change (= natural variability):	-0.9%
LA4S1		19.1%	54.8%	35.6%
			no. of cease-to-flow days increased:	**+36.9%**
			Assessment B:	Level 3
Method C:	Change to median flow (Q50)			
Reference Site Q50 [ML/d]		Q50 (pre-)	Q50 (post-)	% Change
O'Hares Creek		7.71	8.13	+5%
WWU		0.58	0.47	-19%
Natural variability		Min	Mean	Max
from 2 x Ref. Sites		-19%	-7%	+5%
Assessment Site Q50 [ML/d]		Q50 (pre-)	Q50 (post-)	% Change
LA4S1		0.081	0.008	-90%
'Expected' post-mining Q50 at		Min	Mean	Max
LA4S1		0.066	0.076	0.085
Change beyond natural		Min	Mean	Max
% change (of pre-mining Q50)		-71.3%	**-83.5%**	-95.6%
% change (of 'expected' Q50)		-88%	**-89%**	-91%
ML/d change from natural		-0.058	**-0.068**	-0.077
			Assessment C:	Level 3

5.3.9 LA3S1 – Lake Avon tributary

LA3 is a tributary to Lake Avon. Longwalls 15-16 mined close to this watercourse , while Longwall 17 was 250 m away, and Longwalls 18-19 did not mine under this catchment. The pre-mining baseline period is only 2 months (Table C4, Appendix C), and so the statistical assessment of impacts is considered somewhat unreliable, however mining effects on flows are obvious.

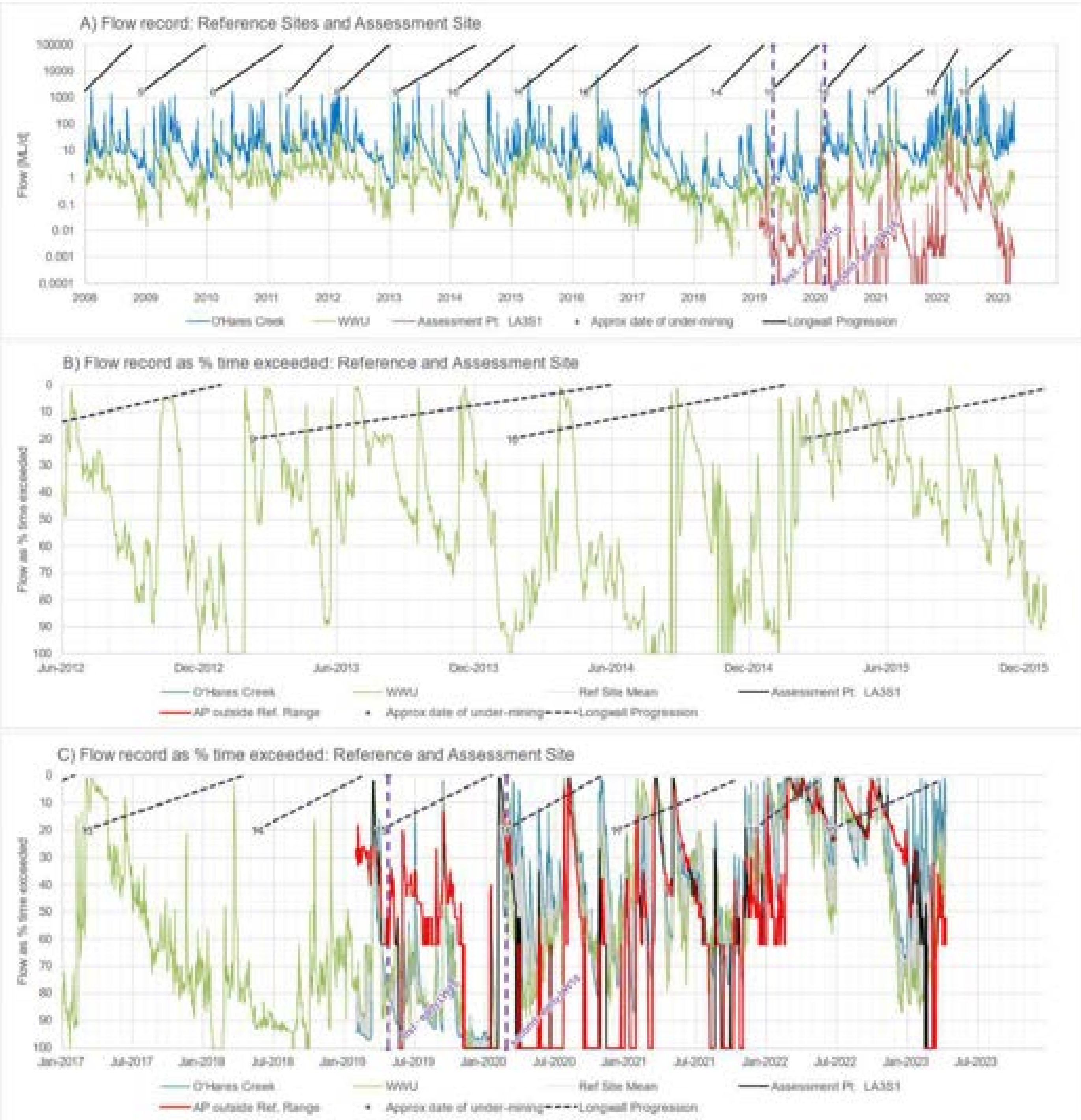


Figure 20. LA3S1 vs Reference Sites A) flows; B) and C) flow duration statistics [Q%iles]

Figures B and C (above) show the Q%ile hydrograph for the LA3S1 Assessment Point versus the Q%ile hydrographs for the Reference Sites, O'Hares Creek and WWU. For this assessment 'natural variability' is defined as the range between the Q%ile for the Reference Sites on each day.

Table 23. Flow assessments A, B and C for the sub-catchment to LA3S1

LA3S1		Pre-mining	Post-mining	
		to early LW15	end LW19 + 30 days	
		3/02/2019	29/04/2019	
		28/04/2019	28/04/2023	
Method A:	Assessment of flow variability:			
Period	Compared to Reference Sites, gauge is at: Lower flow (higher Q%ile)			Higher flow (lower Q%ile)
Pre-mining	2%		78%	of the time
Post-mining	48%		30%	of the time
Change	**45%**		-47%	of the time
			Assessment A:	Level 3
Method B:	Change in cease-to-flow frequency:			
	Cease to flow as % of daily record during		pre- and post- mining periods	
Site	Pre-mining		Post-mining	Change
O'Hares Creek	0.0%		0.0%	0.0%
WWU	0.0%		4.2%	+4.2%
	Average Ref. Site change (= natural variability):			+2.7%
LA3S1	0.0%		26.9%	+26.9%
	no. of cease-to-flow days increased:			**+24.8%**
			Assessment B:	Level 3
Method C:	Change to median flow (Q50)			
Reference Site Q50 [ML/d]		Q50 (pre-)	Q50 (post-)	% Change
O'Hares Creek		2.20	14.17	+545%
WWU		0.21	0.61	+191%
Natural variability		Min	Mean	Max
from 2 x Ref. Sites		+191%	+368%	+545%
Assessment Site Q50 [ML/d]		Q50 (pre-)	Q50 (post-)	% Change
LA3S1		0.015	0.003	-80%
'Expected' post-mining Q50 at		Min	Mean	Max
LA3S1		0.044	0.070	0.097
Change beyond natural		Min	Mean	Max
% change (of pre-mining Q50)		-270.7%	**-448%**	-624.8%
% change (of 'expected' Q50)		-93%	**-96%**	-97%
ML/d change from natural		-0.041	**-0.067**	-0.094
			Assessment C:	Level 3

5.3.10 LA2S1 – Lake Avon tributary

Longwall 15 approached within approximately 160 m of LA2. Longwalls 16-17 mined beneath LA2. Longwall 18 passed approximately 100 m south of LA2. Longwall 19 is 2 km distant.

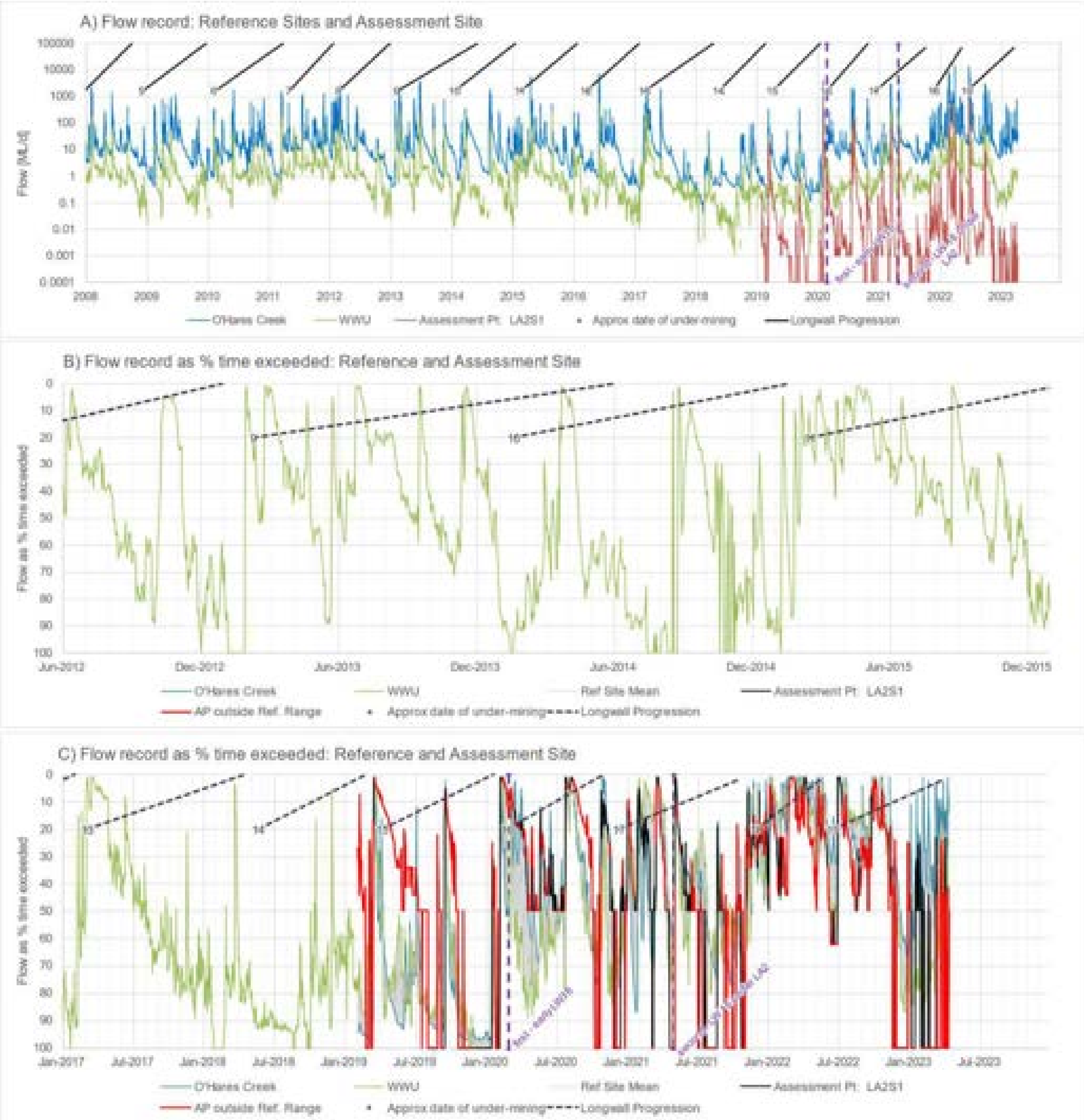


Figure 21. LA2S1 vs Reference Sites A) flows; B) and C) flow duration statistics [Q%iles]

Figures B and C (above) show the Q%ile hydrograph for the LA2S1 Assessment Point versus the Q%ile hydrographs for the Reference Sites, O'Hares Creek and WWU. For this assessment 'natural variability' is defined as the range between the Q%ile for the Reference Sites on each day.

Table 24. Flow assessments A, B and C for the sub-catchment to LA2S1

LA2S1		Pre-mining	Post-mining	
		to early LW16	end LW19 + 30 days	
		4/02/2019	2/03/2020	
		1/03/2020	28/04/2023	
Method A:	Assessment of flow variability:			
Period	Compared to Reference Sites, gauge is at: Lower flow (higher Q%ile)		Higher flow (lower Q%ile)	
Pre-mining	22%		60%	of the time
Post-mining	48%		24%	of the time
Change	**+26%**		-35%	of the time
			Assessment A:	↑ to Level 3
Method B:	Change in cease-to-flow frequency:		(this assessment uses **0.005 ML/d** as 'cease-to-flow')	
	Cease to flow as % of daily record during		pre- and post- mining periods	
Site	Pre-mining		Post-mining	Change
O'Hares Creek	21.2%		0.0%	-21.2%
WWU	19.1%		0.0%	-19.1%
	Average Ref. Site change (= natural variability):			-10.6%
LA2S1	68.4%		55.0%	-13.4%
	no. of cease-to-flow days increased:			**+6.8%**
			Assessment B:	Level 1
Method C:	Change to median flow (Q50)			
Reference Site Q50 [ML/d]		Q50 (pre-)	Q50 (post-)	% Change
O'Hares Creek		1.25	18.21	1352%
WWU		0.14	0.90	550%
Natural variability		Min	Mean	Max
from 2 x Ref. Sites		550%	951%	1352%
Assessment Site Q50 [ML/d]		Q50 (pre-)	Q50 (post-)	% Change
LA2S1		0.002	0.004	100%
'Expected' post-mining Q50 at		Min	Mean	Max
LA2S1		0.013	0.021	0.029
Change beyond natural		Min	Mean	Max
% change (of pre-mining Q50)		-450%	**-851%**	-1252%
% change (of 'expected' Q50)		-69%	**-81%**	-86%
ML/d change from natural		-0.009	**-0.017**	-0.025
			Assessment C:	Level 3

5.3.11 ND1 – Native Dog Creek tributary

ND1 is a tributary to Native Dog Creek, which flows into Lake Avon. Some Elouera Colliery longwalls are this sub-catchment. Longwall 17 mined under the northern edge of this sub-catchment. Longwall 18 mined under the headwaters of ND1 and tributary ND1C. Longwall 19 is 2 km to the northeast.

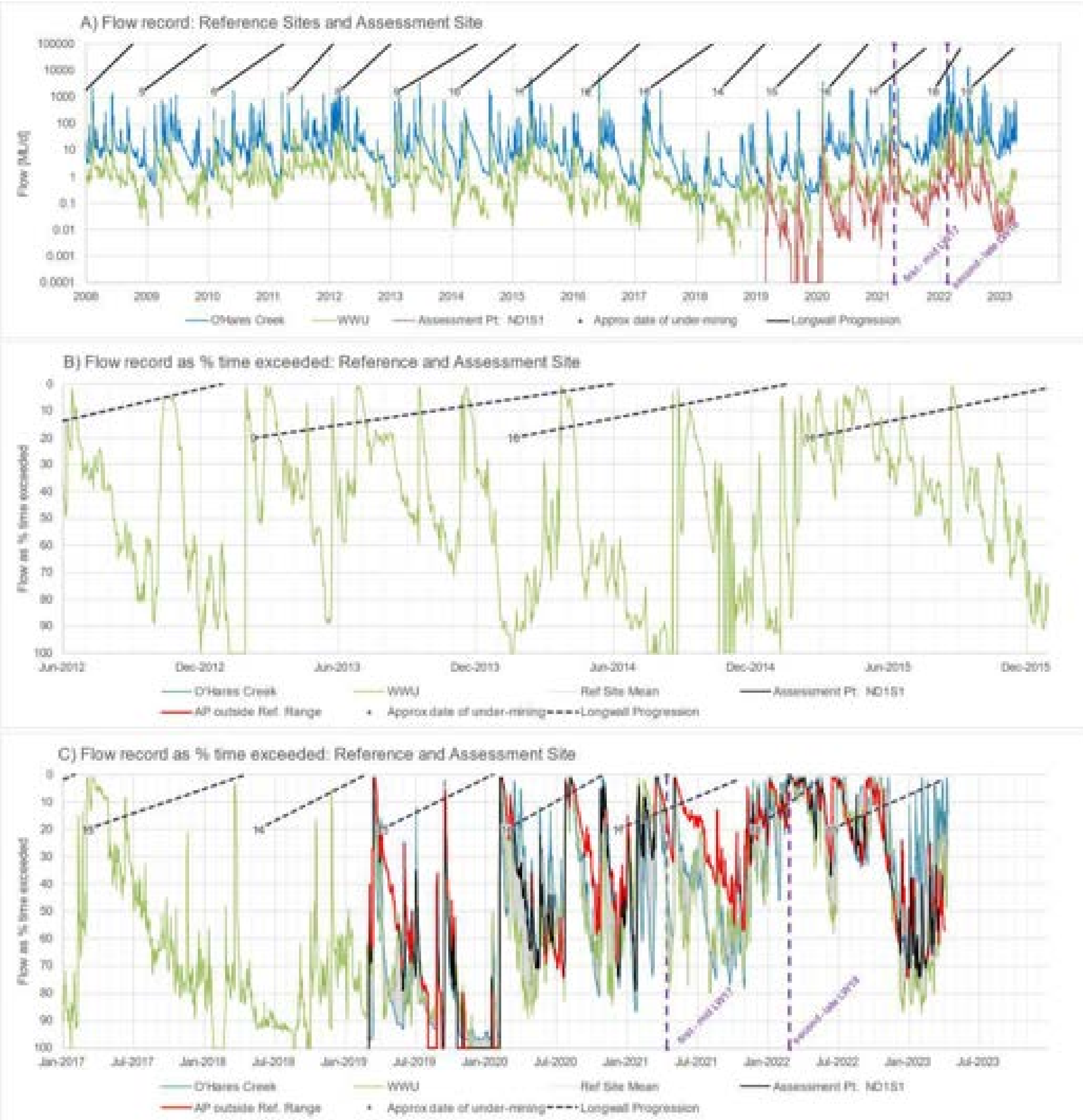


Figure 22. ND1 vs Reference Sites A) flows; B) and C) flow duration statistics [Q%iles]

Figures B and C (above) show the Q%ile hydrograph for the ND1S1 Assessment Point versus the Q%ile hydrographs for the Reference Sites, O'Hares Creek and WWU. For this assessment 'natural variability' is defined as the range between the Q%ile for the Reference Sites on each day.

Table 25. Flow assessments A, B and C for the sub-catchment to ND1S1

ND1S1		Pre-mining	Post-mining	
		to mid LW17	end LW19 + 30 days	
		3/03/2019	19/04/2021	
		18/04/2021	28/04/2023	
Method A:	Assessment of flow variability:			
Period	Compared to Reference Sites, gauge is at: Lower flow (higher Q%ile)			Higher flow (lower Q%ile)
Pre-mining	17%		38%	of the time
Post-mining	18%		52%	of the time
Change	**+1%**		+14%	of the time
			Assessment A:	Not triggered

Method B:	Change in cease-to-flow frequency:		
	Cease to flow as % of daily record during	pre- and post- mining periods	
Site	Pre-mining	Post-mining	Change
O'Hares Creek	0.0%	0.0%	0.0%
WWU	8.0%	0.0%	-8.0%
		Average Ref. Site change (= natural variability):	-4.0%
ND1S1	17.5%	0.0%	-17.5%
		no. of cease-to-flow days increased:	**-13.5%**
		Assessment B:	Not triggered

Method C:	Change to median flow (Q50)		
Reference Site Q50 [ML/d]	Q50 (pre-)	Q50 (post-)	% Change
O'Hares Creek	6.99	21.15	202%
WWU	0.36	1.17	226%
Natural variability	Min	Mean	Max
from 2 x Ref. Sites	202%	214%	226%
Assessment Site Q50 [ML/d]	Q50 (pre-)	Q50 (post-)	% Change
ND1S2	0.023	0.280	1115%
'Expected' post-mining Q50 at	Min	Mean	Max
ND1S2	0.070	0.072	0.075
Change beyond natural	Min	Mean	Max
% change (of pre-mining Q50)	615%	**603%**	591%
% change (of 'expected' Q50)	203%	**192%**	181%
ML/d change from natural	+0.141	**+0.139**	+0.136
		Assessment C:	Not triggered

5.3.12 NDCS1 – Native Dog Creek

NDC is Native Dog Creek, which flows into Lake Avon. Elouera Colliery longwalls directly mined under this watercourse between 1994-2007. Dendrobium Longwall 17 mined near the northern edge of tributary ND1 catchment, and. Longwall 18 mined under the headwaters of ND1 and tributary ND1C. Longwall 19 is 2 km to the northeast.

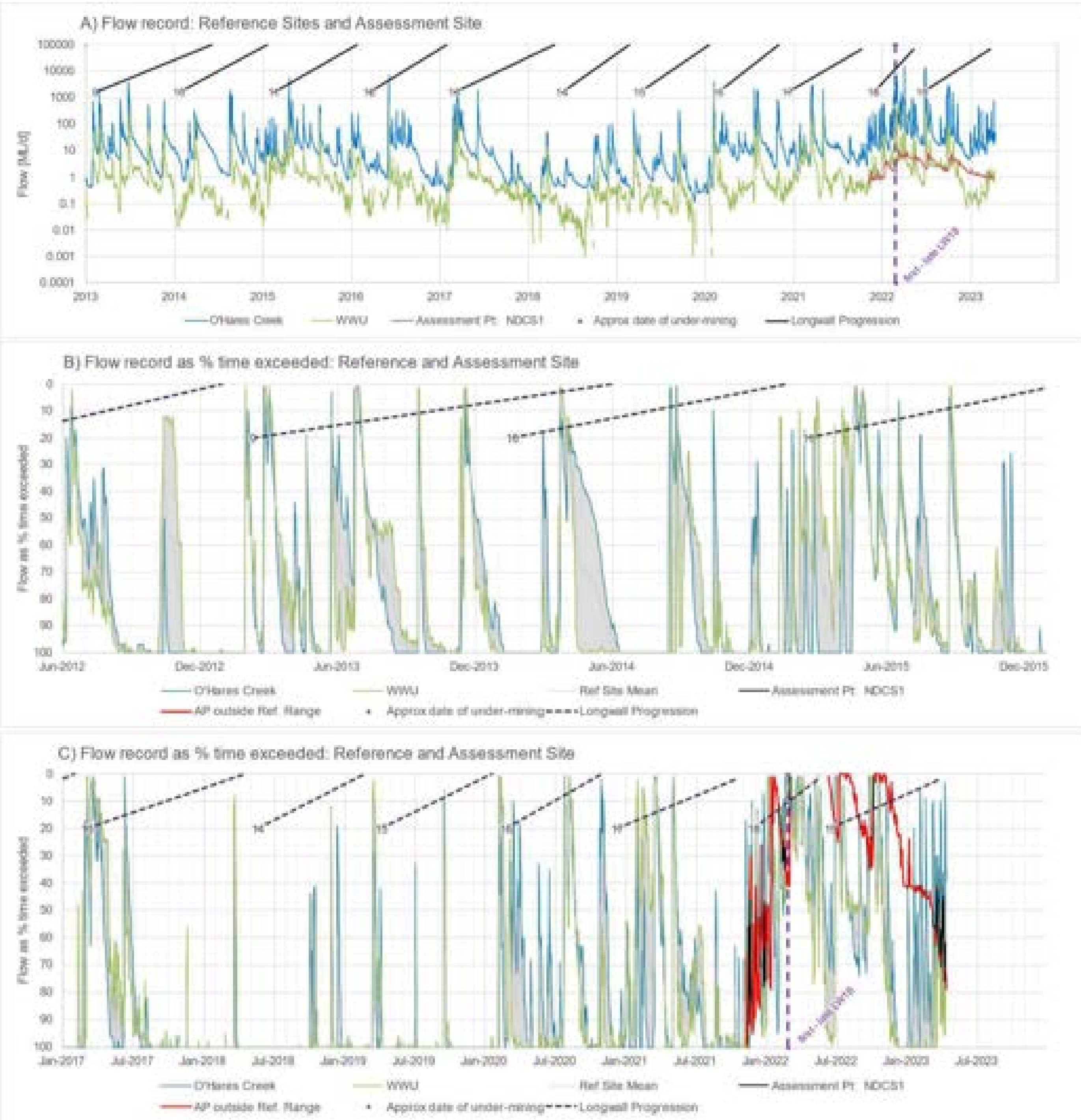


Figure 23. NDCS1 vs Reference Sites A) flows; B) and C) flow duration statistics [Q%iles]

Figures B and C (above) show the Q%ile hydrograph for the ND1S1 Assessment Point versus the Q%ile hydrographs for the Reference Sites, O'Hares Creek and WWU. For this assessment 'natural variability' is defined as the range between the Q%ile for the Reference Sites on each day.

The pre-mining period (if using Longwall 18, rather than Longwall 17, as the first significant Dendrobium-related stress in this catchment) is only 90 days, and so analysis is not fully reliable.

Table 26. Flow assessments A, B and C for the sub-catchment to NDCS1

NDCS1	Pre-mining	Post-mining	
	to late LW18*	end LW19 + 30days	
	14/11/2021	2/03/2022	
	1/03/2022	28/04/2023	
Method A:	Assessment of flow variability:		
Period	Compared to Reference Sites, gauge is at: Lower flow (higher Q%ile)		Higher flow (lower Q%ile)
Pre-mining	35%	43%	of the time
Post-mining	10%	77%	of the time
Change	**-25%**	34%	of the time
		Assessment A:	Not triggered
Method B:	Change in cease-to-flow frequency:		
	Cease to flow as % of daily record during	pre- and post- mining periods	
Site	Pre-mining	Post-mining	Change
O'Hares Creek	0.0%	0.0%	0.0%
WWU	0.0%	0.0%	0.0%
		Average Ref. Site change (= natural variability):	0.0%
NDCS1	0.0%	0.0%	0.0%
		no. of cease-to-flow days increased:	**0%**
		Assessment B:	Not triggered
Method C:	Change to median flow (Q50)		
Reference Site Q50 [ML/d]	Q50 (pre-)	Q50 (post-)	% Change
O'Hares Creek	30.40	35.21	+16%
WWU	2.69	1.87	-30%
Natural variability	Min	Mean	Max
from 2 x Ref. Sites	-30%	-7%	16%
Assessment Site Q50 [ML/d]	Q50 (pre-)	Q50 (post-)	% Change
NDCS1	1.050	2.791	166%
'Expected' post-mining Q50 at	Min	Mean	Max
NDCS1	0.731	0.973	1.216
Change beyond natural	Min	Mean	Max
% change (of pre-mining Q50)	+196.2%	+173.1%	+150.0%
% change (of 'expected' Q50)	+282%	**+187%**	+130%
ML/d change from natural	+2.060	+1.818	+1.575
		Assessment C:	Not triggered

5.3.13 SC10C – Sandy Creek minor tributary

SC10C is a minor tributary to Sandy Creek, which flows into Lake Cordeaux. Area 3A longwalls 7 and 8 mined beneath this watercourse, while Longwall 19 approach to within 250-300 m of (previous mined-under sections of SC10C.

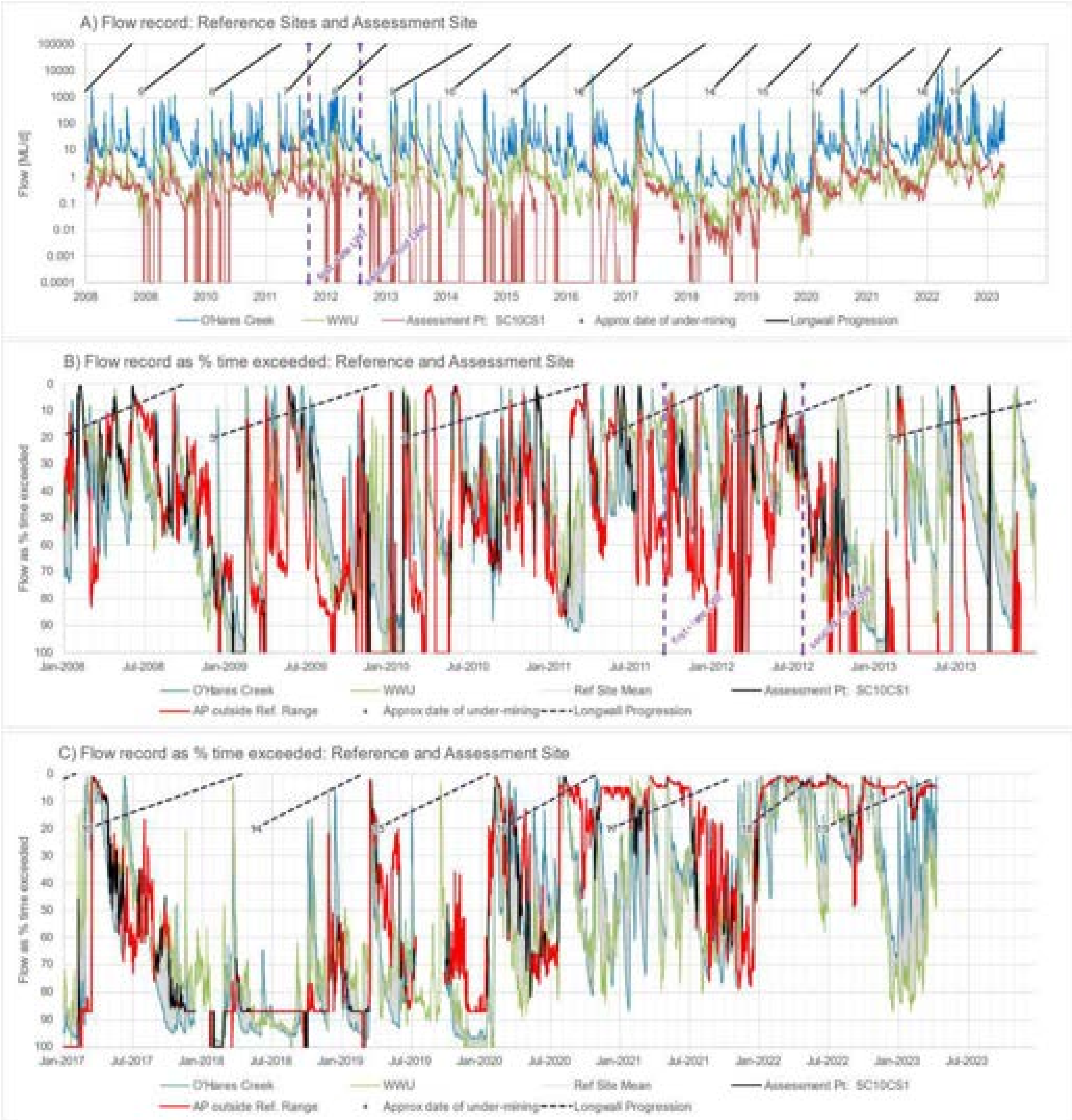


Figure 24. SC10C vs Reference Sites A) flows; B) and C) flow duration statistics [Q%iles]

Figures B and C (above) show the Q%ile hydrograph for the SC10CS1 Assessment Point versus the Q%ile hydrographs for the Reference Sites, O'Hares Creek and WWU. For this assessment 'natural variability' is defined as the range between the Q%ile for the Reference Sites on each day.

Table 27. Flow assessments A, B and C for the sub-catchment to SC10C

SC10CS1	Pre-mining	Post-mining	
	to late LW7	end LW19 + 30 days	
	1/01/2008	18/09/2011	
	17/09/2011	28/04/2023	
Method A:	**Assessment of flow variability:**		
Period	Compared to Reference Sites, gauge is at: Lower flow (higher Q%ile)		Higher flow (lower Q%ile)
Pre-mining	49%	24%	of the time
Post-mining	48%	32%	of the time
Change	**-1%**	8%	of the time
		Assessment A:	Not triggered
Method B:	**Change in cease-to-flow frequency:**		
	Cease to flow as % of daily record during	pre- and post- mining periods	
Site	Pre-mining	Post-mining	Change
O'Hares Creek	0.0%	0.0%	0.0%
WWU	5.5%	4.3%	-1.3%
		Average Ref. Site change (= natural variability):	-0.6%
SC10CS1	11.8%	28.4%	16.6%
		no. of cease-to-flow days increased:	**17.3%**
		Assessment B:	Level 2
Method C:	**Change to median flow (Q50)**		
Reference Site Q50 [ML/d]	Q50 (pre-)	Q50 (post-)	% Change
O'Hares Creek	11.18	9.52	-15%
WWU	0.94	0.58	-38%
Natural variability	Min	Mean	Max
from 2 x Ref. Sites	-38%	-27%	-15%
Assessment Site Q50 [ML/d]	Q50 (pre-)	Q50 (post-)	% Change
SC10CS1	0.379	0.195	-49%
'Expected' post-mining Q50 at	Min	Mean	Max
SC10CS1	0.234	0.278	0.323
Change beyond natural	Min	Mean	Max
% change (of pre-mining Q50)	-10.2%	-22%	-33.7%
% change (of 'expected' Q50)	-17%	-30%	-40%
ML/d change from natural	-0.039	-0.083	-0.128
		Assessment C:	Level 3

Interestingly, at this site, if considering the period from Jan-2017 to now, the Assessments presented above are all 'Not triggered', which is consistent with the hydrograph shown in Figure A above. This is consistent with recovery of groundwater levels and the emergence of iron-staining in this watercourse, even accounting for the recent extraction of Longwall 19.

5.3.14 SC10 – Sandy Creek tributary

SC10 is a tributary to Sandy Creek, which flows into Lake Cordeaux. Longwalls 7-8 mined beneath this catchment, and the south-eastern corner of Longwall 8 mined beneath the watercourse. Longwall 19 mined within 40 m of this watercourse. The control changed at this site (Dec-2021) and then due to heavy rainfall, this upgrade was not completed; therefore, recent data may not be completely reliable.

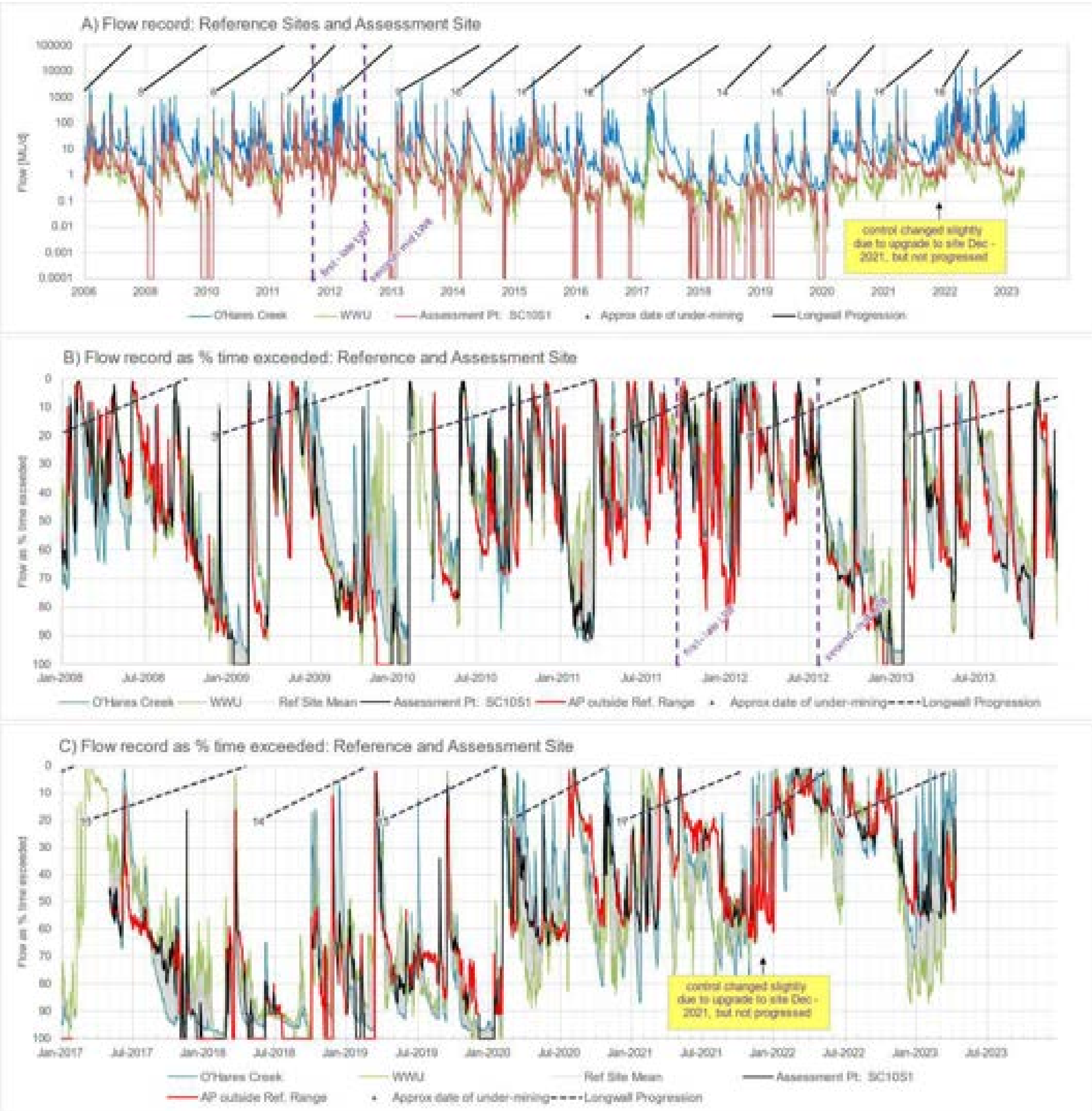


Figure 25. SC10 vs Reference Sites A) flows; B) and C) flow duration statistics [Q%iles]

Figures B and C (above) show the Q%ile hydrograph for the SC10S1 Assessment Point versus the Q%ile hydrographs for the Reference Sites, O'Hares Creek and WWU. For this assessment 'natural variability' is defined as the range between the Q%ile for the Reference Sites on each day.

Table 28. Flow assessments A, B and C for the sub-catchment SC10

SC10S1		Pre-mining	Post-mining	
		to late LW7	end LW19 + 30 days	
		1/01/2008	18/09/2011	
		17/09/2011	28/04/2023	
Method A:	Assessment of flow variability:			
Period	Compared to Reference Sites, gauge is at: Lower flow (higher Q%ile)			Higher flow (lower Q%ile)
Pre-mining	40%		17%	of the time
Post-mining	40%		19%	of the time
Change	**+1%**		2%	of the time
			Assessment A:	Not triggered

Method B:	Change in cease-to-flow frequency:		
	Cease to flow as % of daily record during	pre- and post- mining periods	
Site	Pre-mining	Post-mining	Change
O'Hares Creek	0.0%	0.0%	0.0%
WWU	5.7%	4.3%	-1.4%
	Average Ref. Site change (= natural variability):		-0.7%
SC10S1	7.0%	10.4%	3.4%
	no. of cease-to-flow days increased:		**+4.1%**
		Assessment B:	Not triggered

Method C:	Change to median flow (Q50)		
Reference Site Q50 [ML/d]	Q50 (pre-)	Q50 (post-)	% Change
O'Hares Creek	11.27	8.96	-21%
WWU	0.93	0.52	-44%
Natural variability	Min	Mean	Max
from 2 x Ref. Sites	-44%	-32%	-21%
Assessment Site Q50 [ML/d]	Q50 (pre-)	Q50 (post-)	% Change
SC10S1	1.254	0.812	-35%
'Expected' post-mining Q50 at	Min	Mean	Max
SC10S1S	0.703	0.850	0.996
Change beyond natural	Min	Mean	Max
% change (of pre-mining Q50)	+8.7%	**-3.0%**	-14.7%
% change (of 'expected' Q50)	+15.4%	**-4.4%**	-18.5%
ML/d change from natural	+0.109	**-0.038**	-0.184
		Assessment C:	Not triggered

5.3.15 SCL2 / 2122205 – Sandy Creek

Sandy Creek flows into Lake Cordeaux near Area 3A. Area 2 Longwall 5 mined along the eastern edge of this catchment, while Area 3A Longwalls 7-8 mined beneath this catchment, as did Longwall 19. All these longwalls were at least 400 m from the watercourse (but closer to tributaries, e.g. SC10).

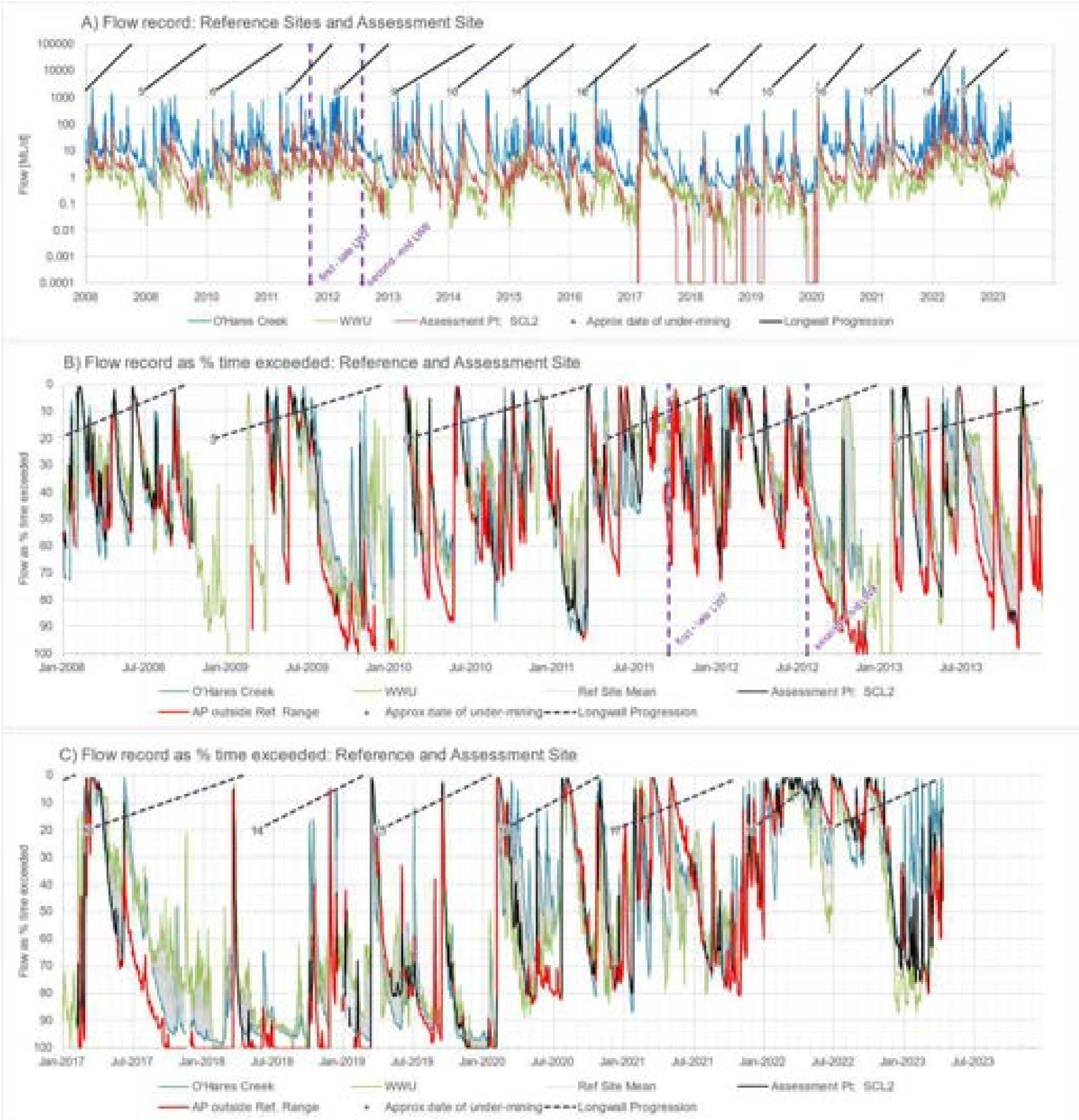


Figure 26. SCL2/2122205 vs Reference Sites A) flows; B) and C) flow duration statistics [Q%iles]

Figures 26B and 26C show the Q%ile hydrograph for the Sandy Creek Assessment Point versus the Q%ile hydrographs for the Reference Sites, O'Hares Creek and WWU. For this assessment 'natural variability' is defined as the range between the Q%ile for the Reference Sites on each day.

Table 29. Flow assessments A, B and C for the sub-catchment to SCL2/2122205

SCL2		Pre-mining	Post-mining	
		to late LW7	end LW19 + 30 days	
		1/01/2008	18/09/2011	
		17/09/2011	28/04/2023	
Method A:	Assessment of flow variability:			
Period	Compared to Reference Sites, gauge is at: Lower flow (higher Q%ile)			Higher flow (lower Q%ile)
Pre-mining		56%	9%	of the time
Post-mining		53%	13%	of the time
Change		**-3%**	4%	of the time
			Assessment A:	Not triggered
Method B:	Change in cease-to-flow frequency:			
		Cease to flow as % of daily record during	pre- and post- mining periods	
Site		Pre-mining	Post-mining	Change
O'Hares Creek		0.0%	0.0%	0.0%
WWU		0.3%	3.6%	+3.3%
			Average Ref. Site change (= natural variability):	+1.6%
GS 2122205		0.0%	7.7%	+7.7%
			no. of cease-to-flow days increased:	**+6.0%**
			Assessment B:	Level 1
Method C:	Change to median flow (Q50)			
Reference Site Q50 [ML/d]		Q50 (pre-)	Q50 (post-)	% Change
O'Hares Creek		12.68	10.09	-20%
WWU		0.98	0.61	-38%
Natural variability		Min	Mean	Max
from 2 x Ref. Sites		-38%	-29%	-20%
Assessment Site Q50 [ML/d]		Q50 (pre-)	Q50 (post-)	% Change
SCL2		2.168	1.518	-30%
'Expected' post-mining Q50 at		Min	Mean	Max
SCL2		1.346	1.535	1.725
Change beyond natural		Min	Mean	Max
% change (of pre-mining Q50)		+7.9%	**-0.8%**	-9.6%
% change (of 'expected' Q50)		+12.8%	**-1.2%**	-12.0%
ML/d change from natural		+0.172	**-0.018**	-0.208
			Assessment C:	Not triggered

5.3.16 Discussion of flow assessments A, B, C.

Comments are made here on specific sub-catchments and assessments where the above assessments required some further explanation.

LA4 (Section 5.3.8): as noted in previous EOP reports, there was an apparent modification to the accuracy in the estimation and/or reporting of low flows from 2016, approximately coincidental with pre- and post-mining periods. This includes a number of suspected ‘false zeroes’ from earlier in the record that we could not confidently ‘process’ or ‘infill’. Our review of visual inspection records (“flow observations”) by IMCEFT, such those summarised on the maps presented in Appendix G and considering the changes to the frequency of low flows above cease-to-flow. As such we have modified the ‘cease-to-flow’ to a very low flow (0.02 ML/d) and used this in Assessment B, giving a Level 2 trigger. A similar behaviour is apparent at:

- WC15 (Section 5.3.5): based on assessment of recorded low flows, we have adopted a low-flow (0.005 ML/d) in place of true ‘cease-to-flow’ for Assessment B, and as a result a Level 2 TARP was considered more appropriate than ‘Not triggered’ (consistent with previous End of Panel reporting).
- LA2 (Section 5.3.10): based on assessment of recorded low flows, we have adopted a low-flow (0.005 ML/d) in place of true ‘cease-to-flow’ for Assessment B, and as a result a Level 1 TARP was considered more appropriate than ‘Not triggered’.

5.3.17 Comparison against rainfall-runoff modelling

Up until Longwall 14, effects of surface water flow quantity were assessed via comparison of observed flow against rainfall-runoff modelling, either the RUNOFF-2005 model (used by Ecoengineers up until 2015) and then AWBM (used for Longwalls 13 and 14). As discussed in Section 5.1, this was superseded in consultation with agencies, with comparison against Reference Sites preferred. The IAPUM (Section 1.3) has recently requested that this be re-instated, and the most conservative result (of the new, agreed TARPs and the rainfall-runoff comparison) be adopted as the finding.

While the use of rainfall-runoff modelling itself is valid (especially so if appropriate Reference Sites are not available), the issue is that the pre-Longwall 15 methods and the now-agreed TARPs have multiple differences, including:

1. assessment period (longwall by longwall or cumulatively since mining);
2. the choice of indicator, being changes to ‘catchment yield’ expressed as a percentage of long-term average rainfall (as per the calculation recommended by Ecoengineers (2011) or changes to other flow indicators such as cease-to-flow frequency and median flow).

Therefore, while the rainfall-runoff method is used here for limited sites, as per IAPUM’s request, this is only as a secondary check until further discussion with agencies has occurred.

Appendix H presents a summary of rainfall-runoff modelling using the superseded assessment methods. This is done specifically for those sub-catchments where Assessment C (for median flow) does not already trigger TARP Level 3, and so provides a secondary check on effects.

DCU: Section H1 presents a summary of rainfall-runoff modelling. Hydrographs and ratios for the pre- and post-mining periods do not clearly indicate a systematic or significant change in catchment behaviour during Longwall 19 (or post-mining in general). The calculation of catchment yield did not trigger the former TARP. This finding is consistent with the agreed TARPs.

WC12: Section H2 presents a summary of rainfall-runoff modelling. Hydrographs, ratios and flow duration curves for the pre- and post-mining periods suggest that a mild change in catchment behaviour might have occurred. The calculation of catchment yield triggered the former TARP Level 1. So while mining effect was not indicated by TARP Assessments B and C, the Level 1 trigger (from the rainfall-runoff modelling) indicates a very minor potential effect.

WWL: Section H3 presents a summary of rainfall-runoff modelling. Hydrographs, ratios and flow duration curves for the pre- and post-mining periods do not clearly indicate a systematic or significant change in catchment behaviour. Using the calculation of 'catchment yield' derived by Ecoengineers (2011) indicates that there is effectively no reduction in flow to the period ending with Longwall 19, i.e. no triggering of the former TARP.

ND1: Section H4 presents a summary of rainfall-runoff modelling. Hydrographs, ratios and flow duration curves for the pre- and post-mining periods suggest that flows since mining occurred under this catchment (and to the end of Longwall 19) may have declined relative to modelled flows (TARP Level 2). This finding is significantly different to the findings with the agreed TARPs using Reference Sites, although its reliability is subjective given the difficulty in finding a completely appropriate rainfall sequence for the runoff modelling.

SC10: Section H5 presents a summary of rainfall-runoff modelling. Using the calculation of 'catchment yield' derived by Ecoengineers (2011) indicates that there is effectively no reduction in flow to the period ending with Longwall 19, i.e. no triggering of the former TARP. However, we caveat this with the statement that the rainfall-runoff modelling of this site is difficult, and this affects the reliability of any finding using the rainfall-runoff modelling.

GS2122205 / Sandy Creek: Section H6 presents a summary of rainfall-runoff modelling. Hydrographs, ratios and flow duration curves for the pre- and post-mining periods suggest that flows during Longwall 19 may have declined slightly relative to modelled flows, but overall since mining first occurred under this catchment, this site does not trigger the former rainfall-runoff model TARP. This finding is consistent with the findings with the agreed TARPs using Reference Sites.

5.4 Assessment D: flow reduction Wongawilli Creek

Surface water flow observations made by IMCEFT are recorded in a semi-qualitative fashion. At each field site (such as at the upstream or downstream end of a pool), an observation of flow conditions is made as follows:

0	No flow visible
1	Subsurface flow observed
2	Surface seepage observed
3	Surface trickle observed
4	Surface flow observed

Field surveys typically make an observation at each of the nominated sites around Area 3A and 3B over the period of a month. The "Outflow" results of IMCEFT's surveys are plotted on the maps in Appendix G for each month during the period covering the extraction of Longwall 197. As noted on the maps, observations are limited in two months during Longwall 19 (July and October-2022) due to the heavy rainfall conditions and catchment closures (Section 1.2.1).

Sites along the main channel of Wongawilli Creek are the subject of Assessment D, and these sites are shown with a hollow black circle in Appendix G to minimise confusion with sites on tributaries yet very close to the main branch of Wongawilli Creek.

While there are often “no flow” observations on the tributaries which flow into Wongawilli Creek, there are consistent observations of flow along Wongawilli Creek itself. Of the completed surveys, all months are “Not triggered”. As a result, the further calculation of Assessment D is not required.

Table 30. Assessment D for Wongawilli Creek: Longwall 19

During Longwall 18	Assessment D
June-2022, Aug-2022, Sep-2022, Oct-2022, Nov-2022, Dec-2022 **Jan-2023, Feb-2023, Mar-2023, Apr-2023**	Not triggered
Jul-2022, Oct-2022	Catchment closed

Any inferred loss of flow from Assessment D is then used in assessing compliance against Performance Measures for Wongawilli Creek.

5.5 Assessment against surface water flow Performance Measures

There are four agreed Performance Measures for surface water flows in the Area 3B WIMMCP.

Wongawilli Creek – minor environmental consequences	
Agreed measure:	*Methods C, D, to be compared against predictions made in contemporary groundwater modelling conducted to the satisfaction of the Secretary to assess whether effects that cannot be explained by natural variability “exceed prediction”.*

Assessment C at WWL does not indicate a discernible reduction beyond natural variability in Q50 (Table 21). Therefore, this Performance Measure is met.

Assessment D for flows along the middle of Wongawilli Creek (Table 30) was not triggered. While loss of baseflow is highly likely to occur during the assessment period, weather conditions mask any effect. Therefore, the estimated losses cannot be assessed.

Donalds Castle Creek – minor environmental consequences	
Agreed measure:	*Method C to be compared against predictions made in contemporary groundwater modelling conducted to the satisfaction of the Secretary to assess whether effects that cannot be explained by natural variability “exceed prediction”.*

Assessment C at DCU does not indicate a discernible reduction beyond natural variability in Q50 (Table 17). Therefore, this Performance Measure is met.

Sandy Creek – minor environmental consequences	
Agreed measure:	*Method C to be compared against predictions made in contemporary groundwater modelling conducted to the satisfaction of the Secretary to assess whether effects that cannot be explained by natural variability “exceed prediction”.*

Assessment C at GS2122205 does not indicate a discernible reduction beyond natural variability in Q50 (Table 17). Therefore, this Performance Measure is met.

Cordeaux River – negligible reduction in the quantity of surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek	
Agreed measure:	*Flow reduction as determined from measured at flow gauging station WWL_A.*

Assessment C at WWL does not indicate a reduction in Q50 (Table 21). Therefore, this Performance Measure is met.

Lake Avon – negligible reduction in the quantity of surface water inflows to Lake Avon

Agreed measure:	-	*Surface water inflows calculation = [Impacts at gauged catchments (LA2 + LA3 + LA4 + NDT1) + estimated impacts at ungauged but undermined catchments (e.g. LA5)] / [total inflow to LA].*

The calculation is presented as follows. In mined-under but un-monitored catchments, "inferred" losses are calculated as the same % reduction as a nearby monitored and mined-under catchment. If not mined under directly, but adjacent or neighbouring mining, then 25% of the % loss in the nearest mined under catchment is applied as the inferred loss.

Sub-catchment	Gauged?	Mined under?	Catch area [km2]		"measured" loss at Q50	"inferred" loss at Q50	
LA1	N	N	0.29*			0	
LA2	Y	Neighbour	0.824		-0.017		
LA3	Y	Y	0.375		-0.067		
LA4	Y	Y	0.817		-0.068		
LA5	N	Y	0.53*			-0.044	
LA6	N	Neighbour	0.97*			-0.020	
ND1	Y	Y	1.13		0.000		
NDC	Y	Y	3.74		0.000		
Total for mined-under or neighbouring catchments			**8.4**			**-0.216**	**ML/d**
Lake Avon		N	142^	5.9%		Q50	Qmean
Inflow from catchment WaterNSW estimate):						26	151
Inferred mining loss as % of total inflow:						-0.8%	-0.14%

* catchment area estimated by WatershedHG from GIS.

^ catchment area from https://www.waternsw.com.au/supply/visit/avon-dam

The sub-catchments where mining effects related to Dendrobium are present or inferred constitute about 6% of the total catchment to Lake Avon. The "measured" + "inferred" reduction in Q50 flow in these LA catchments = 0.216 ML/d (78 ML/yr). This is 0.8% of median Lake Avon inflow or 0.1% of average Lake Avon inflow for the period 2015 to Apr-2023, based on WaterNSW lake inflow data.

The estimated losses are equivalent to:

- 22% of predicted losses for the Lake Avon catchment made by groundwater modelling (281 ML/yr) from the approved Longwall 17 SMP Application); and
- 200% of low-end predicted losses for Lake Avon catchment made by groundwater modelling (39 ML/yr) and 58% of the high-end losses (137 ML/yr) from the approved Longwall 18 SMP Application).
- <u>Therefore, the estimated losses are "within prediction", and this Performance Measure is met.</u>

Lake Cordeaux – negligible reduction in the quantity of surface water inflows to Lake Cordeaux

Measure*:	*Surface water inflows calculation = [Impacts at gauged catchments (SC + LC5 + LC6) + estimated impacts at ungauged but undermined catchments (e.g. LC9)] / [total inflow to LC].*

*note that the method employed here is not yet been 'agreed' with agencies. However, the calculation presented uses a method consistent with that for inflow to Lake Avon.

The calculation is presented as follows. In mined-under but un-monitored catchments, "inferred" losses are calculated as the same % reduction as a nearby monitored and mined-under catchment. If not mined under directly, but adjacent or neighbouring mining, then 25% of the % loss in the nearest mined under catchment is applied as the inferred loss.

Sub-catchment	Gauged?	Mined under?	Catch area [km2]		"measured" loss at Q50	"inferred" loss at Q50	
LC4	N	N	0.84				
LC5	Y	N	1.861				
LC6	Y	N	1.16				
LC9	N	N	0.76				
Sandy Creek (GS212205)	Y	Y	7.029		-0.02		
LC13 (in A2)	N	Y	0.93			-0.077	(based on LA4)
Others in A2	N	Y	0.75			-0.062	(based on LA4)
Others in A1	N	Y	1.3			-0.033	(based on LA2+3+4)
Total for mined-under or neighbouring catchments			**10.0**			**-0.190**	**ML/d**
Lake Cordeaux			91^	11.0%		Q50	Qmean
Inflow from catchment (WaterNSW estimate):						16	89
Inferred mining loss as % of total inflow:						-1.3%	-0.2%

* catchment area estimated by WatershedHG from GIS.

^ catchment area from https://www.waternsw.com.au/supply/visit/cordeaux-dam

The sub-catchments where mining effects related to Dendrobium are present or inferred constitute about 11% of the total catchment to Lake Cordeaux. The “measured” + “inferred” reduction in Q50 flow in these LC catchments = 0.19ML/d (69 ML/yr). This is 1.3% of median Lake Cordeaux inflow or 0.2% of average Lake Cordeaux inflow for the period 2015 to Apr-2023, based on WaterNSW lake inflow data.

The estimated losses are equivalent to:

- 17% of predicted losses for the Lake Cordeaux catchment made by groundwater modelling (420 ML/yr) from the approved Longwall 19 SMP Application); and
- 174% of low-end predicted losses for Lake Cordeaux catchment made by groundwater modelling (40 ML/yr) and 68% of the high-end losses (102 ML/yr) from the approved Longwall 22 and 23 SMP Application (noting that this estimate is for the case without Longwalls 22 and 23).
- Therefore, the estimated losses are “within prediction”, and this Performance Measure is met.

5.6 Watercourse pool levels and outflow status

This section reviews the observed water levels and outflow status in pools that occur along watercourses that pass within the zone of influence (<400 m) of Longwall 19, and the previous Longwall 18 in Area 3B. Representative pools are monitored for water level and outflow status during each monitoring visit. Water level dataloggers are installed in key pools to supplement existing manual baseline water level measurements.

Pool outflow is summarised using “heatmap” plots showing observed flow status at each pool for monthly monitoring periods, with the passage or close approach of longwalls marked as lines. Pools are arranged from upstream (bottom of the plot) to downstream (top), a convention adopted simply because most watercourses in Area 3B flowed in a northerly direction. Observations of “no water in the pool” are overlain as “-“ symbols. Where more than one monitoring round was carried out in a month, the minimum condition was used in the figure. Grey cells represent periods during which no observations were made and usually reflects site access or extended catchment closures.

The Area 3A WIMMCP includes assessment of pool levels along Wongawilli Creek and Sandy Creek against prescribed TARP level thresholds as follows:

Level 1: Single pool on a subject Creek is observed as dry [when it is typically full].

Level 2: A single pool on a subject creek is observed as dry in consecutive monitoring events, or, two or more pools are observed as dry in a single monitoring event.

Level 3: Fracturing resulting in diversion of flow such that <10% of the pools have water levels lower than baseline period.

Exceeding Predictions: Fracturing resulting in diversion of flow such that >10% of the pools have water levels lower than baseline period.

A summary of current TARP levels is provided in Table 31. Further discussion relating to the assessment of pools is in the following subsections.

Table 31. Current TARP levels related to pools on subject creeks.

Creek	Total pools	Dry Pools*	Comments	TARP Level
Wongawilli Creek	124	0	A number of pools along Wongawilli Creek became dry during the severe 2017-2019 drought. Since 2020 all monitored, pools have returned to full and flowing status (Section 5.6.2)	None
Sandy Creek	52	0	The third-order watercourse of Sandy Creek is entirely outside the 400 m area of mining influence for Longwall 19 (855 m at closest point)	None

Note: * Dry pools are pools observed to be dry that are typically not dry under similar weather conditions.

5.6.1 Pools along Wongawilli Creek

Stream mapping by IMCEFT identified 124 pools along Wongawilli Creek, separated by various rock bars, channels and woody debris. Figure 27 provides an overview of outflow status for 34 monitored pools along Wongawilli Creek as a temporal heat map. Pools monitored for outflow status were observed to contain water and have observable flow during monitoring events from 2011 to late 2016. During the severe drought of 2017-2019 most pools were observed to cease to flow, and several became completely dry. Since 2020 all monitored, pools have returned to full and flowing status. There is no apparent change in pool status as a result of mining in Area 3B or Longwall 19 in Area 3A.

Additional pools monitored with water level dataloggers are discussed in the following subsections.

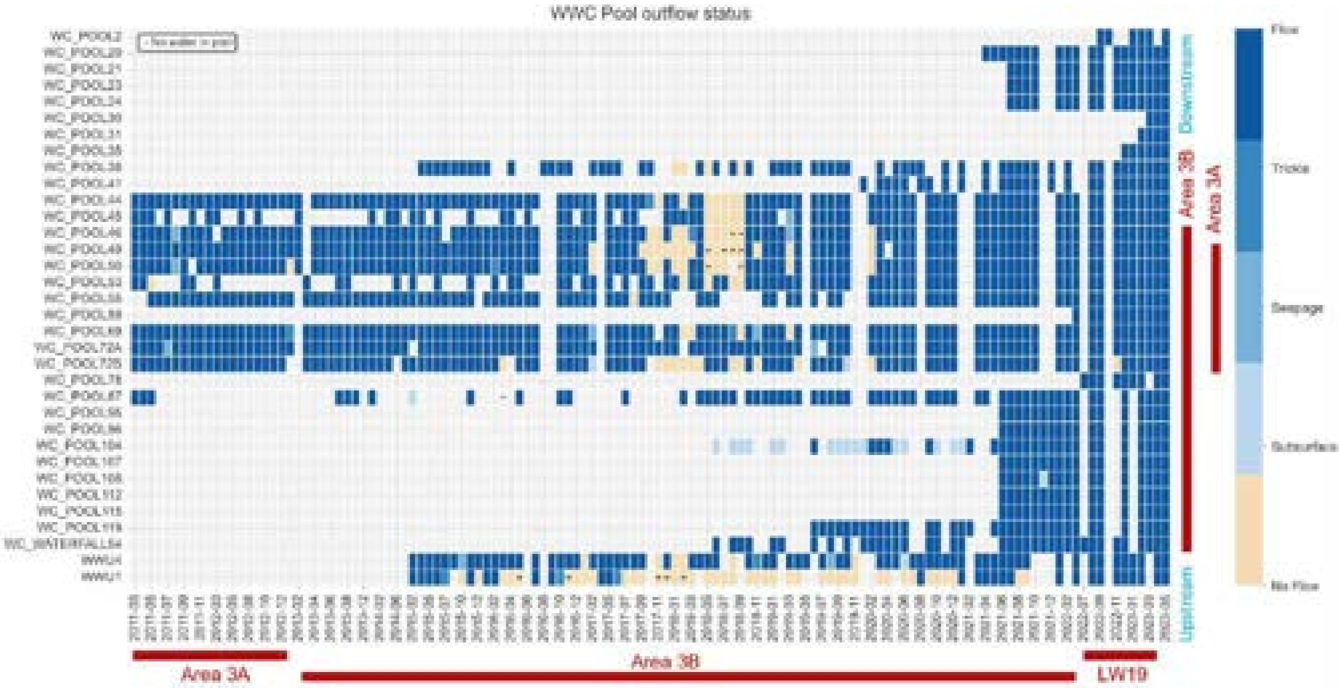


Figure 27. Flow status of pools on Wongawilli Creek

5.6.2 Wongawilli Creek Pool 50 (previously Pool 43A)

Pool 50 is located on Wongawilli Creek, 348 m east of Longwall 9 in Area 3B (extracted between 9/2/2013 and 2/6/2014) and 315 m northwest of Longwall 6 in Area 3A (9/2/2010 - 28/3/2011). Pool 50 is controlled by a rock bar. On 20/11/2017, it was noted during a site visit that water levels in Pool 50 on Wongawilli Creek were below the baseline (impact number DA3B_LW13_015, dated 28/11/2017). The observation triggered a TARP Level 3 because a previously reported fracture (first observed on 18/12/2013) is present in the sandstone forming the pool base. No significant changes to the downstream control were noted by the IMCEFT at Pool 50.

An assessment was carried out into the cause of the declining water levels in Pool 50 by Watershed (2018). The assessment concluded that the decline in pool levels was likely due to depressurisation of the underlying formations (HBSS and BGSS; Figure 29) due to mining adjacent to the creek, exacerbated by the very low rainfall and flow conditions during the 2017-2019 drought. The decline in pool levels started prior to the formation of the fracture (Figure 28) suggesting that water loss from the pool was not related to the formation of the fracture.

Piezometric levels in the sandstone substrate adjacent to Wongawilli Creek have recovered as mining in Area 3B has moved south and away from Pool 50 (Figure 29). Since 2021, piezometric levels in the HBSS adjacent to the pool have recovered to above the elevation of the creek bed. Water levels in Pool 50 have trended higher since 2020 in response to both higher rainfall conditions and recovering groundwater levels. Pool measurements declined slightly in early 2023 in response to drier conditions.

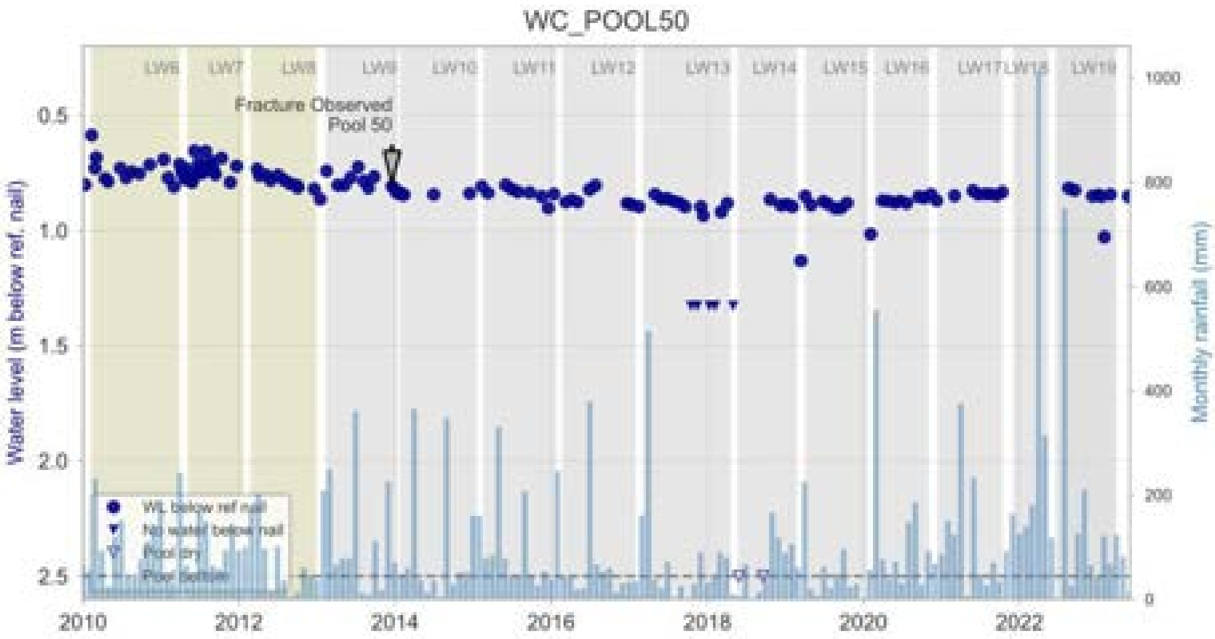


Figure 28. Time series plot of water level observations in Pool 50

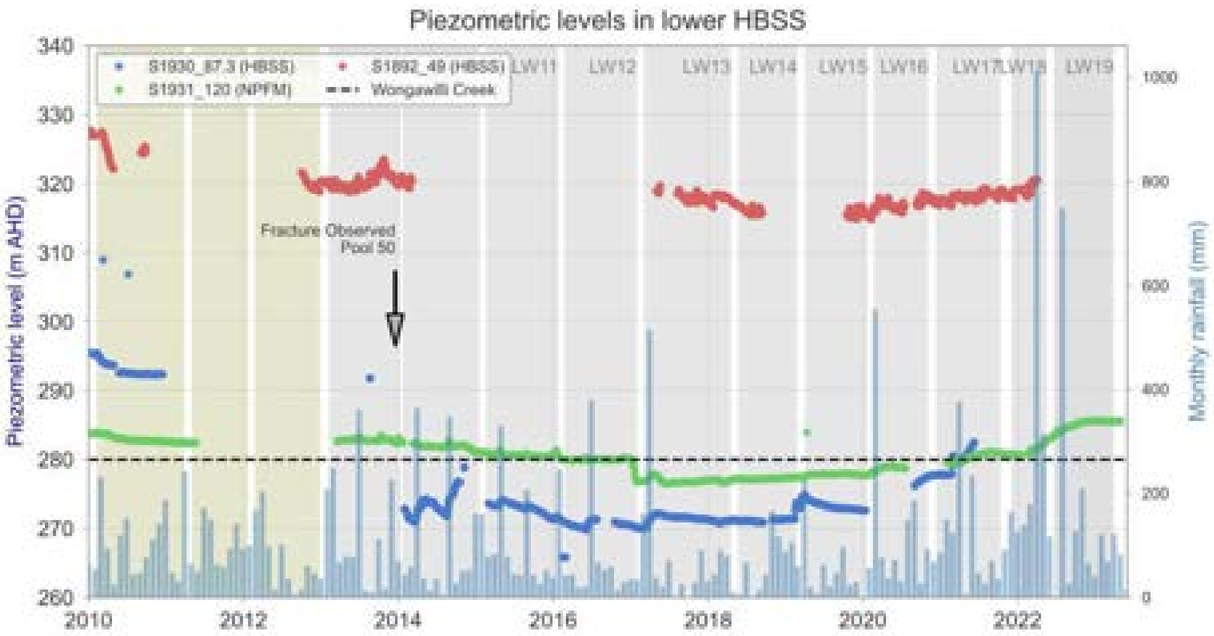


Figure 29. Groundwater hydrographs for lower HBSS adjacent to Wongawilli Creek

5.6.3 Pool level dataloggers in Wongawilli Creek

Pool level dataloggers are installed in seven pools along Wongawilli Creek adjacent to Area 3A and 3B: WWU, Waterfall 54, Pool 45, Pool 49, Pool 50 (WCS2), Pool 41 (WCS1). The dataloggers measure the water level at hourly intervals relative to a surveyed benchmark at the respective sites. Hydrographs for the loggers are included in Appendix F.

Most of the loggers were installed in 2020 and therefore have limited baseline data. Loggers at Pools 50 and 41 were installed in 2018. The hydrographs for those pools show different recession characteristics that are related to the geometry of the pools and their control points:

No adverse trends related to mining are evident as of the end of the current reporting period.

5.6.4 Pools along tributary WC15

WC15 is a second order stream that flows in a north-easterly direction across the eastern part of Area 3B and joins Wongawilli Creek at WC_Pool 69. The watercourse was approached within 40 m by Longwalls 13 and 14, and the upper reaches of WC15 were directly mined under by Longwalls 15 to 17. Longwall 19 passed within 400 m of the lower 106 m of the WC15 watercourse. Subsidence effects from Longwall 19 are likely to be negligible compared with Area 3B longwalls which directly mined under the watercourse.

Nine pools are routinely monitored along the WC15 watercourse. Figure 30 summarises observations of flow status of each pool for monthly monitoring periods prior to and following the passage or close approach of Longwalls 13 to 17 and Longwall 19. Baseline data, prior to Longwall 13 and the 2017-2018 drought, show that all monitored pools are filled and overflow for several months following large rainfall events (and near-continuously at Pool 9) and ceased to flow or became dry during prolonged periods of low rainfall. As with other watercourses, pool levels and flow were affected by the 2017-2019 drought such that all pools were observed to have no flow and/or were dry on several occasions.

From observations shown in Figure 30, it is expected that all pools on WC15 would have filled and overflowed during between 2020 and 2022 due to the higher-than-average rainfall. It is apparent that the pool level and flow status in all monitored pools upstream of Pool 13 during 2020 is different from baseline conditions and likely impacted by Longwalls 14 to 16. Those upstream pools have remained affected since that time. The passage of Longwall 17 to 19 had no discernible affect in addition to the existing impacts. Monitoring locations on WC15 are outside the area of mining influence for Longwall 18.

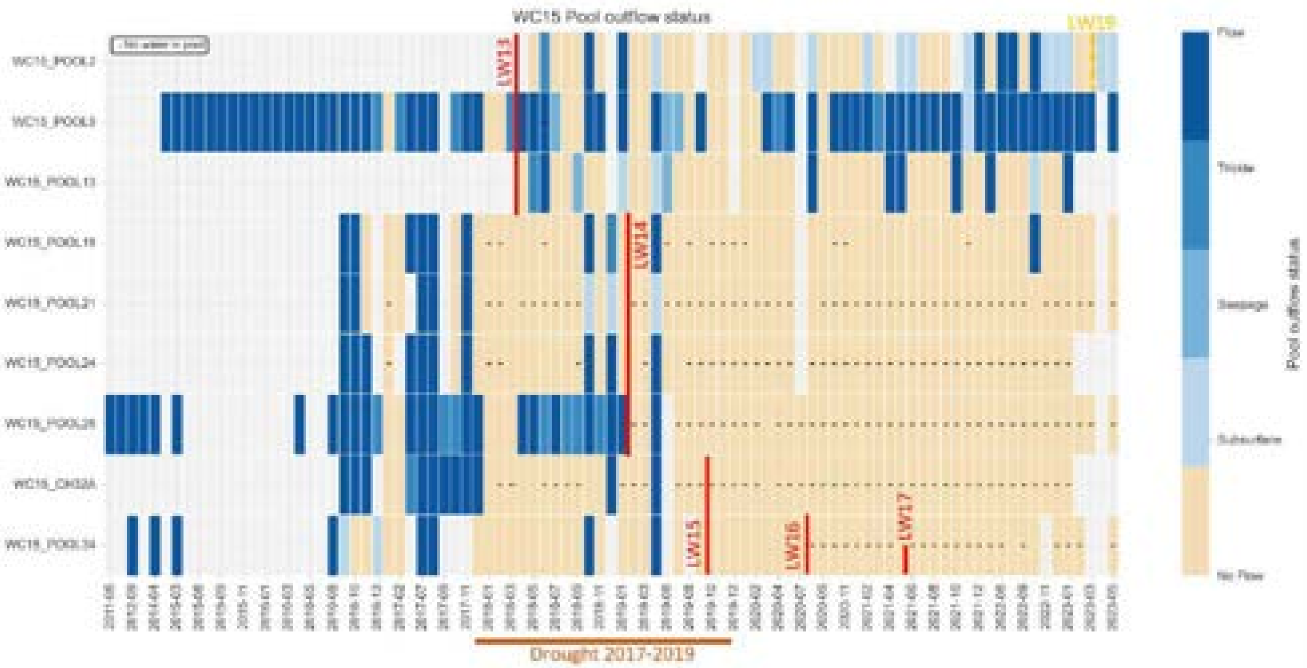


Figure 30. Flow status of pools on the WC15 watercourse

5.6.5 Pools along tributary WC14

Water levels are monitored at three pools along the WC14 watercourse. The upper reaches of WC14, at and above Pool 16 were directly mined beneath by Longwall 19 between 22/12/2022 and 7/2/2023. The pool water level and flow status are summarised in Figure 31, noting that the baseline monitoring is limited to the lower-most Pool 3. Despite the short record for upper watercourse pools, it is apparent that Pool 16 ceased to flow and became dry following the passage of Longwall 19 beneath the site (Figure 31, Figure 32). Fracturing and pool water loss is common in watercourses that directly overlie extracted longwalls. Although no fractures associated with Longwall 19 were recorded at the pool, fracturing was observed approximately 50 m downstream (Impact reference LW19_043; Table 8) and recurrence of iron staining ~170 m downstream of Pool 16 (LW19_003).

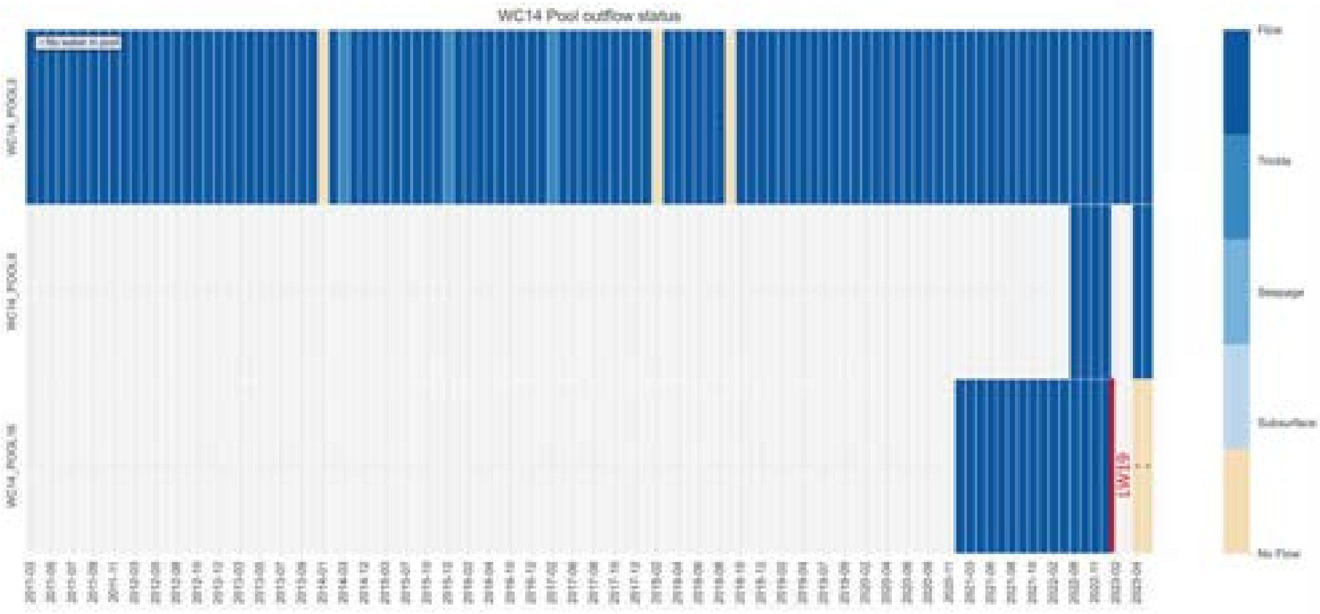


Figure 31. Flow status of pools on the WC14 watercourse

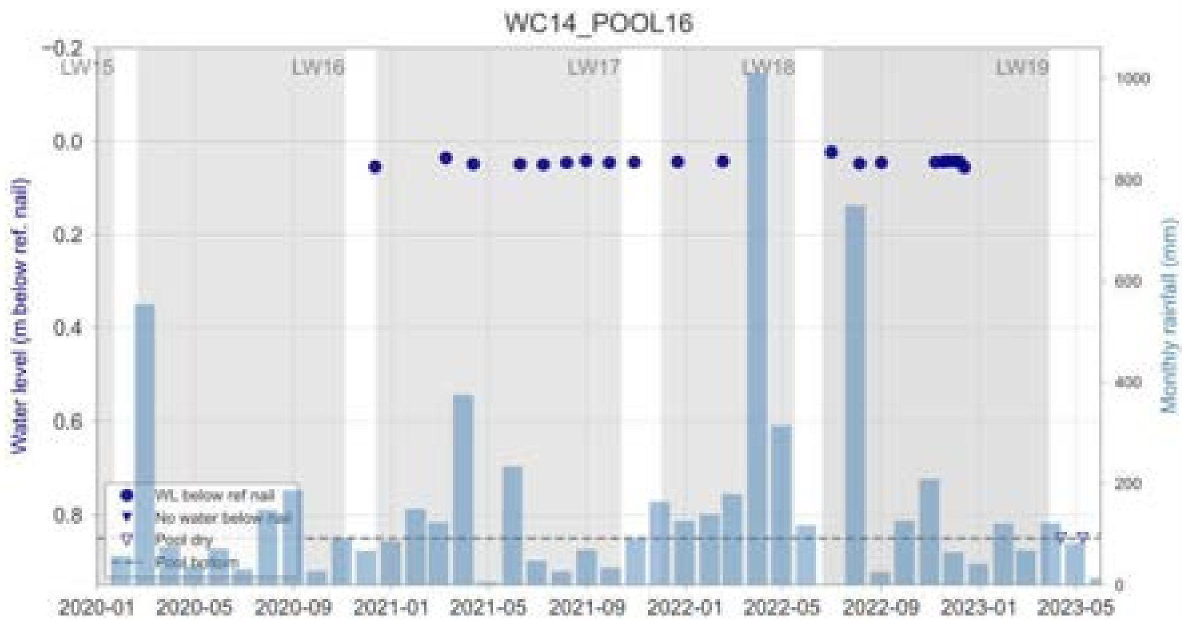


Figure 32. Pool water level observations at WC14_Pool16

5.6.6 Pools along tributary SC10

SC10 is a major second-order tributary to Sandy Creek which flows northward to join Sandy Creek at SCK_Pool 6. There are 39 mapped pools along the main second-order watercourse of SC10, separated by rock bars and channels. Figure 33 shows that all monitored sites except Pool 29 have remained full and flowing since 2020 with no apparent changes to status following Longwall 19, nor previous mining at Area 3A.

SC10_Pool 29 is recorded as having no outflow or seepage outflow (also observed during the baseline period) since the passage of Longwall 19, despite intermittently filling and outflowing in the past. Longwall 19 passed Pool 29 at a distance of 270 m on 22/7/2022. Based on previous reports by MSEC, fracturing impacts to watercourses is possible, although unlikely at that distance. A follow-up inspection of the pool was carried out by IMCEFT on 10/7/2023. No evidence for impacts were observed at the pool, nor at any other location along the watercourse. The field teams have noted that the downstream pool control consists of woody debris and sediment and that there has been build-up of sediment around the reference stake (used as water level benchmark) since its installation. It is therefore possible that the outflow characteristics of the pool have been altered as result of flooding since 2020. Sediment build-up around the stake can also change the 'Dry Below Nail' base. Further monitoring at the site will continue.

Water level dataloggers were installed in four pools along SC10 prior to Longwall 19 (SC10_Pool 11, 14, 23 and 26a. With reference to the hydrographs in Appendix F, no anomalous water level variations are noted in Pools 11, 14 and 23. The hydrograph for Pool 26a shows erratic declines in water level and increased recession rate compared with the other three pools, from late 2023. Longwall 19 passed 210 m from Pool 26a on 18/7/2022. With the limited monitoring record it is not possible to determine if the observed fluctuations are related to mining or in response to drier conditions since late 2023. It is recommended that IMC review these pool hydrographs again in the next EOP report.

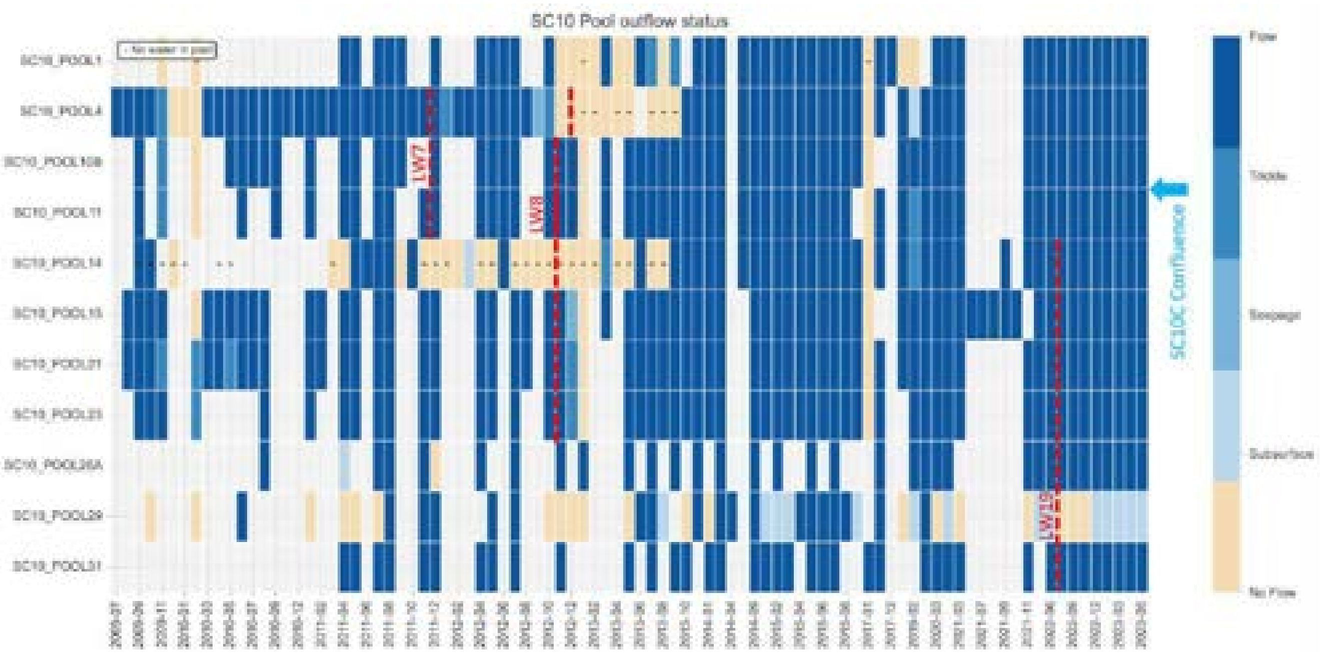


Figure 33. Flow status of pools on the SC10 watercourse

5.6.7 Wongawilli Creek Waterfall 54

There was a requirement for an adaptive management approach to the extraction of Longwall 17, with respect to subsidence and hydrology of WF54 on Wongawilli Creek. Assessments were agreed as part of the Wongawilli Creek and Waterfall 54 Management Strategy (Illawarra Metallurgical Coal, 2021). During the extraction of Longwall 17, frequent analysis and assessment of hydrology at the waterfall was reported to DPIE (Watershed HydroGeo, 2021a).

Further analysis was carried out following identification of a rockfall (as reported to agencies), with reporting provided to agencies (Watershed HydroGeo, 2022). The full detail of the method and findings (including no evidence of a change to hydrology at WF54 as a result of longwall mining) is presented in those earlier documents.

For this EOP, although Longwall 19 is relatively distant from WF54, the data from WF54 was assessed to check on hydrological behaviour since the last assessment (Dec-2022). Figure 35 presents a timeseries of the pre- and post-mining data from WF54 and the WWU reference site.

The upper and lower bounds of the “expected” WF54 stage are calculated from the upstream WWU stage, using the scatter or noise in the pre-mining data (orange lines). This shows the pre-mining data (green) is generally within the expected range but occasionally strays outside the range, typically during significant rainfall (see red dots on lower chart, which show exceedances). The post-mining data has generally continued within those bounds, with a similar frequency of exceedances. The most recent period (since December-2022) shows almost no exceedances, corresponding in part to the generally lower rainfall since that time. As with previous analysis ((Watershed HydroGeo, 2021b, 2022), this suggests there has been no discernible change in the relationship between WWU and WF54.

5.6.8 Native Dog Creek tributary ND1

ND1 is a second-order watercourse that flows west to join Native Dog Creek below the FSL of Lake Avon. When the water level of Lake Avon is above ~318 m AHD, tributary ND1 enters the lake directly. Longwall 18 commenced at a distance of 265 m from ND1_Pool2 and mined directly beneath the upper reaches of ND1C, including ND1C_Pool2 in early April 2022. The longwall passed within 37 m of ND1_Pool30 on or around 1/4/2022.

Five pools are routinely monitored along the ND1 watercourse with a further three pools monitored on upstream first-order tributaries ND1A, ND1B and ND1C (Figure 33). The data show no evidence for changes to flow status in pools along the main second-order watercourse following Longwall 18. ND1_Pool30 appears to have been dry on at least one occasion prior to the passage of Longwall 18 and therefore the recent observations of no water in the pool are not demonstrably related to mining. ND1C_Pool2 was recorded as dry following the passage of Longwall 18, in contrast to baseline conditions when the pool frequently flowed and is likely a mining effect.

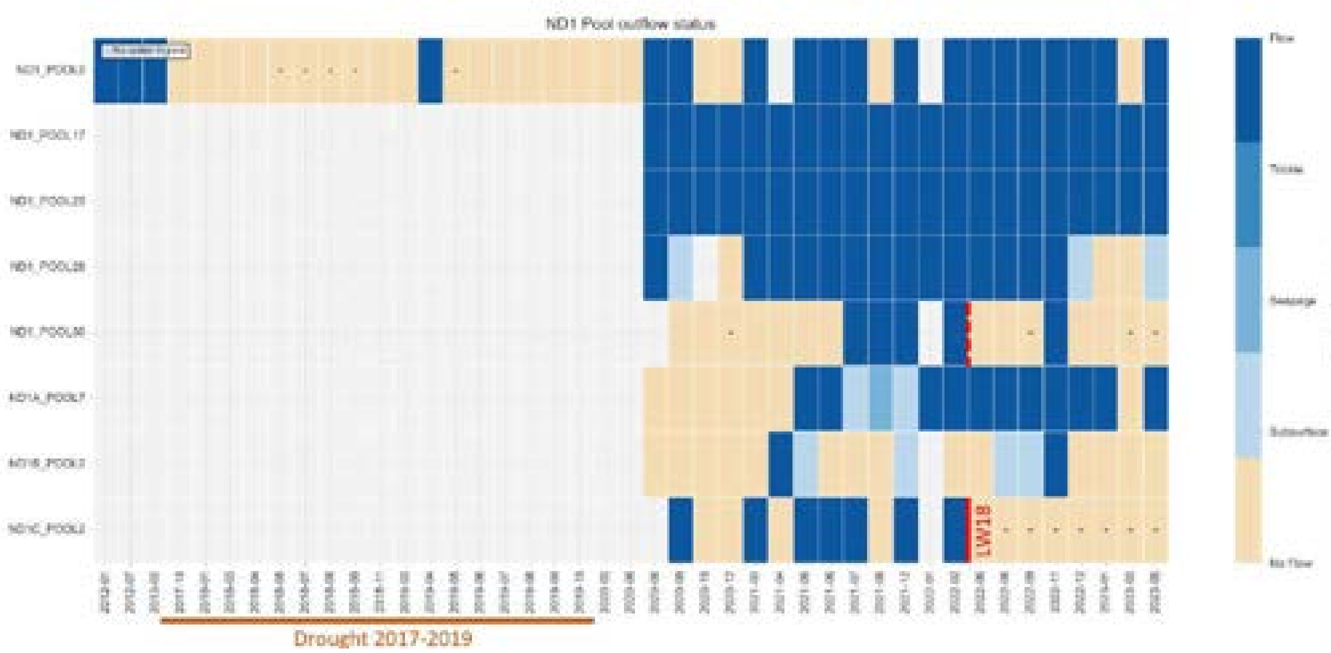


Figure 34. Flow status of pools on the ND1 watercourse

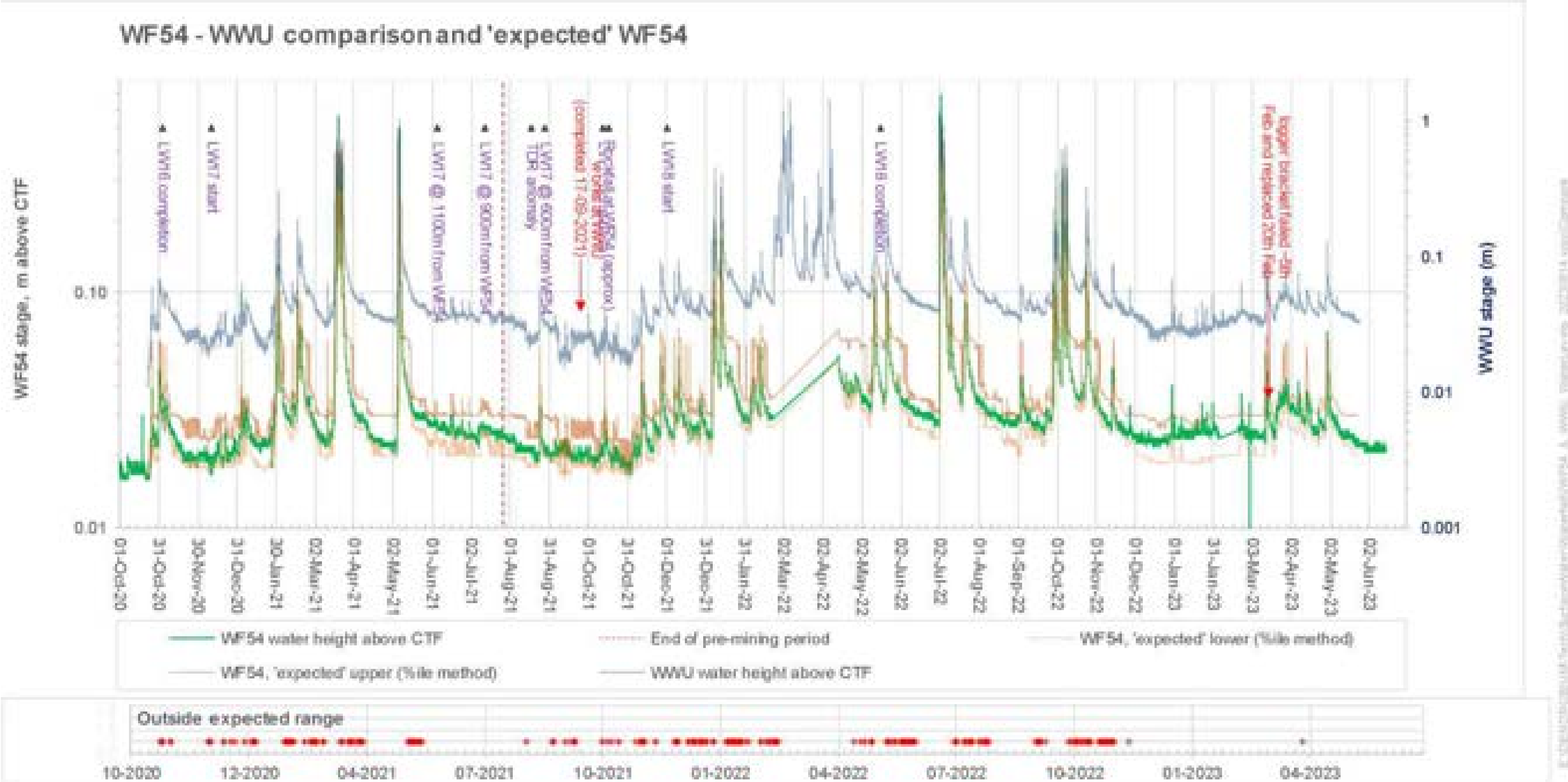


Figure 35. Comparison of WF54 stage with range in "expected" stage

6. Assessment of shallow groundwater (swamps)

6.1 Shallow groundwater levels

Trigger values for subsidence-induced decreases in groundwater levels, at surface and near-surface monitoring sites at Area 3A swamps, have been established within the Swamp Impact Monitoring Management and Contingency Plan (SIMMCP) for Longwall 19 (2021b). Shallow groundwater level has been identified as an indicator of potential changes in ecosystem functionality of the swamps. TARPS are defined as follows:

Table 32. Performance criteria related to shallow groundwater levels at swamp monitoring sites

TARP Level	Criteria	Response
1	Groundwater **level** lower than baseline level at **any** monitoring site within a swamp (in comparison to reference swamps); and/or; **Rate** of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at **any** monitoring site (measured as average mm/ day during the recession curve).	Increased intensity and frequency of vegetation monitoring and/or further investigations of subsidence impacts on bedrock base and rockbars
2	Groundwater **level** lower than baseline level at **50%** of monitoring sites (within 400 m of mining) within a swamp (in comparison to reference swamps); and/or **Rate** of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at **50%** of monitoring sites (within 400 m of mining) within the swamp.	
3	Groundwater **level** lower than baseline level at **>80%** of monitoring sites (within 400m of mining) within a swamp (in comparison to reference swamps); and/or **Rate** of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at **>80%** of monitoring sites (within 400 m of mining) within the swamp.	

Groundwater level hydrographs for each shallow piezometer are presented in **Appendix D**. The hydrograph is plotted together with ground elevation and the elevation of the piezometer base, longwall timing, groundwater level recession rate (in mm/day), and the dates that longwalls pass under (if relevant) or within 400 m of a piezometer. Assessment of mining effects is based on these hydrographs.

A summary of hydrograph responses and cumulative effects at Areas 3A and 3B swamps is included in Table 35 for Impact Sites. In accordance with the definition of the TARPs, the sites within 400 m of mining *and* within the mapped swamp areas are assessed for triggers related to mining impacts.

An overview of shallow groundwater levels and cumulative effects is shown in Figure 36 and Figure 37 as the monthly median % saturation at each reference and impact swamp piezometer. The % saturation is calculated as the level of groundwater within the swamp piezometer relative to the total thickness of the sediments at that location (from base of the piezometer to the ground surface).

6.1.1 Reference swamp sites

IMC maintains shallow groundwater monitoring sites at reference swamps located well outside the mining zone of influence. Those sites provide an important comparison when assessing swamp sites closer to the mine for possible shallow groundwater impacts. Shallow groundwater at all reference sites recovered after the 2017-2019 drought as a result of higher-than-average rainfall between 2020 to 2022. Drying condition is 2023 has resulted in a decline in shallow groundwater levels in several reference swamps; however all reference swamps sites remain saturated or partially saturated as of June 2023.

A review of shallow groundwater hydrographs for reference swamps in Appendix D (and evident in Figure 36) indicate two main hydrological end-member types:

1. Near-continuously saturated swamp sediments. Examples include Swamps 7, 22 and 25. Swamp sediments at these locations remain saturated during periods of prolonged drought. It is assumed that at these locations, groundwater levels within the swamp are sustained by discharge from adjacent and underlying sandstone substrate (groundwater-connected swamps).

2. Intermittently saturated swamp sediments. Examples include Swamps 33, 84, 85, 86 and 88. Swamp sediments at these locations saturate, typically to the ground surface, following large rainfall events and remain saturated for several weeks to months as shallow groundwater levels recede to below the base of the swamp. The duration of saturation and rate of recession vary between locations and likely depend on the characteristics of the swamp substrate, controlling rock-bar and contributions from adjacent or up-gradient perched sandstone aquifers. It is assumed that at these locations, the swamp sediments are likely perched above the water table in the sandstone substrate.

Continuously saturated locations tend to be within deep valleys (valley-fill) where adjacent ridges rise ≥ 50 m above the swamp level. Intermittently saturated swamp locations tend to reside in shallow valleys where the adjacent ridges rise ≤ 20 m above the swamp level (typical of headwater swamps).

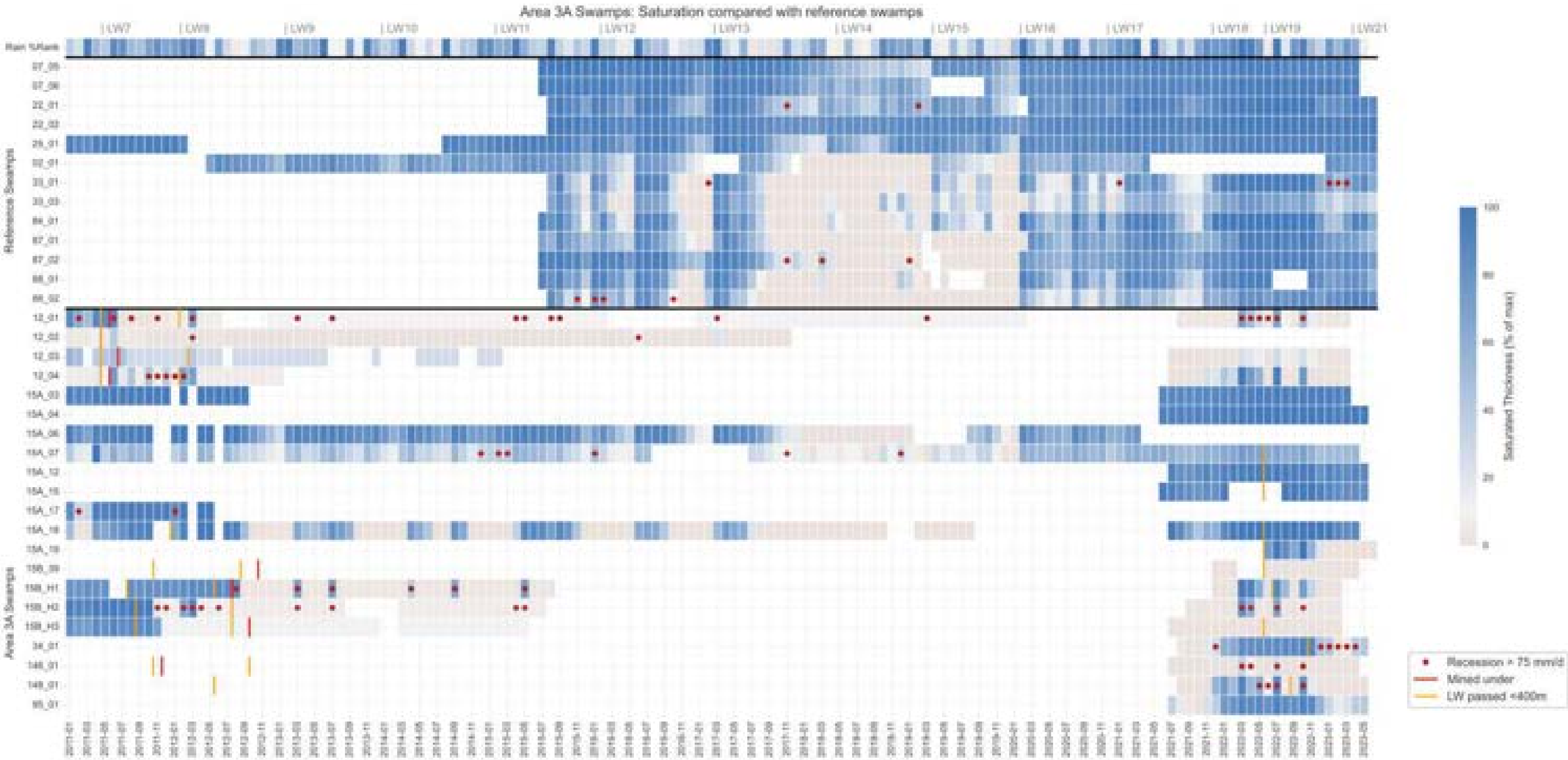


Figure 36. Overview of swamp saturation levels by month, Area 3A

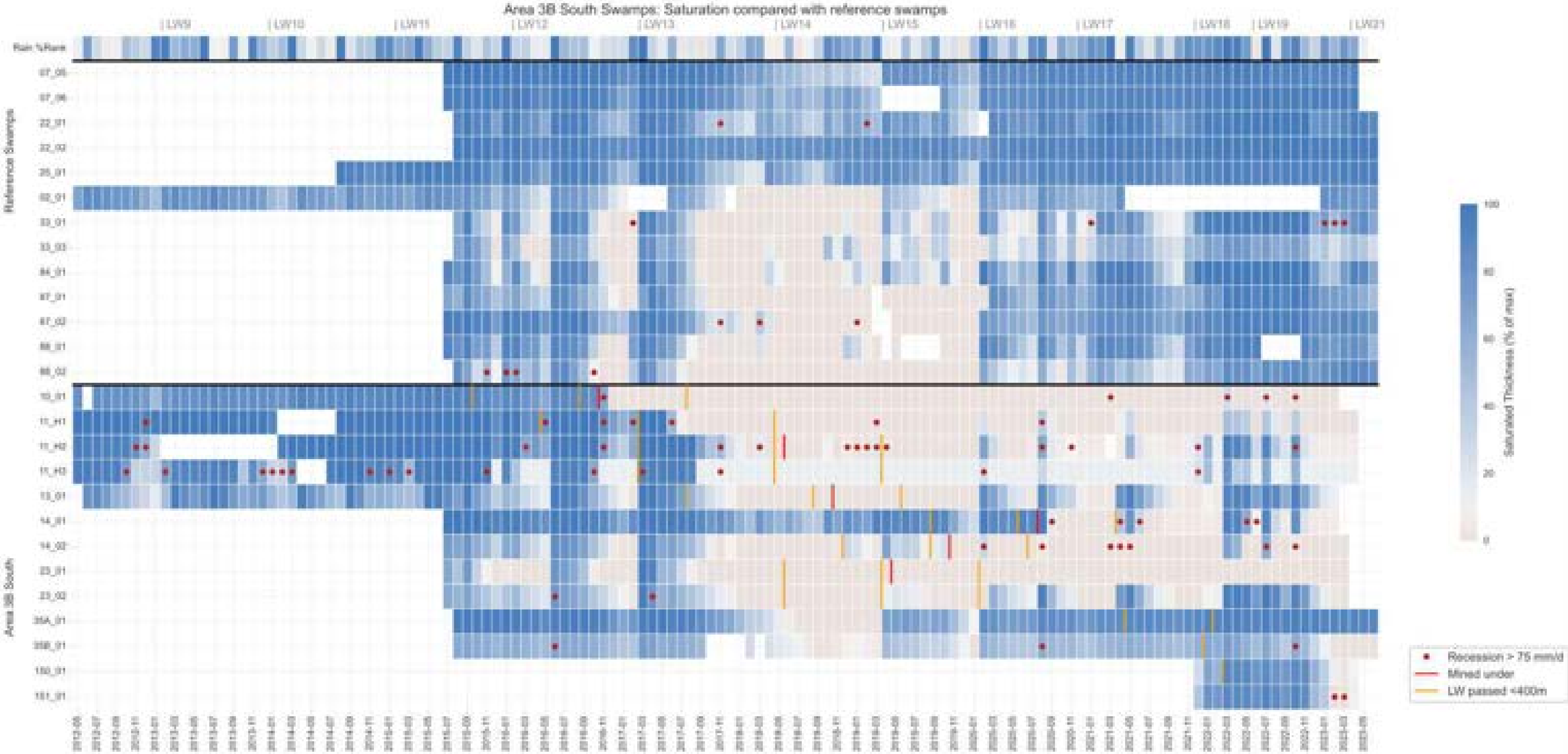


Figure 37. Overview of swamp saturation levels by month, Area 3B South

6.1.2 Impact swamp sites

Swamps and swamp piezometers that are located within 400 m of Longwall 19 are listed in Table 33. The table summarises shallow groundwater observations with reference to the saturation heat maps in Figure 36 and Figure 37, and the shallow groundwater hydrographs presented in Appendix D. The likelihood that the groundwater level characteristics at a piezometer has been affected by mining subsidence is assessed by comparing saturation levels, shallow groundwater level trends and recession rates with baseline data and reference swamps as describe in previous sections.

Note that in this assessment, Swamps 35a, 35b and 150, located within the area of influence of Longwall 18 are reassessed in light of additional monitoring data since its completion (Table 34).

An independent assessment of responses at swamp piezometer sites 15a_19 and 35b_01 was carried out by Watershed Hydrogeo (2023). Those findings are consistent with the assessment below.

Table 33. Summary of observation at swamp piezometers within Longwall 19 influence

Swamp	Piezo-meter	Closest distance (m)	Date of closets approach	Date LW passed <400 m	Observations	Evidence for mining effect?
12	12_04	398	12/3/2023	12/3/2023	Previously mined beneath by Longwall 7 (2/6/2011); Impacted previously	Previous
15A	15A_07	168	17/7/2022	20/6/2022	Shallow groundwater levels and recessions consistent with previous and reference sites	No
	15A_12	172	20/6/2022	20/6/2022	Shallow groundwater levels and recessions consistent with previous and reference sites	No
	15A_15	298	13/7/2022	20/6/2022	Shallow groundwater levels and recessions consistent with previous and reference sites	No
	15A_18	275	20/6/2022	20/6/2022	Intermittent saturation; no evidence for change in saturation behaviour	No
	15A_19	70	11/7/2022	20/6/2022	WL dropped below piezo base on 31/12/2022 and has not recovered. Recession rates elevated following LW.	Likely
15B	15B_H1	248	4/9/2022	19/7/2022	Previously mined beneath by Longwall 8 (21/8/2012). Impacted previously	Previous
	15B_H2	357	1/8/2022	10/7/2022	Longwall 8 passed within 10 m (24/9/2012). Impacted previously	Previous
	15B_H3	343	16/7/2022	20/6/2022	Previously mined beneath by Longwall 8 (8/10/2012). Impacted previously	Previous
	15B_39	175	20/6/2022	20/6/2022	Previously mined beneath by Longwall 8 (13/11/2012). Impacted previously	Previous
148	148_01	38	5/12/2022	24/9/2022	WL dropped below piezo base on 20/11/2022 with no significant saturation since despite moderate rainfall in March 2023.	Yes
34	34_01	361	29/11/2022	2/11/2022	Shallow groundwater saturation behaviour and recessions similar to previous.	No

Table 34. Summary of observation at swamp piezometers within Longwall 18 influence

Swamp	Piezo-meter	Closest distance (m)	Date of closets approach	Date LW passed <400 m	Observations	Evidence for mining effect?
35a	35a_01	3	30/4/2022	21/2/2022	Swamp remains saturated following passage of Longwalls 17 and 18. Recession rates remain low.	No
35b	35b_01	108	3/3/2022	15/1/2022	Increase in recession rate following passage of Longwall 18; Shallow groundwater levels below expected in early 2023 compared with previous and reference sites	Yes
150	150_01	281	4/5/2022	23/3/2022	Limited baseline. Decline in shallow groundwater level and slight increase in recession rate. See additional comments bellow.	No

Swamp 150 is a headwater swamp of tributary ND1B. The swamp vegetation occurs on an area of shallow sediment accumulation on gently sloping Hawkesbury Sandstone substrate and is sustained by seepage of shallow groundwater. Shallow groundwater within the swamps sediments is perched relative to groundwater levels within the Hawkesbury Sandstone. Given its position in the landscape it is likely to saturate intermittently and may completely desaturate during prolonged dry periods in a similar manner to reference swamps 88_01 and 88_02. Given the distance of site 150_01 from Longwall 18 and its position high on the opposite valley slope, it is considered unlikely that the observed decline in saturation is related to Longwall 18.

In summary, a review of shallow groundwater hydrographs at swamp sites within the area of influence of Longwall 19 indicates mining subsidence effects at site 148_01 and a likely effect at site 15a_19. Swamp site 148_01 is located within 40 m of the longwall footprint. Previous assessment of swamp impacts at Dendrobium indicate that impacts are likely within approximately 60 m of the longwall footprint and therefore the effects at Swamp 148 are within expectations (Watershed HydroGeo, 2021c, 2019b). Swamp site 15a_19 is located 70 m from Longwall 19 which is just beyond the 60 m distance within which swamp impacts are commonly observed, but within the distance for which subsidence impacts are considered possible (MSEC, 2020b).

Review of swamp sites within the area of influence of Longwall 18 indicates that site 35b_01 is likely to have been affected by mining related fracturing and/or drawdown within the sandstone substrate, noting that no surface fracturing has been observed at the site. Site 35b_01 is located 108 m from Longwall 18, beyond the 60 m distance within which swamp impacts are commonly observed. Swamp 35b is located within a deep valley adjacent to Longwall 18 and was predicted to experience 425 mm of valley closure movement (MSEC, 2020c) with impacts considered *possible* (HGEO, 2020).

Table 35. Summary of cumulative shallow groundwater effects and TARP status at *Impact Sites*

SWAMP	TARP SITES	RELEVANT LONGWALLS	PIEZOMETERS WITH AN OBSERVED RESPONSE			OBSERVED BEHAVIOUR	COMMENT	TARP LEVEL
			YES	UNCLEAR OR >400M	NO			
01a	6	Longwall 9, Longwall 10	01, 04, 04i, 04ii, 04iii, 04iv, 04v		02	Groundwater levels lower than baseline and recession rate greater than baseline at greater than 50% to 90% of monitoring sites	Limited baseline data for five piezometers.	Level 3
01b	5	Longwall 9	02, 02iii	02ii, 02iv	01	Groundwater levels lower than baseline and recession rate greater than baseline at greater than 50% of monitoring sites.	Limited baseline data for five piezometers	Level 2
03	1	Pillar 11/12	01			Possible increase in recession rate and apparently reduced response to rainfall after Longwall 11 passed and Longwall 12 undermined.	Rapid recession after rain during Longwall 13 supports impact at Swamp 3	Level 3
05	6	Longwall 9, Longwall 10, Longwall 11	01, 02, 03, 03ii, 04	05		Groundwater levels lower than baseline and recession rate greater than baseline at >80% of monitoring sites	Unclear if piezometer 5_05 impacted by either Longwall 11 or 12 due to limited baseline.	Level 3
08	0	Longwall 9, Longwall 10 Longwall 11	*01, 04, 02*			Groundwater levels lower than baseline and recession rate greater than baseline at a number of piezometers, not within swamp boundary.	Outside swamp boundary (Not subject to TARP)	n/a
10	1	Longwall 12	01			Sharp decline in groundwater levels below base of the piezometer after Longwall 12. Level and rate of decline anomalous compared with baseline.	Mined under by Longwall 12	Level 3
11	3	Longwalls 13-14	H1, H2, H3			All three piezometers show mostly desaturated conditions following the passage of Longwall 14 with only brief periods of saturation following rainfall events.	Partially mined under by Longwall 13 and by Longwall 14	Level 3
12	3	Longwalls 6-8, 19	01, 03, 04			All three piezometers show low levels of saturation compared with reference swamps after being directly mined under by Longwall 7.	Mined under by Longwall 7	**Level 3**
13	1	Longwalls 13-14	01			Groundwater level below the piezometer base since early 2018; Impact apparent as of Longwall 15. Swamp re-saturated 2020-2021 but not to the same level as previously.	Partially mined under by Longwall 13 and by Longwall 14	Level 3
14	2	**Longwalls 15-18**	01, 02			Evidence for impact to swamp groundwater levels at 14_01 and 14_02 following Longwalls 16 and 15 respectively. Effects confirmed in post-Longwall 17 assessment. No further effects related to Longwall 18.	Partially mined under by Longwalls 15, 16 and 17	Level 3

15a	7	**Longwall 8, 19**	19	03, 04,	07, 12, 15, 18	Evidence for impact at 15a_19 following extraction of longwall 19.	Located 70 m from Longwall 17	Level 1
15b	4	**Longwall 7,8,19**	H1, H2, H3, 39			All four sites show evidence for impact; low saturation levels and high recession rates compared with reference sites. Impacts associated with Longwall 7.	Most of swamp directly mined under by Longwalls 7 and 8	Level 3
23	2	Longwalls 15-17	01, 02			Evidence for impact to swamp groundwater levels and duration of saturation at 23_01 and 23_02, following passage of Longwalls 15 and 16.	Partially mined under by Longwall 15, passed within 400 m by Longwalls 16 and 17.	Level 3
35a	1	**Longwalls 17,18**			01	No evidence of mining effects from Longwall 17 or 18.	Longwall 18 overlapped the northern fringes of the swamp	**n/a**
35b	1	**Longwall 18**	01			Increase in recession rate following passage of Longwall 18; Shallow groundwater levels below expected in early 2023 compared with previous and reference sites	Longwall 18 passed ~108 m from 35b_01.	**Level 3**
146	1	**Longwall 6, 7**	01			Site shows low levels of saturation and high recession rates compared with reference sites indicating impacts associated with Longwall 7, prior to installation of the piezometer.	Site directly mined under by Longwall 7 before installation.	Level 3
148		**Longwall 19**	01			WL dropped below piezo base on 20/11/2022 with no significant saturation since despite moderate rainfall in March 2023.	Longwall 19 passed within 38 m of 148_01	**Level 3**
149	0	**Longwalls 17, 18**			-	No shallow groundwater monitoring due to shallow soil profile. Swamp likely to be affected.	Longwall 17 passed directly beneath swamp.	**n/a**
150/151	2	**Longwall 18**		151_01	150-_01	Piezometers installed in 2021; Decline in groundwater levels at 150 in early 2023 likely related to dry conditions in this perched swamp.	Longwall 18 passed within 281 m of Swamp 150_01 and 436 of Swamp 151_01.	**n/a**

Note: “ i ” in site name (e.g. 04i) indicates installation during Longwall 9 extraction. * at these swamps which are located away from active or recent mining areas the data has been logged (recorded) at the piezometer, but not collected since that time.

6.2 Soil moisture

Significant changes in soil moisture characteristics compared with baseline monitoring is identified as an indicator of potential changes in ecosystem functionality of the swamps. Response trigger conditions related to soil moisture at swamp monitoring sites are listed in the SIMMCP (South32, 2020b), and reproduced in Table 36.

Table 36. TARP trigger conditions related to soil moisture at swamp monitoring sites

TARP Level	Trigger conditions	Response
1	Soil moisture level lower than baseline level at **any** monitoring sites (within 400 m of mining) within a swamp (in comparison to reference swamps).	Increased intensity and frequency of vegetation monitoring and/or further investigations of subsidence impacts on bedrock base and rockbars
2	Soil moisture level lower than baseline level at **50%** of monitoring sites (within 400 m of mining) within a swamp (in comparison to reference swamps).	
3	Soil moisture level lower than baseline level at **>80%** of monitoring sites (within 400 m of mining) within a swamp (in comparison to reference swamps).	

The TARP has been assessed by comparing the average moisture content of the soil profile during the longwall assessment period against that of the baseline period. If the average soil moisture level drops below the minimum level recorded during the baseline period, a TARP is triggered. The TARP level increases according to the proportion of monitoring sites that exceed this criterion at each swamp within the area of mine influence (Table 36). This is the same approach used by the IMCEFT for regular impact reporting. The baseline period is the period of monitoring before the site is first mined under or passed within 400 m.

Soil moisture hydrographs for all active monitoring locations are presented in **Appendix E**. Assessment of soil moisture hydrographs for locations within Areas 3A and 3B zone of influence (< 400 m) are presented in Table 37.

In relation to Swamps within the zone of influence for Longwall 19, average soil moisture levels declined to below baseline levels at piezometers at Swamp sites S148_01 and S15a_19, consistent with impacts to shallow groundwater, although the baseline period for logged data is limited for these sites. At site S15a_07, average soil moisture dropped below the pre-Longwall 19 baseline briefly in late 2022. Site S15a_07 is located 168 m from Longwall 19 and has limited baseline data. Average soil moisture level at S15_15 dropped slightly below pre-Longwall 19 baseline on 11/3/2023. These observations correspond to the following new TARP levels for Swamps within the Longwall 19 area of influence:

Swamp 15a: Level 2

Swamp 148: Level 3

Table 37. Cumulative assessment of soil moisture hydrographs in Areas 3A and 3B

Swamp	Longwall	Sensors and TARP triggers			Comment	TARP Level
		Not triggered	Triggered	Insufficient baseline or >400m		
05	9-11		S05_05, S05_01, S05_02, S05_08		All four sites show soil moisture decline below baseline after LW passed; baseline <2 y). Possible recovery at S05_S08.	3
08	9-11	S08_05			Soil moisture falls below baseline after undermining. *Not within mapped swamp boundary.*	n/a
11	13,14		S11_01, S11_02, S11_05		Soil moisture at all sensors dropped to lowest levels following LW13 and LW14. Likely mining effect, exacerbated by dry conditions. Some recovery in 2021.	3
12	6,7,8,19		S12_01, S12_04		Both sites record average soil moisture below Longwall 19 baseline; noting that the sites were previously mined under and impacted by Longwall 7	3
13	13,14	S13_03	S13_01, S13_02,		Soil moisture at all sensors dropped to lowest levels during 2017-2019 drought. Apparent recovery in 2020 and 2021 at S13_S03. Other sensors record lower moisture levels than baseline.	2
14	15-17		S14_01, S14_02		Soil moisture at S14_S01 below baseline in contrast to recovery at reference swamps 22, 85 and 86. S14_S02 shows lower moisture levels and durations compared with baseline and reference swamps.	3
15a	19	S15a_12, S15a_18	S15a_07, S15a_15, S15a_19	S15a_03, S15a_04,	Soil moisture in 3 out of 5 sensors within 400m dropped below baseline during review period.	**2**
15b	7,8,19		S15b_39	S15b_H1, S15b_H2, S15b_H3	Logging sensors installed after Longwall 8 passed beneath or near sites. Likely impacted.	1
23	15-17	S23_01 S23_02			No TARP trigger (previously Level 2). Both sensors show recovery in 2020 and 2021 with moisture levels varying within the baseline range.	-
34	19	S34_01			No TARP trigger following Longwall 19	-
35a	17,18	S35a_01			No TARP trigger	-
148	8, 19		148_01		Recoded average soil moisture below baseline from 11/2022 after the passage of Longwall 19	**3**
149	17,18	S149_01			Installed in 2021, insufficient baseline. No apparent effects	-
150	17,18	S150_01			No TARP trigger	-
151	18	S151_01			No TARP trigger	-

7. Conclusions

Longwall 19 is the fourth panel to be extracted from Dendrobium Area 3A, although the first since Longwall 8 in 2012. Extraction of Longwall 19 commenced on 20/06/2022 and was completed on 29/03/2023. Effects and potential effects on surface water flow, water quality and shallow groundwater levels are assessed as follows:

7.1 Effects on surface water quality

In general, stream salinity (EC) has decreased since 2020 and during the last four longwalls due to higher-than-average rainfall and significant increase in runoff compared with the preceding drought period (2017-2019). Similarly, Dissolved Oxygen (DO) has been generally elevated due to higher flows.

No new water quality TARPs were triggered in the review period; however, water quality TARPs remain triggered at Lake Avon tributary site LA4_S1 for EC, pH and DO as a result of impacts related to Area 3B. Anomalous water quality effects are noted in streams that have been directly mined under by previous longwalls (e.g. WC21, SC10C, LA4, Donalds Castle Creek). Those effects include transient or persistent increases in EC, increases (or decreases) in pH and increases in dissolved metal concentrations such as Fe, Mn, Al and Zn.

Analysis of flow-corrected trends in water quality indicate increasing EC, sulphate and manganese at WC_FR6, despite generally declining EC in non-flow-corrected data. Flow-corrected trends in EC, pH, Mn, Zn and Al are evident at DCC_FR6. At Sandy Creek Rockbar 5, flow-corrected EC, sulphate, Fe, Mn and Zn remain above baseline levels due to upstream contributions from SC10C which was mined under by Longwalls 7 and 8.

Over the last three years, new or recurrent iron staining has been noted on Wongawilli Creek, WC21, LA5 and SC10C, WC14 and WC15. The increase in iron staining is partly related to increasing groundwater levels due to high rainfall. It is expected that the occurrence of iron seeps will decline as drier conditions return.

7.2 Effects on surface water flow

Surface water flow TARPs were reviewed in 2019 in consultation with relevant government agencies and based on recommendations of the IEPMC (Watershed HydroGeo, 2019a). Key features of the updated TARPs are:

A. A move to rely on comparison of flows recorded at relevant sub-catchment monitoring sites around the Dendrobium mining area against selected reference sites, rather than relying on rainfall-runoff modelling.

B. Assessment of sub-catchment hydrology against a number of different indicators that are considered appropriate to identifying and quantifying potential effects on the broad hydrological behaviour within each sub-catchment, effects on cease-to-flow conditions that may be significant to ecological values, and effects on median flow which is a proxy for the water resource potential.

C. A further assessment has been implemented to analyse the mining effects on low-flows that are known to occur along the “middle reach” of Wongawilli Creek, between Area 3A and 3B.

The results of Assessments A, B and C are summarised on Table 38.

The assessments indicate that sub-catchments in the upper part of the Donalds Castle Creek catchment (i.e. DC13S1 and DCS2) have been and continue to be affected by mining findings for DC13S1, DCS2 (both at Level 3 for all three flow assessments) are similar to those for the EoP report for Longwalls 15-18.

Lake Avon tributaries LA4, LA3 and LA2, have been affected by mining. The effects at LA2 are intensifying(one Level 1 and two Level 3 trigger at LA2 compared to Level 3 for all assessments at the other two sites), and are recent, occurring as a result a Longwall 18 and strengthening slightly during the Longwall 19 period (although based on distance, not affected by Longwall 19 extraction).

Similarly, the flow characteristics at WC21S1 and WC15S1 within the Wongawilli Creek catchment have altered as a result of mining with these sites at Level 3 for two out of three assessments. As with the sub-catchments above, the effects at WC21 and WC15 are similar to those for the previous End of Panel reports. Regarding WC12, despite Longwall 16 terminating within 50 m of and the end of Longwall 17 mining under WC12 respectively, and based on comparison against Reference Sites there are no mining-related effects discernible beyond natural variability/method accuracy (although rainfall-runoff modelling suggests a Level 1 impact), and this has persisted for the Longwall 18 and 19 assessment periods.

Native Dog Creek tributary ND1 (ND1S1) shows no clear sign of effects beyond natural variability when comparing against Reference Sites, although comparison against a rainfall-runoff model suggests a Level 2 impact (which we consider lower reliability given the difficulty in calibrating the model for this subcatchment). The site on the main watercourse (Native Dog Creek site (NDCS1) is slightly upstream of the ND1 tributary confluence with Native Dog Creek. There is only a short pre-mining baseline record available at NDCS1 which limits reliability, however there is no indication of a mining effect beyond natural variability from nearby Dendrobium Longwall 18 at NDCS1.

Sandy Creek and tributaries are assessed formally for the first time due to mining moving back to Area 3A (Longwall 19). Tributary SC10C was clearly affected by mining of Longwalls 7-8 in 2012, including obvious iron-staining effects. The current assessment indicates that SC10C still triggers Level 2 (cease-to-flow) and Level 3 (median flow), although restricting the assessments to a more recent period (since 2017) indicates that in terms of water quantity (flow) effects, flows in this tributary would not trigger the TARP assessments. Tributary SC10 has not triggered any of the three assessments, while SCL2/GS2122205 shows signs of a mild increase in cease-to-flow frequency.

As in recent EoP reports, analysis indicates that mild mining effects are probable at the Donalds Castle Creek downstream monitoring site (DCU). Specifically, the TARP assessments indicate that the general pattern of flow (Assessment A) and the median flows (Assessment C) do not trigger, which suggest that any mining effects or impacts on those indicators are of similar magnitude or less than natural variability. However, the Assessment B, which examines cease-to-flow duration and frequency, indicates that the watercourse at DCU has been experiencing a mild increase (Level 1) in the number of cease-to-flow days compared to the Reference sites. This finding has been consistent for Longwalls 14-19 periods.

Changes to stream flow characteristics are not evident at the downstream gauge on Wongawilli Creek Lower (WWL), despite mining-related effects being clear and significant at upstream tributaries (e.g. WC21, WC15). This suggests that some or all flow lost in headwater catchments is returned downgradient, or that upstream diversions or losses are not significant in relation to the larger catchment water balance given the natural variability and the accuracy of flow measurements. These possible reasons are even more relevant at DCU, where the losses identified in upstream sites DC13S1 (0.1 ML/d) and DCS2 (0.09 ML/d) are >70%% of median flow (Q50) at DCU. Such losses should be clearly apparent at DCU if they were transmitted downstream, but the assessment has not detected a change in median flow at DCU beyond natural variability (i.e. variability at two Reference sites).

Similar behaviour is now observed at Sandy Creek sites. Reductions in Q50 at site SC10CS1 trigger Level 3, but SC10CS1 did not trigger at downstream site SC10S1, although it was close to doing so, and no reductions in Q50 were evident at the downstream site GS2122205.

Analysis of available surface water flow observation records for Wongawilli Creek did not trigger TARP Assessment D for any of the months assessed during the Longwall 19 period.

Table 38. Areas 3A and 3B watercourse flow assessment summary

Site	Water-course	Area	Date mining occurred under sub-catchment	A) Low flow Q%ile outside Reference Site Q%ile		B) Cease-to-flow frequency (beyond natural)		C) Change Q50 (beyond natural) as % of pre-mining Q50			Rainfall-runoff model comparison	Comment
				Change %	TARP Level	Change %	TARP Level	Change ML/d	Change %	TARP Level		
DC13S1	DC13	A3B	09/02/2013	56%	L3	13%	L2	-0.10	-79%	L3	n/a	Effects are similar to those following LW14-18.
DCS2	Donalds Castle Creek	A3B	10/07/2013	54%	L3	29%	L3	-0.09	-56%	L3	n/a	Effects are similar to those following LW14-18.
DCU	Donalds Castle Creek	A3B	09/02/2013	-13%	Not triggered	7%	L1	+0.11	52%	NT	NT	Effects are similar to those following LW14-18.
WC21S1	WC21	A3B	05/10/2013	33%	L3	9%	L1	-0.38	-39%	L3	n/a	Effects are similar to those following LW15-18.
WC15S1	WC15	A3B	28/01/2017	38%	L3	13%	L2	-0.10	-69%	L3	n/a	Similar to LW15-18. (Changes to low flow accuracy means that Assessment B not completely reliable.)
WC12S1	WC12	A3B	18/10/2020	-4.9%	NT	-14%	NT	+0.03	313%	NT	Level 1	Second panel under catchment. No discernible effect.
WWL	Wongawilli Creek	d/s 3A-B	09/02/2010	0%	NT	-5%	NT	+0.27	8%	NT	NT	Effects are similar to those following LW14-18.
WWLA	Wongawilli Creek	d/s 3A-B	09/02/2010									
LA4S1	LA4	A3B	01/04/2015	31%	L3	36%	L3	-0.07	-83%	L3	n/a	Effects similar to those after LW17-18. Low flows are reported to greater accuracy in post-mining period, so Method B modified slightly.
LA3S1	LA3	A3B	28/04/2019	45%	L3	27%	L3	-0.07	-448%	L3	n/a	Effects are similar to those following LW16-18.
LA2S1	LA2	A3B	01/03/2020	26%	**↑L3**	7%	L1	-0.02	-851%	L3	n/a	Effects are similar to those following LW16-18. Reduction in Q50, and slight change in low flow.
NDS1	ND1	A3B	18/04/2021	1%	**NT**	-17%	**NT**	+0.14	603%	**NT**	Level 2	No discernible effect, as for LW18.
NDCS1	Native Dog Ck	A3B	12/02/2022	-25%	**NT**	0%	**NT**	+1.8	173%	**NT**		No discernible effect due to Dendrobium, but short baseline
SC10CS1	SC10C	A3A	17/09/2011	-1%	**NT**	17%	**L2**	-0.08	-22%	**L3**	n/a	Although still Level 2&3 for two indicators, this site shows signs of recovery.
SC10S1	SC10	A3A	17/09/2011	1%	**NT**	3%	**NT**	-0.04	-3%	**NT**	NT	No discernible effect, as for previous LWs
GS 2122205	Sandy Ck	A3A	17/09/2011	-3%	**NT**	8%	**L1**	-0.02	-1%	**NT**	NT	Minor effect on low flows, no other discernible effect.

Bold indicates a change from previous assessment (or newly added assessment), and ↑↓ = direction of change.

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7.2.1 Effects at Waterfall WF54

Detailed analysis of a potential change in hydrological behaviour at WF54 was investigated in late 2022 (Watershed HydroGeo, 2022). This found that some erroneous data was responsible for previous inference of a change in hydrology. The analysis has been repeated for the period to May-2023, and no change in hydrology at this site is apparent from the comparison with data from an upstream Reference Site.

7.2.2 Performance Measures

Performance Measures related to surface water flow in Area 3A and 3B were assessed (Section 5.5) as follows:

Wongawilli Creek – minor environmental consequences
This Performance Measure is met.

Donalds Castle Creek – minor environmental consequences
This Performance Measure is met.

Lake Avon – negligible reduction in the quantity of surface water inflows to Lake Avon
This Performance Measure is met.

Cordeaux River – negligible reduction in the quantity of surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek
This Performance Measure is met.

Sandy Creek – minor environmental consequences
This Performance Measure is met.

Lake Cordeaux – negligible reduction in the quantity of surface water inflows to Lake Cordeaux
This Performance Measure is met.

7.3 Effect on watercourse pool levels

Pools along Wongawilli Creek and Sandy Creek SC10 were observed to be full and flowing during the review period. No pools along these watercourses have become dry as a result of mining.

Despite remaining full during the review period, water levels at SC10_Pool29 appear to have declined from levels observed prior to 2016 and water levels declined on several occasions in Pool SC10_Pool26a before recovering. Those pools are within the Longwall 19 area of potential influence at distances of ~270 and ~210 m. Recent inspections have found no evidence for subsidence impacts at the SC10_Pool29, nor elsewhere along the watercourse. It is recommended that IMC reviews relevant pool hydrographs again in the next EOP report.

The upper reaches of WC14, at and above Pool 16 were directly mined beneath by Longwall 19. Pool 16 ceased to flow and became dry following the passage of Longwall 19 beneath the site, as is common for watercourses directly mined beneath. Water levels and outflow status of the downstream Pool 3 remains unaffected.

7.4 Effects on swamps

It was predicted that subsidence related to Longwall 19 would likely result in shallow groundwater levels impacts in approximately 7% of the area of Swamp 15a and most of Swamp 148. Other swamps within 400 m of Longwall 19 (Swamps 12 and 15b) were previously impacted by subsidence at Area 3A but may experience further effects due to LW19.

A review of shallow groundwater hydrographs at swamp sites within the area of influence of Longwall 19 indicates mining subsidence effects at site 148_01 and a likely effect at site 15a_19, triggering additional swamp TARP Level 3 for Swamp 148 (single piezometer) and Level 1 for Swamp 15a (one of five piezometers). Mining related effects related to previous Area 3A longwalls are evident at Swamps 12, 15b and 146 (>400m from Longwall 19), for which TARP Levels 3 remain.

A reassessment of swamp sites within the area of influence of Longwall 18 indicates that shallow groundwater levels at site 35b_01 are likely to have been affected by mining related fracturing and/or drawdown within the sandstone substrate. The impact results in a TARP Level 3 for Swamp 35b.

Shallow groundwater levels and soil moisture levels in reference swamps have been generally high since 2020. Within the zone of influence for Longwall 19, average soil moisture levels declined to below baseline levels at piezometers at Swamp sites S148_01 and S15a_19, consistent with impacts to shallow groundwater. In addition, average soil moisture dropped below the pre-Longwall 19 baseline at sites S15a_07 and S15a_15 within 400m of Longwall 19, corresponding to TARP Level 2 for Swamp 15a and Level 3 for Swamp 148.

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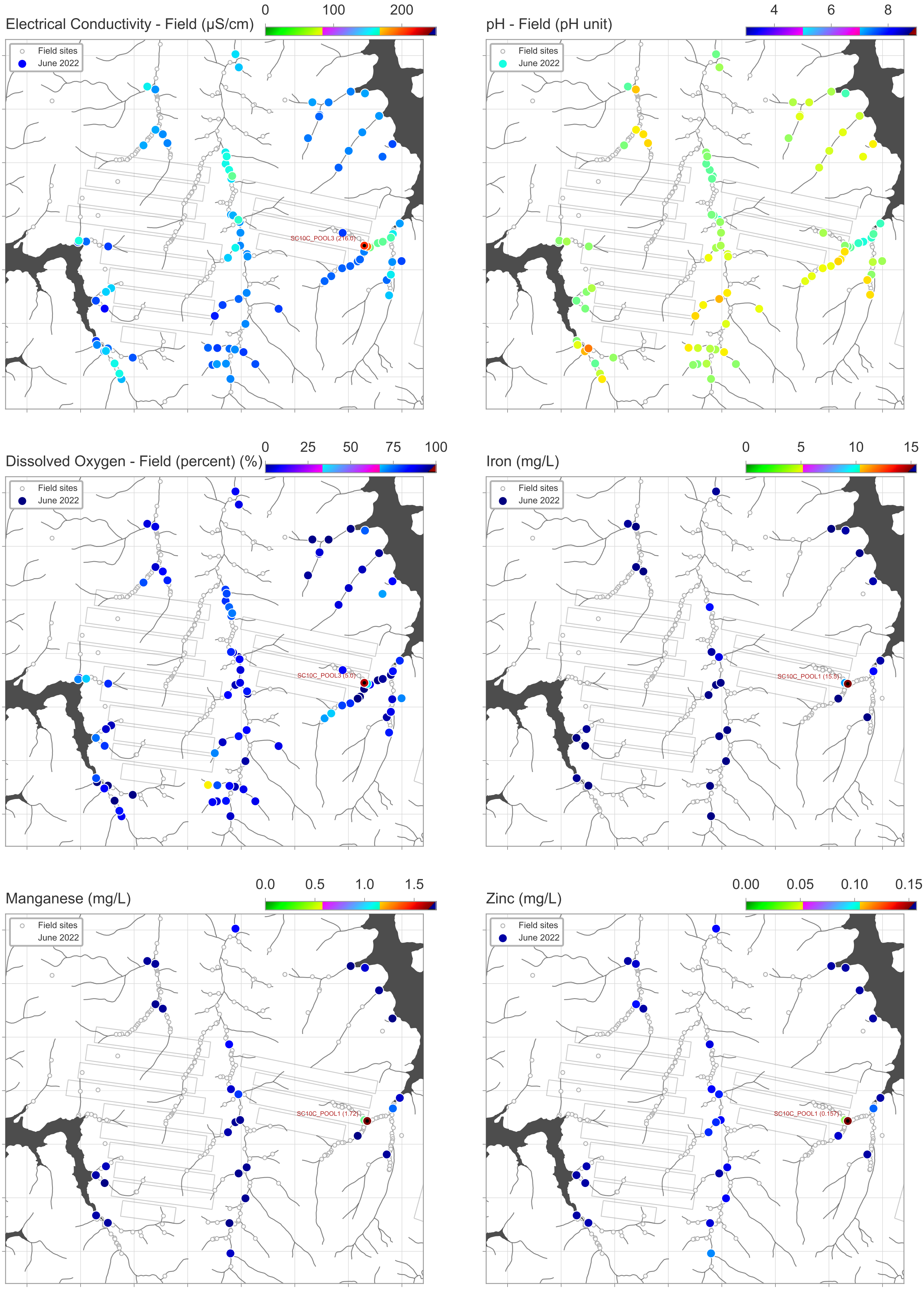
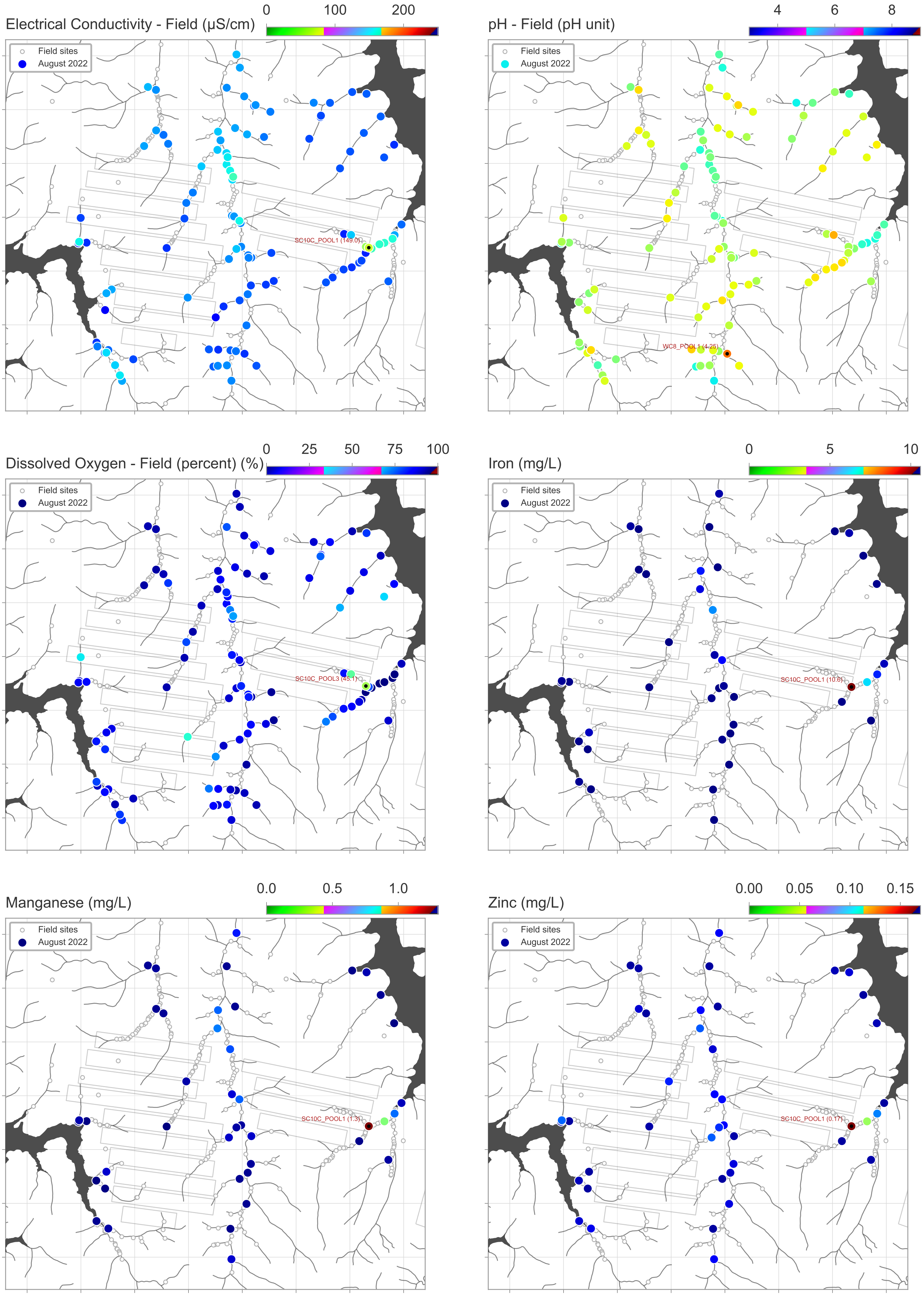
Appendix A1: Water quality hydrographs

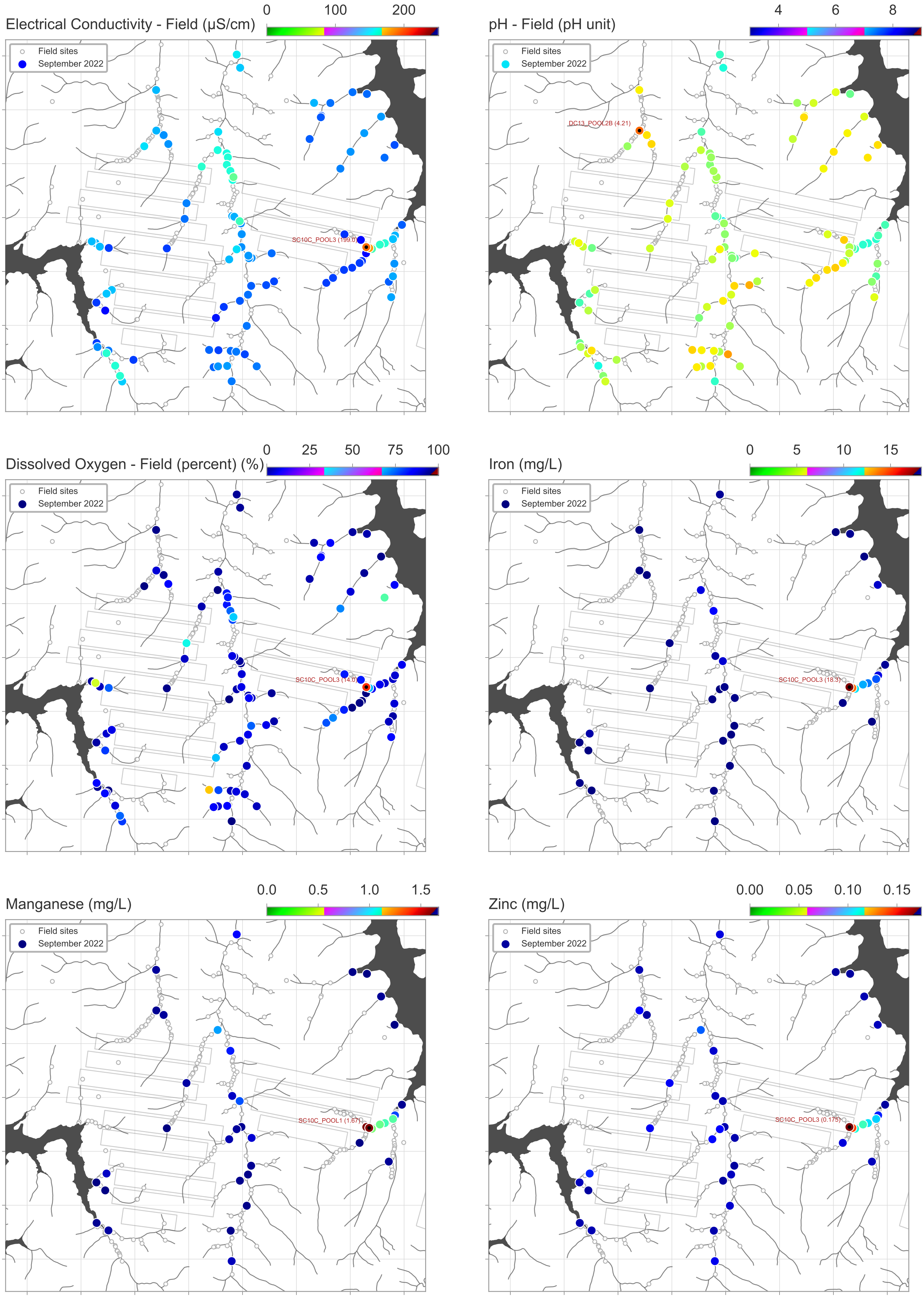
Dendrobium stream water quality June 2022



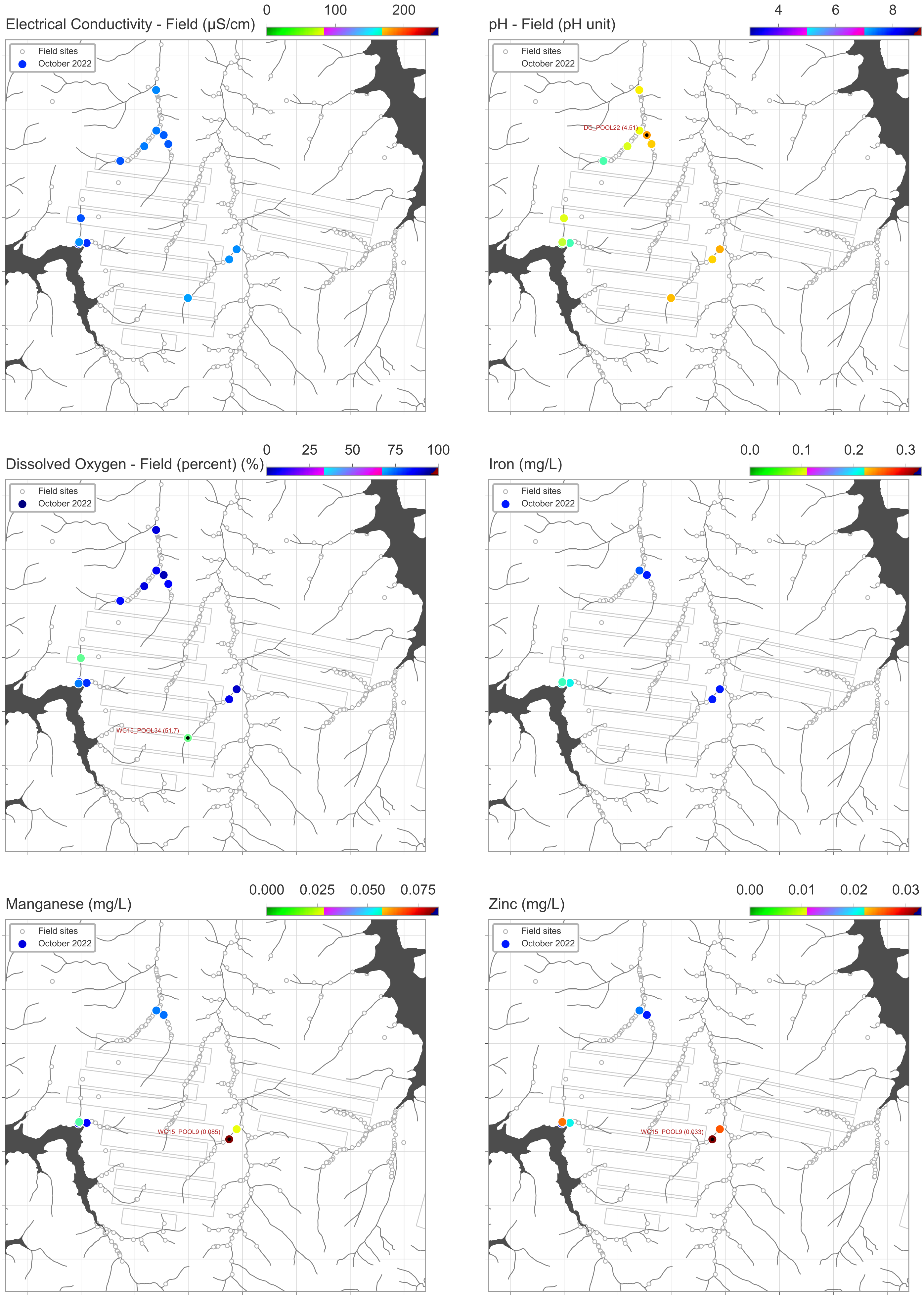
Dendrobium stream water quality August 2022



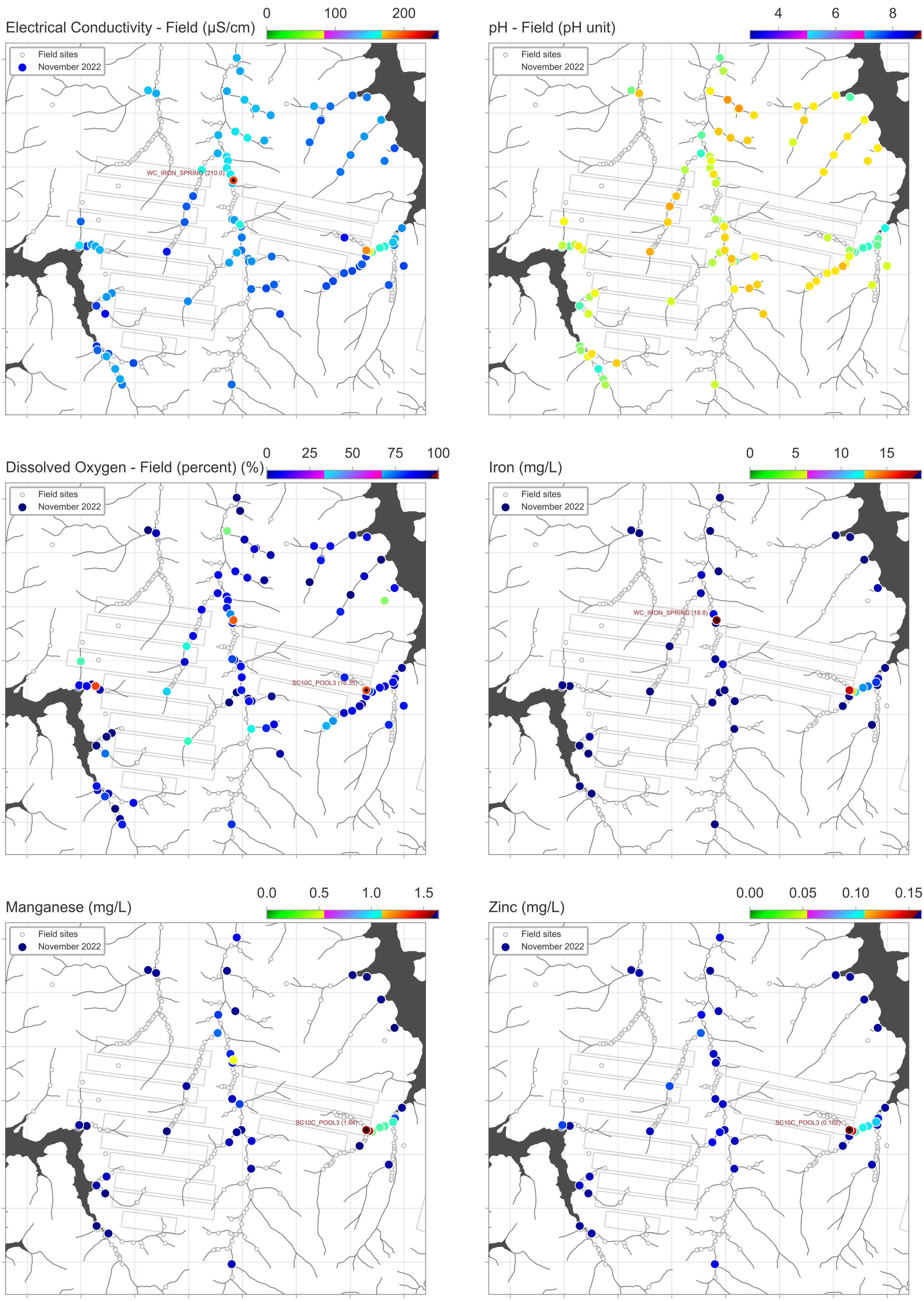
Dendrobium stream water quality September 2022



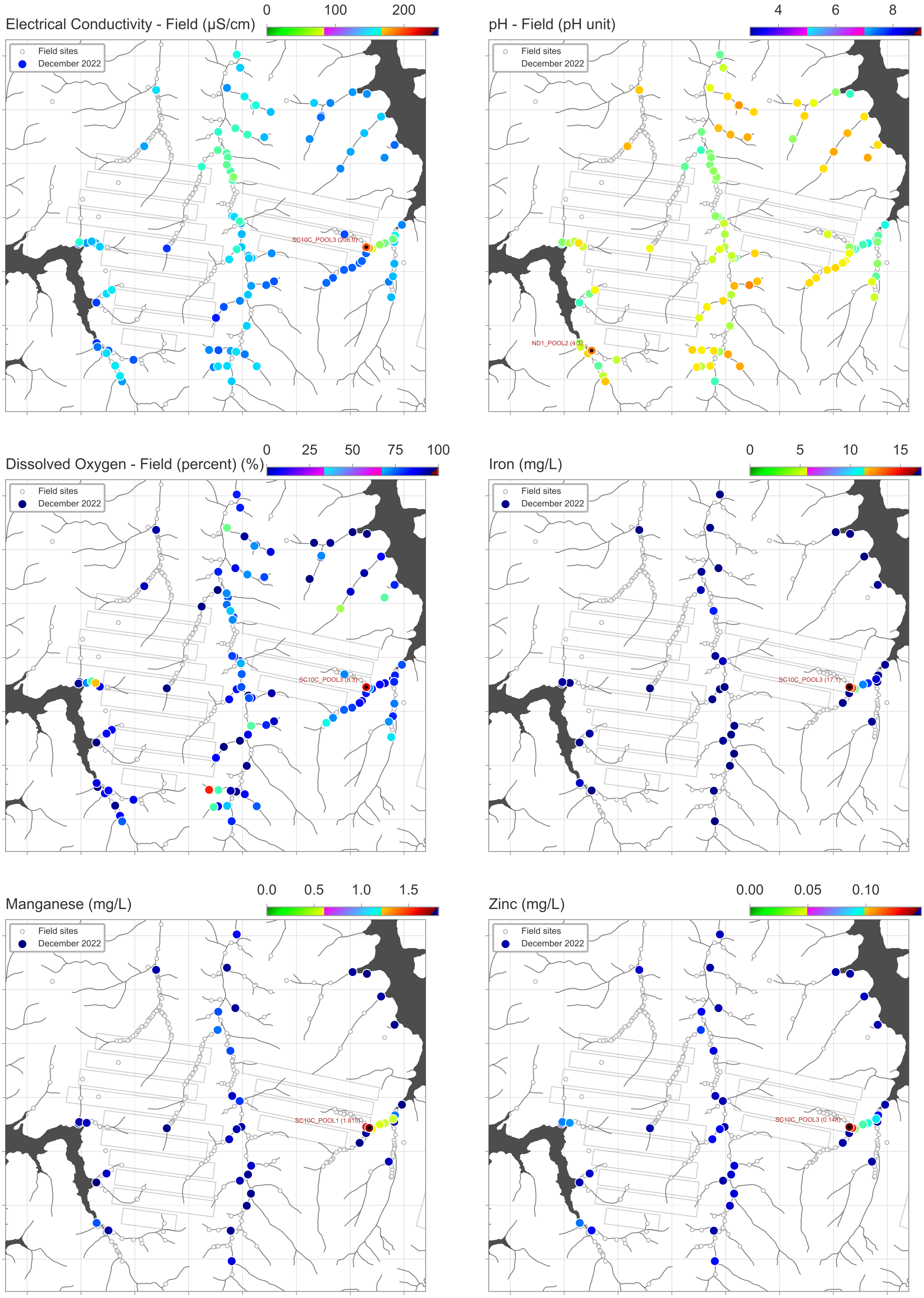
Dendrobium stream water quality October 2022



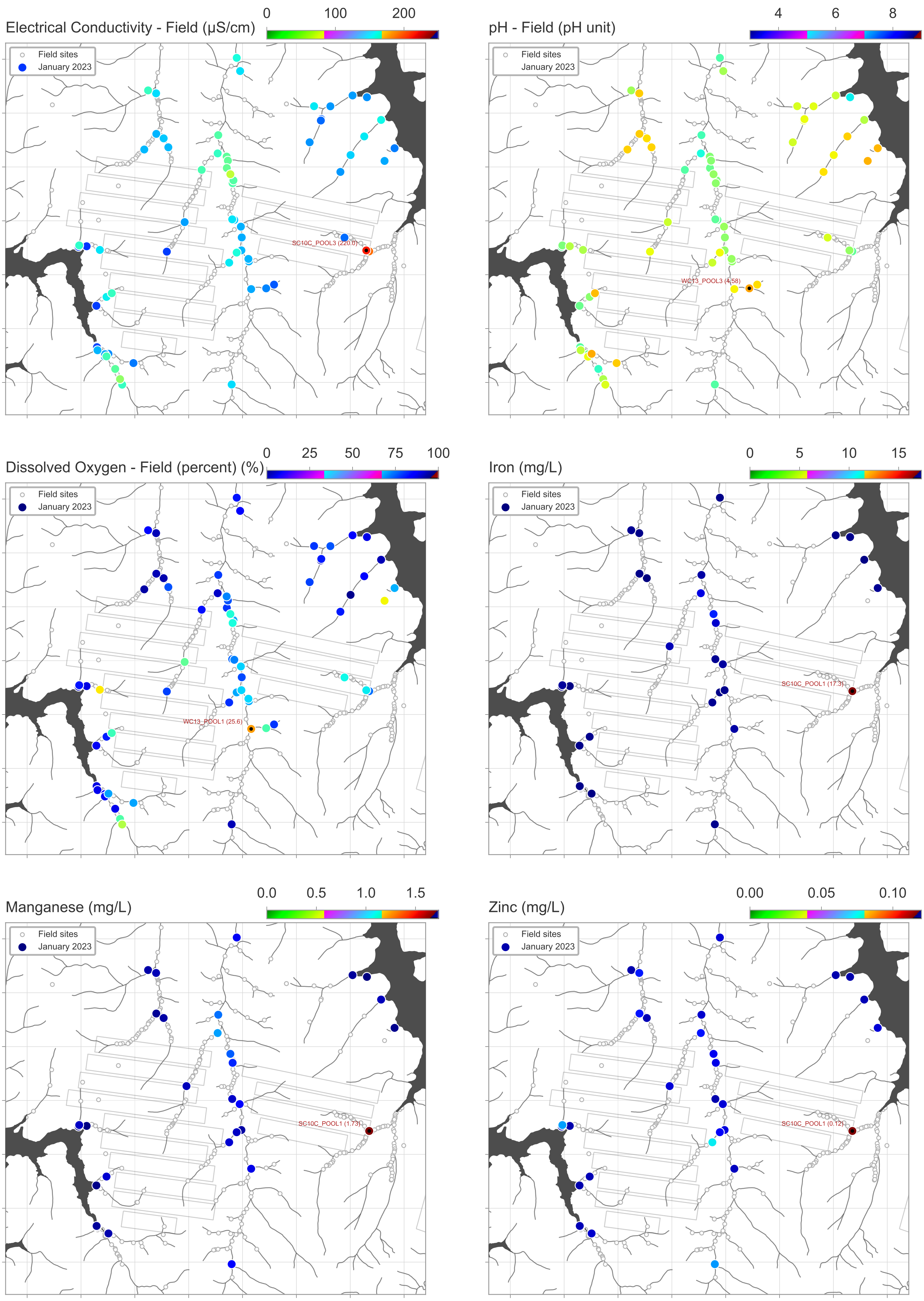
Dendrobium stream water quality November 2022



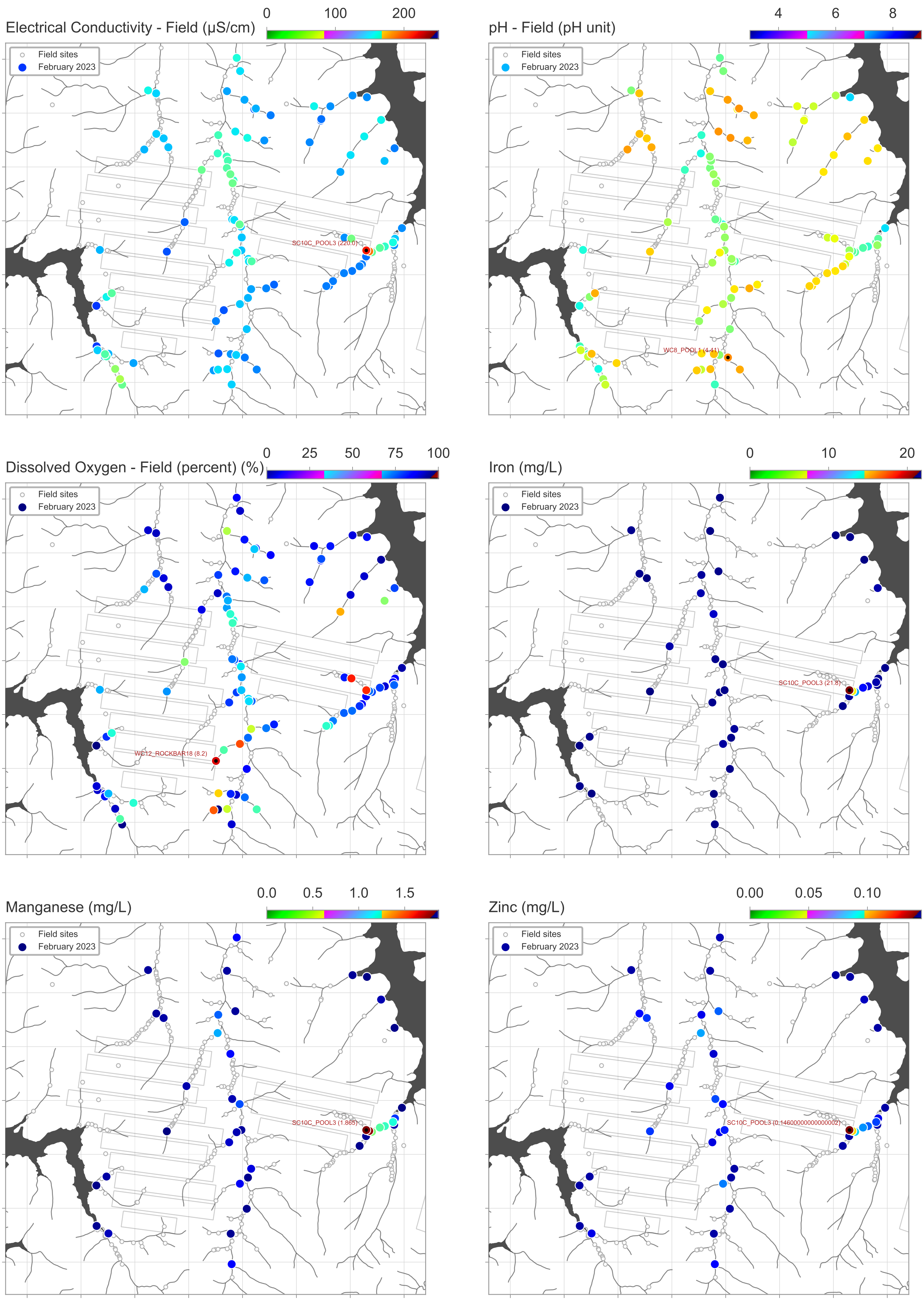
Dendrobium stream water quality December 2022



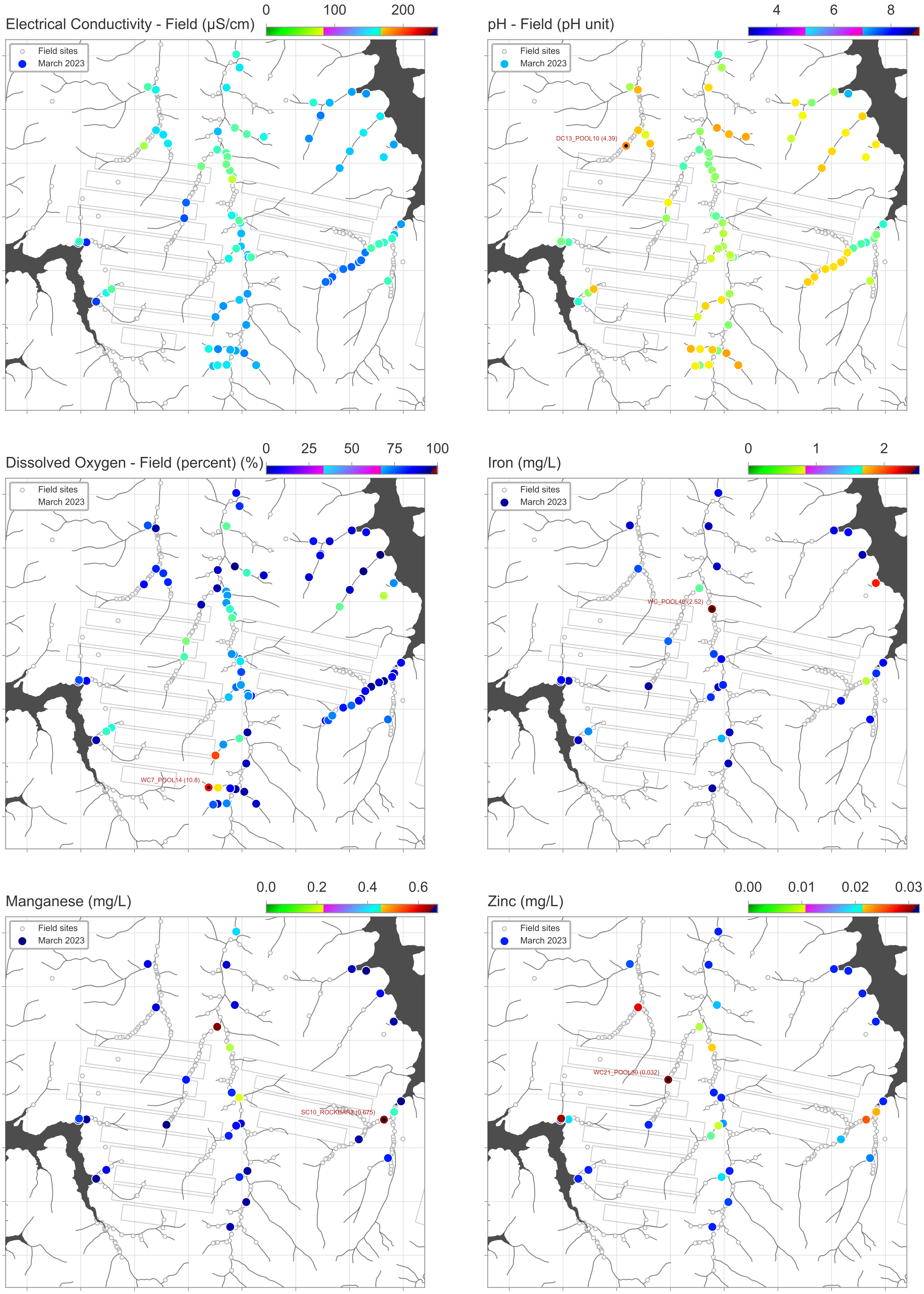
Dendrobium stream water quality January 2023



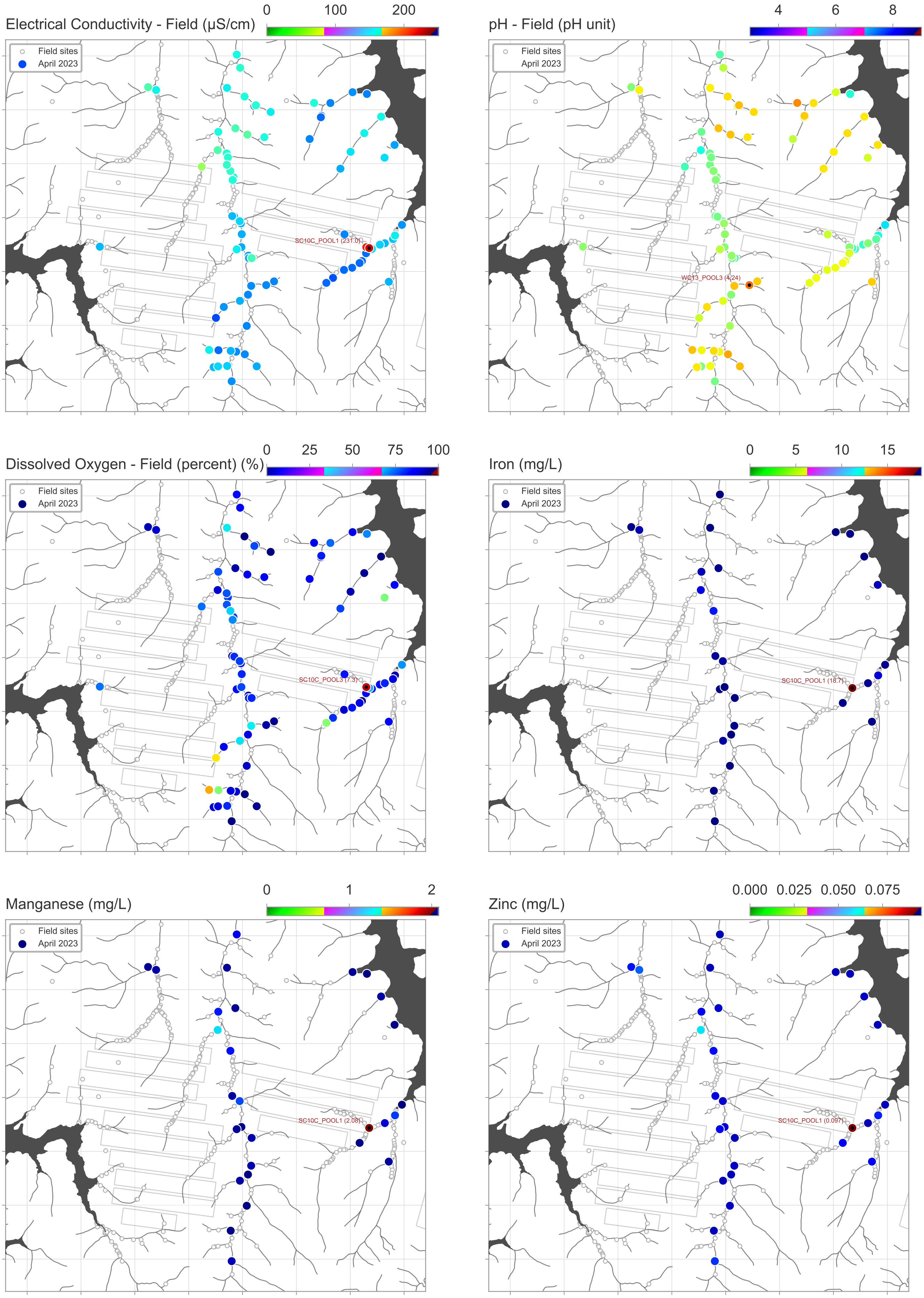
Dendrobium stream water quality February 2023



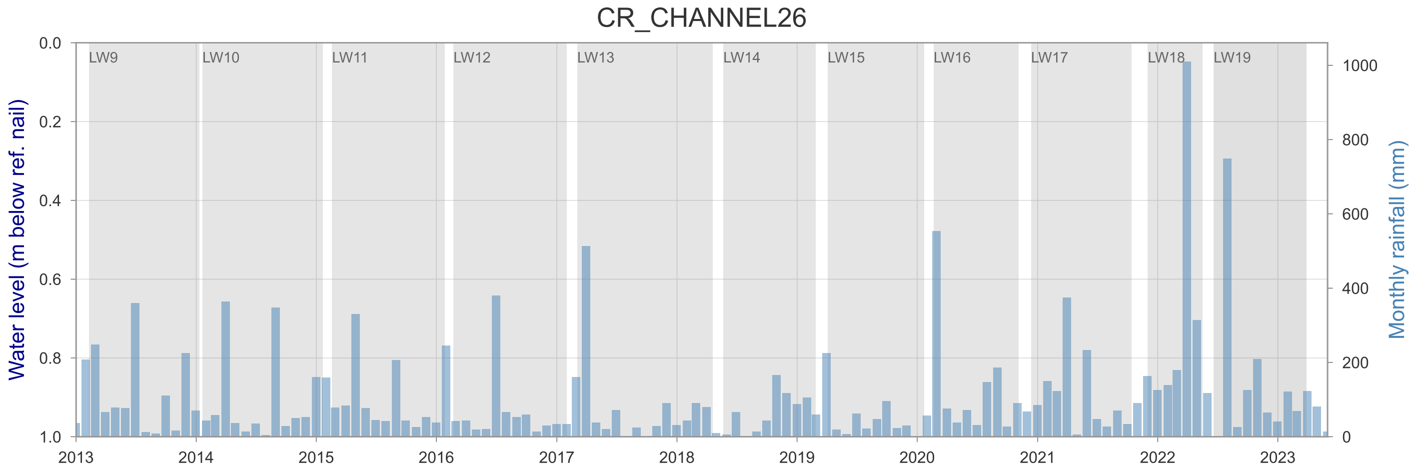
Dendrobium stream water quality March 2023

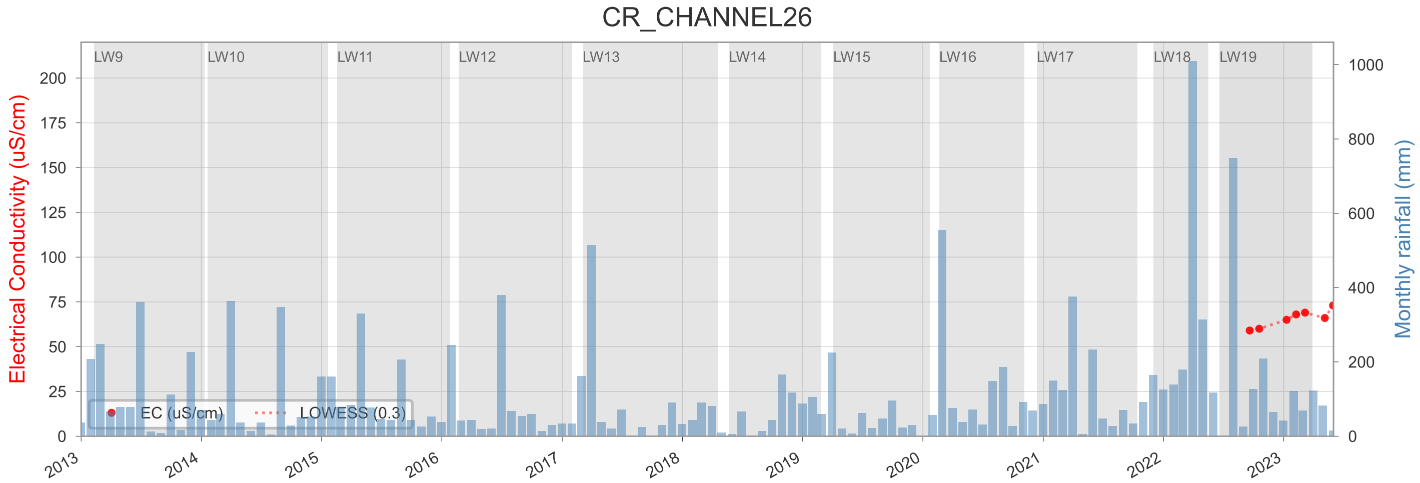


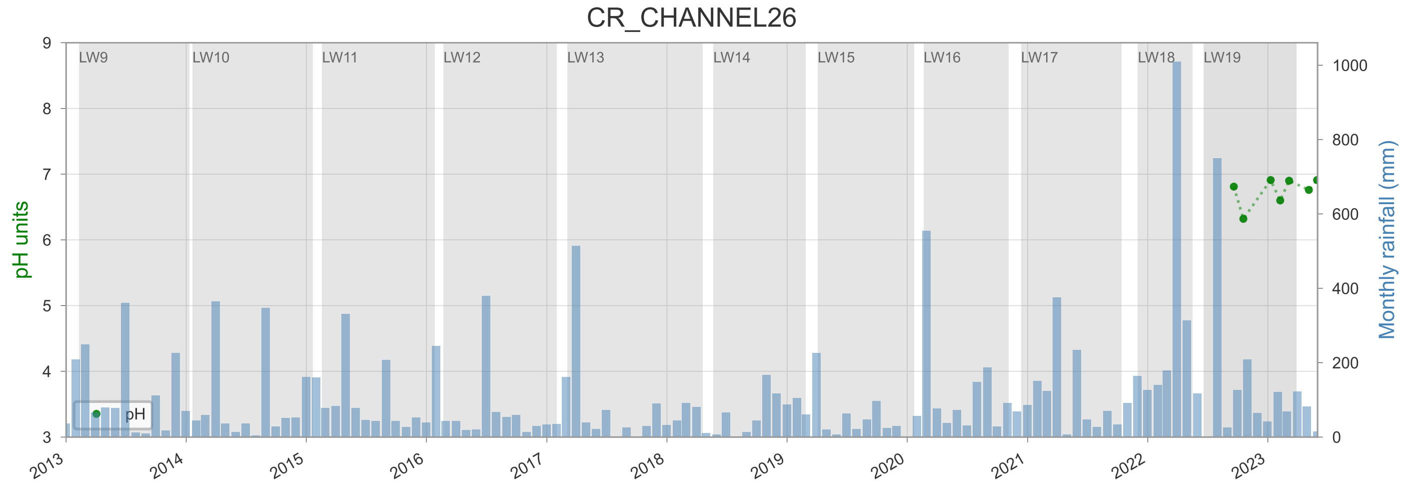
Dendrobium stream water quality April 2023

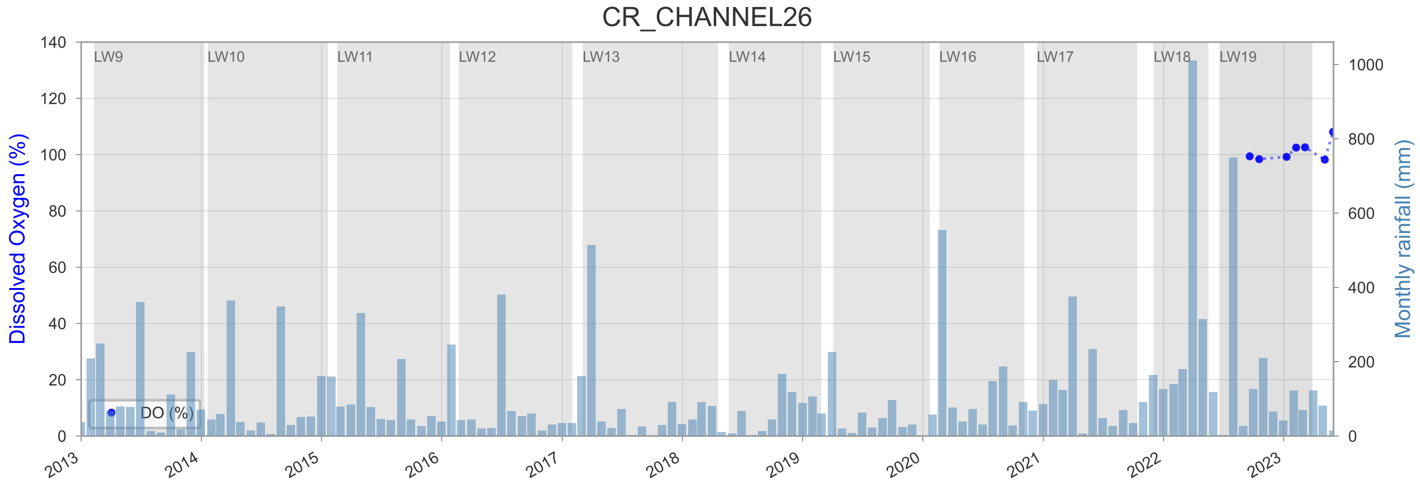


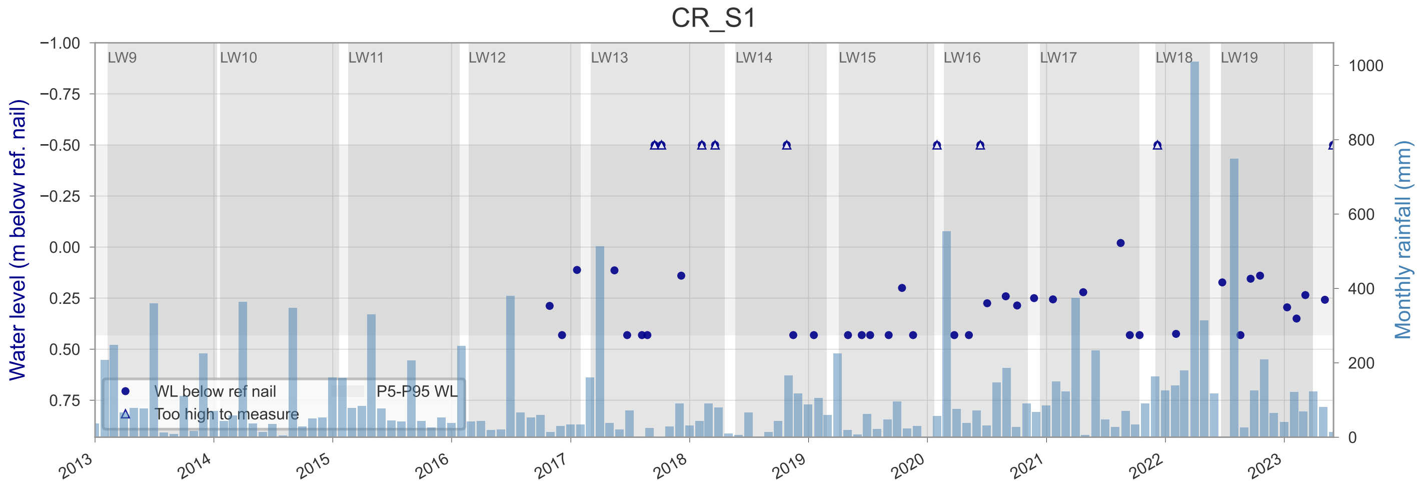

AR19S1
Stream flow (ML/day)
Monthly rainfall (mm)
Flow (ML/d)
P5-P95 flow
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
AR19_S1
Electrical Conductivity (uS/cm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)
AR19_S1
pH units
pH
P5-P95 pH
Median (baseline)
AR19_S1
Dissolved Oxygen (%)
DO (%)
P5-P95 DO
Median (baseline)

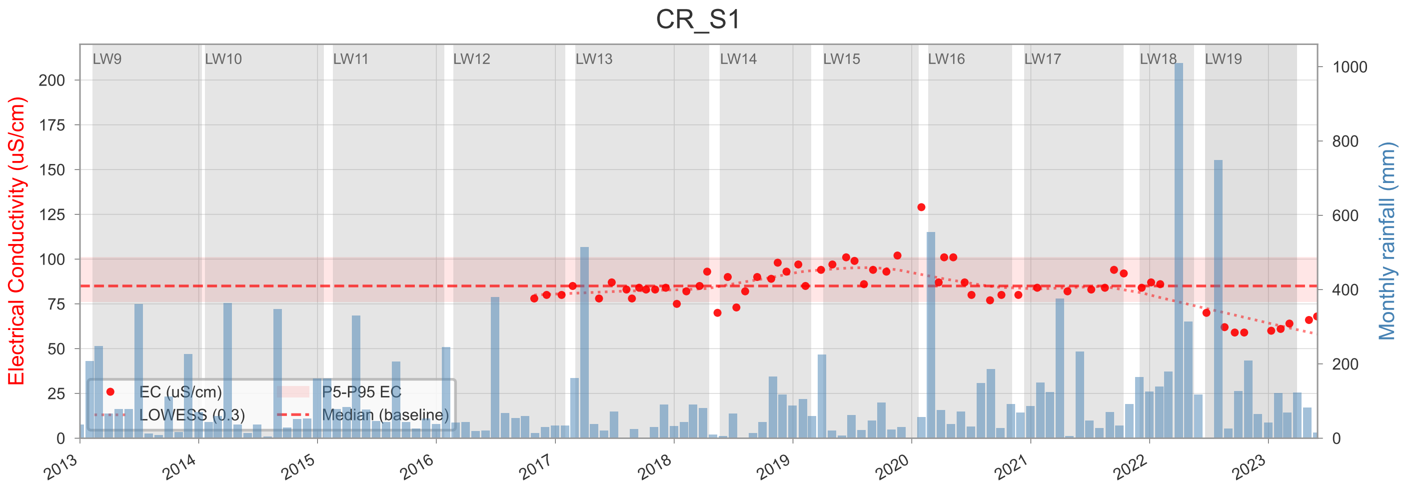

CR_CHANNEL26
Water level (m below ref. nail)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

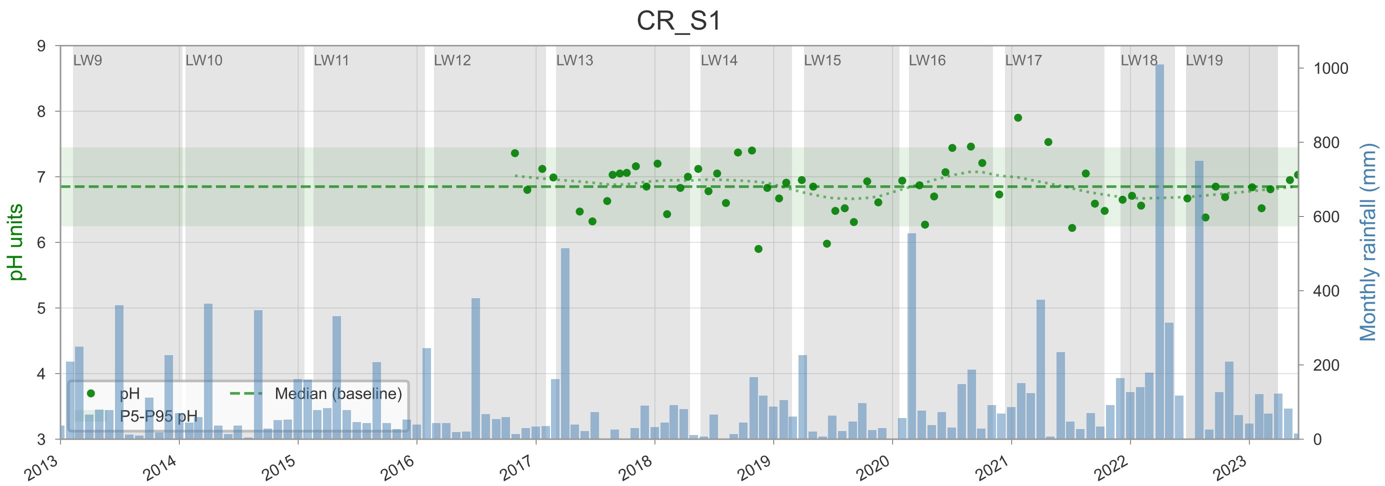

CR_CHANNEL26
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

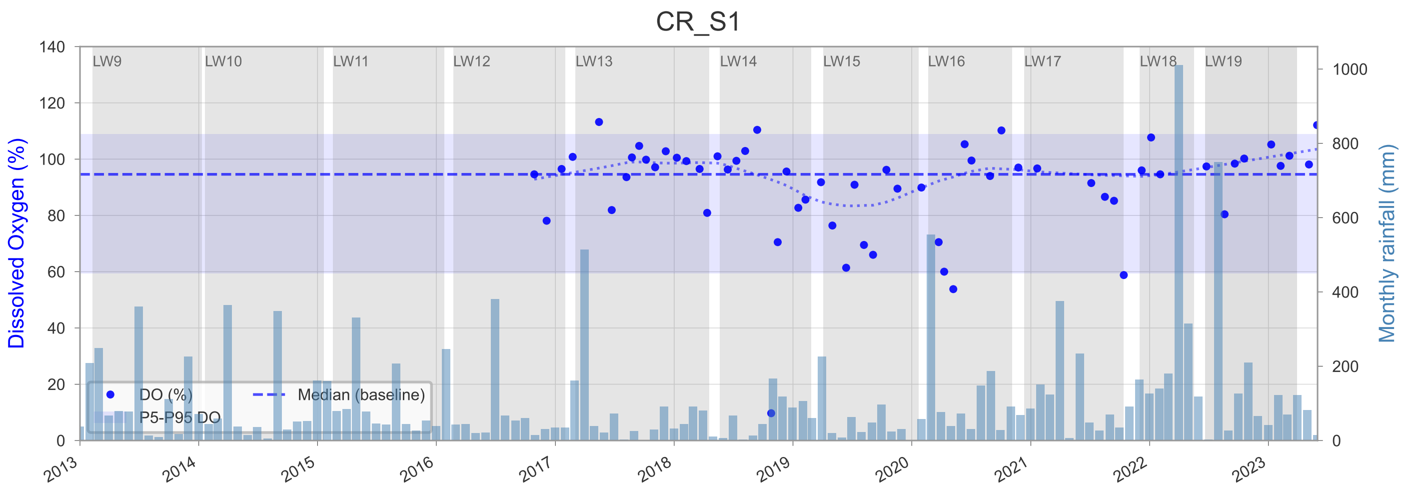

CR_CHANNEL26
pH units
Monthly rainfall (mm)
pH
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

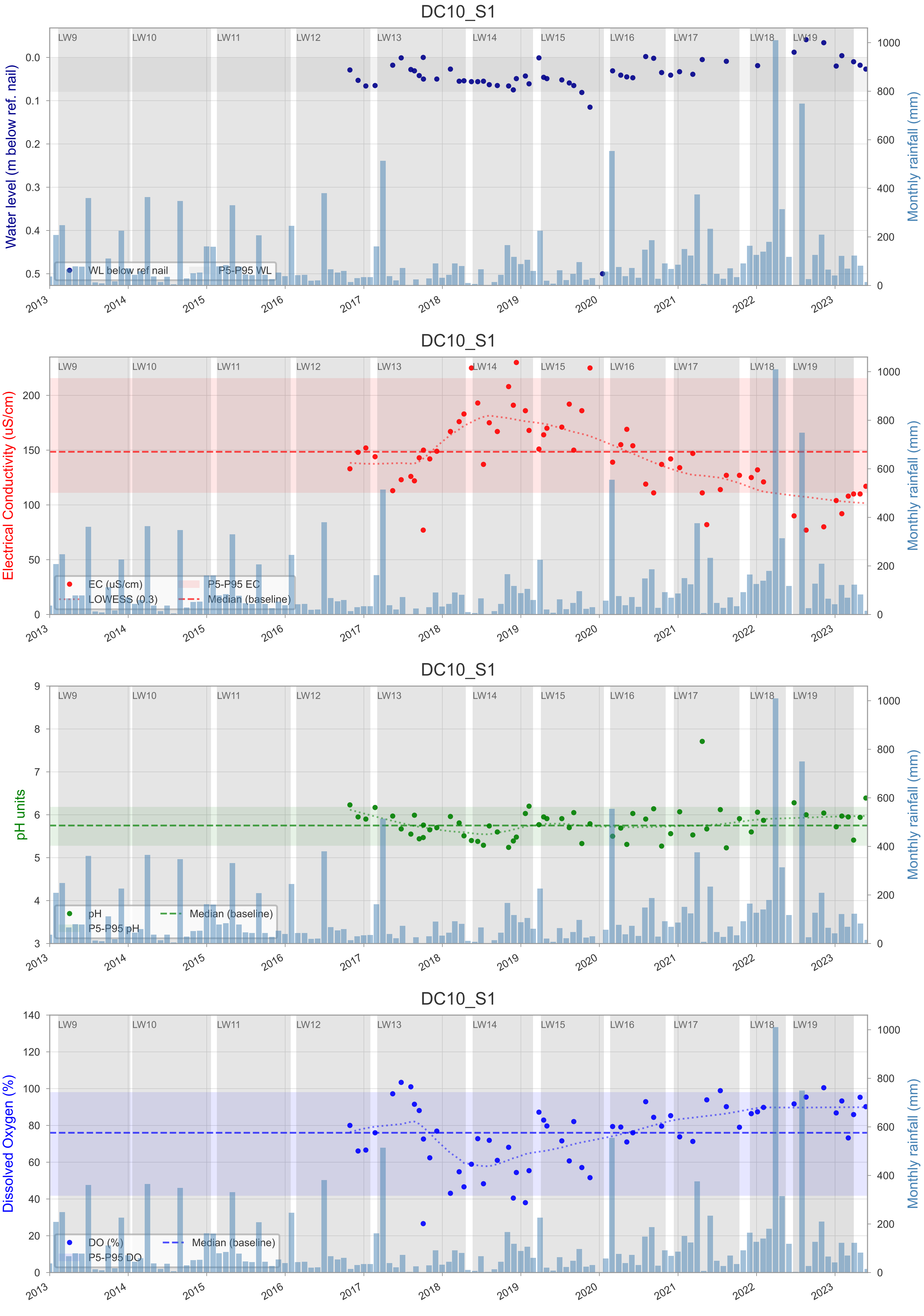

CR_CHANNEL26
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19


CR_S1
Water level (m below ref. nail)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
Too high to measure
P5-P95 WL

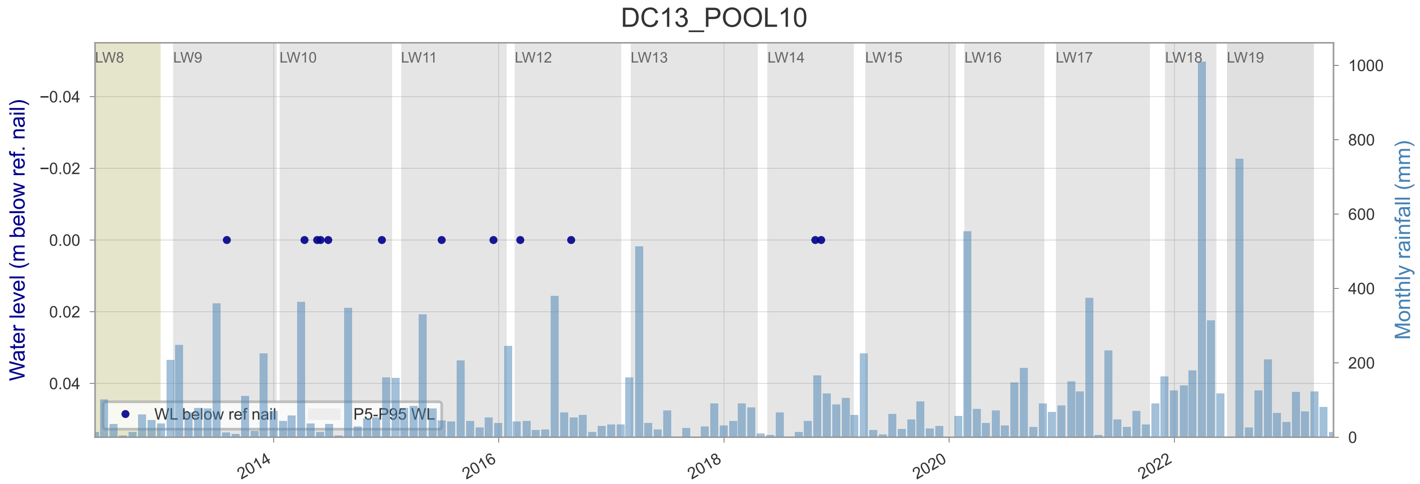

CR_S1
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

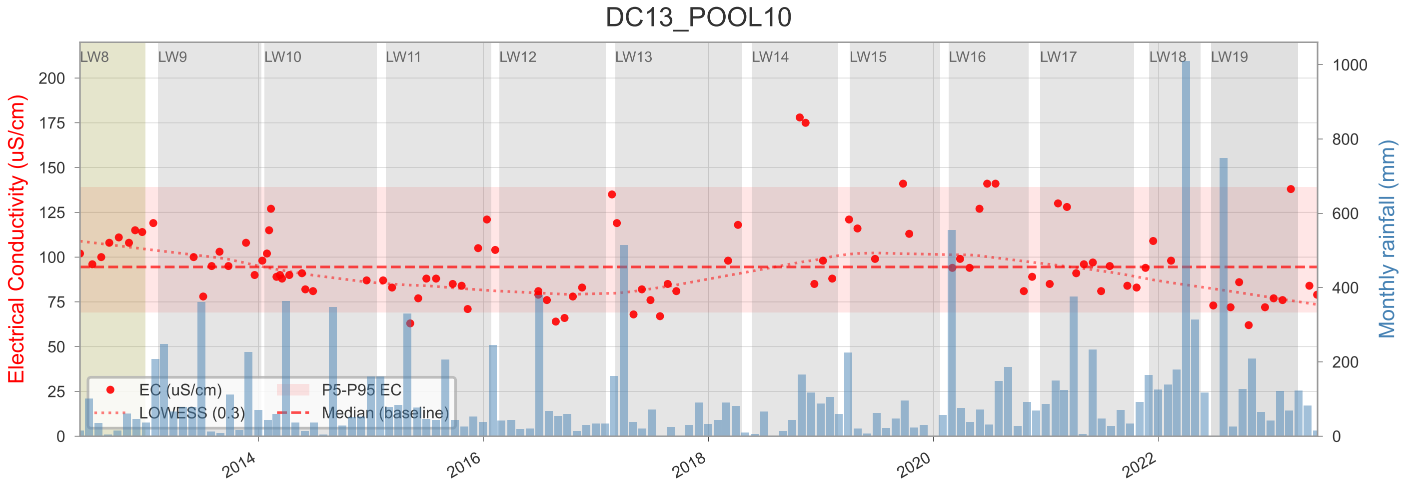

CR_S1
pH units
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH
P5-P95 pH
Median (baseline)

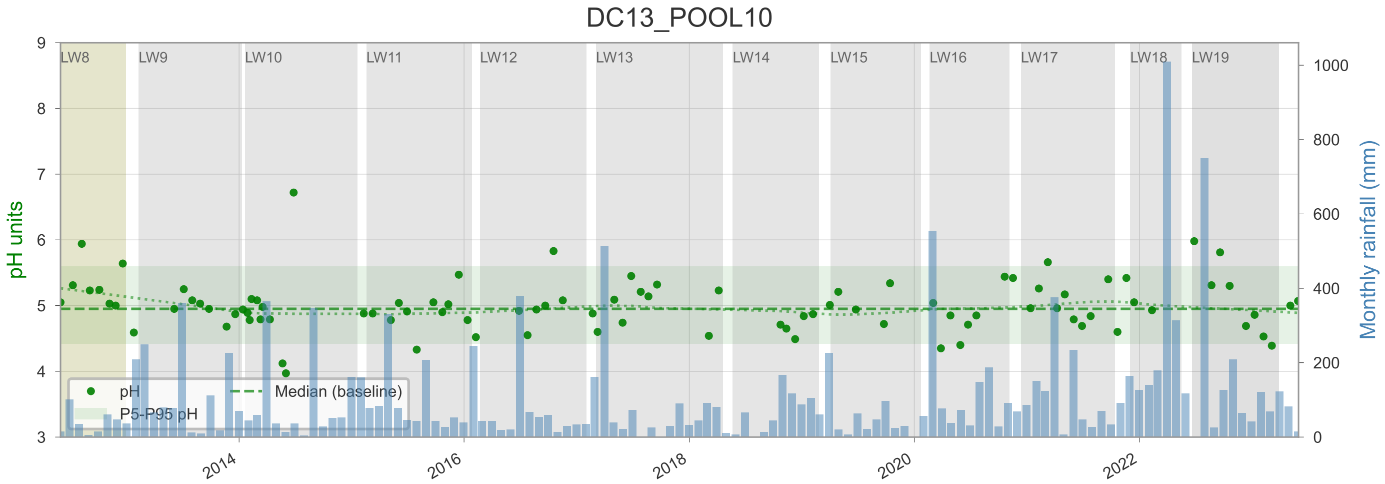

CR_S1
Dissolved Oxygen (%)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
DO (%)
P5-P95 DO
Median (baseline)

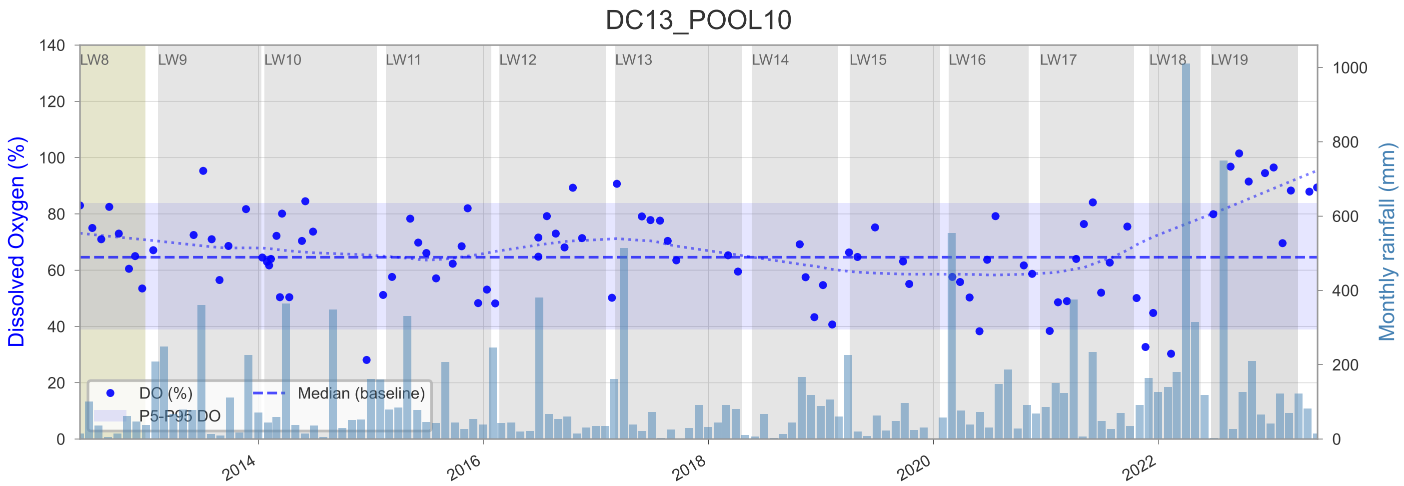


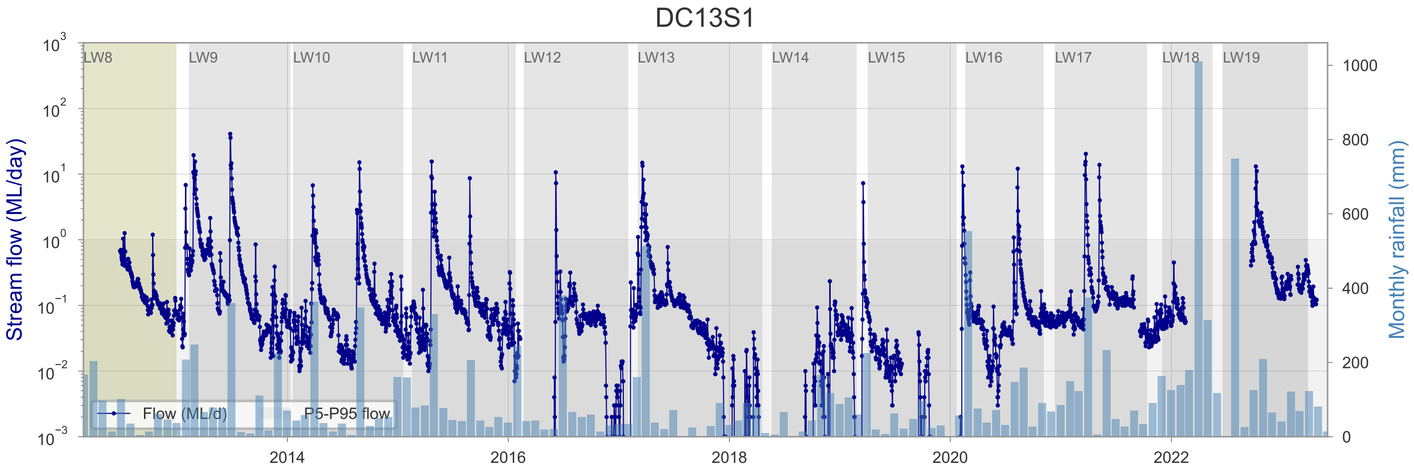
DC10_S1
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
P5-P95 WL
DC10_S1
Electrical Conductivity (uS/cm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)
DC10_S1
pH units
pH
P5-P95 pH
Median (baseline)
DC10_S1
Dissolved Oxygen (%)
DO (%)
P5-P95 DO
Median (baseline)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

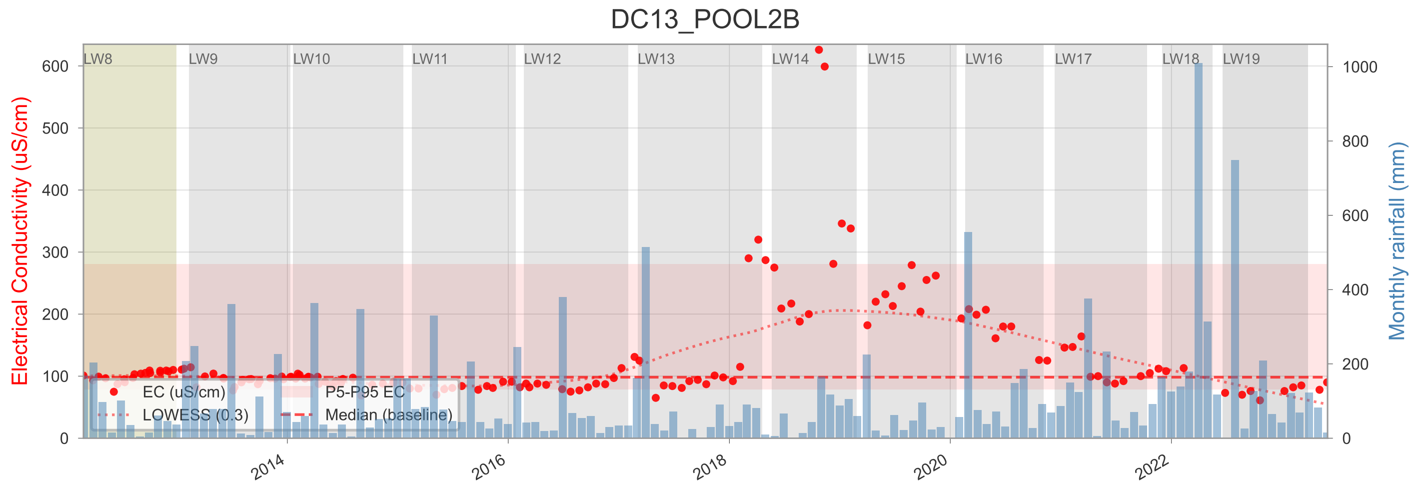

DC13_POOL10
Water level (m below ref. nail)
Monthly rainfall (mm)
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
P5-P95 WL
2014
2016
2018
2020
2022

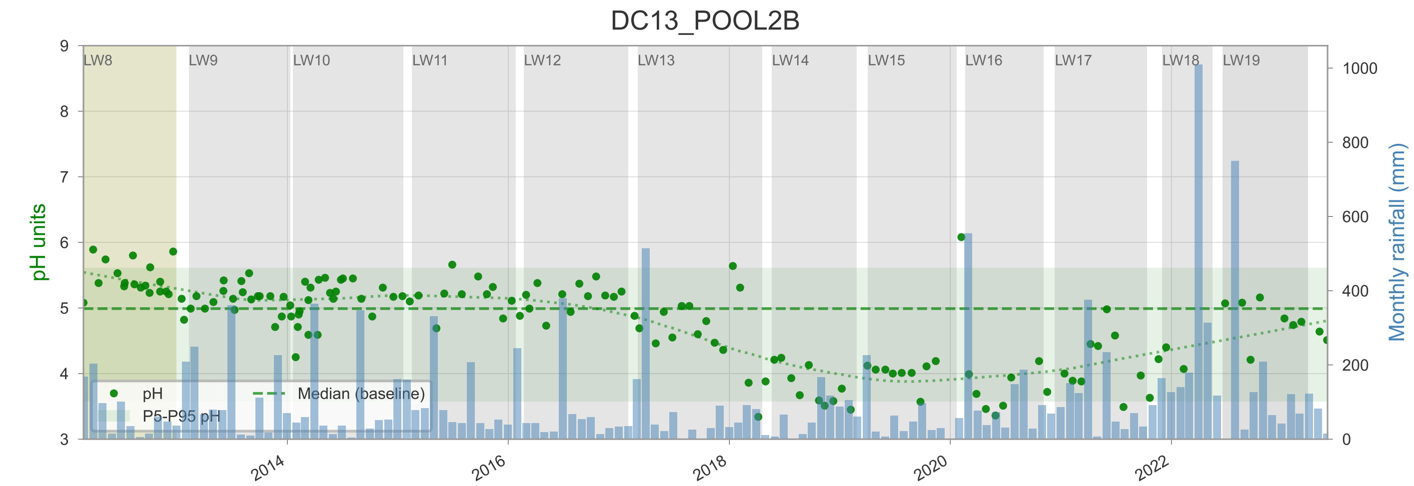

DC13_POOL10
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)
2014
2016
2018
2020
2022

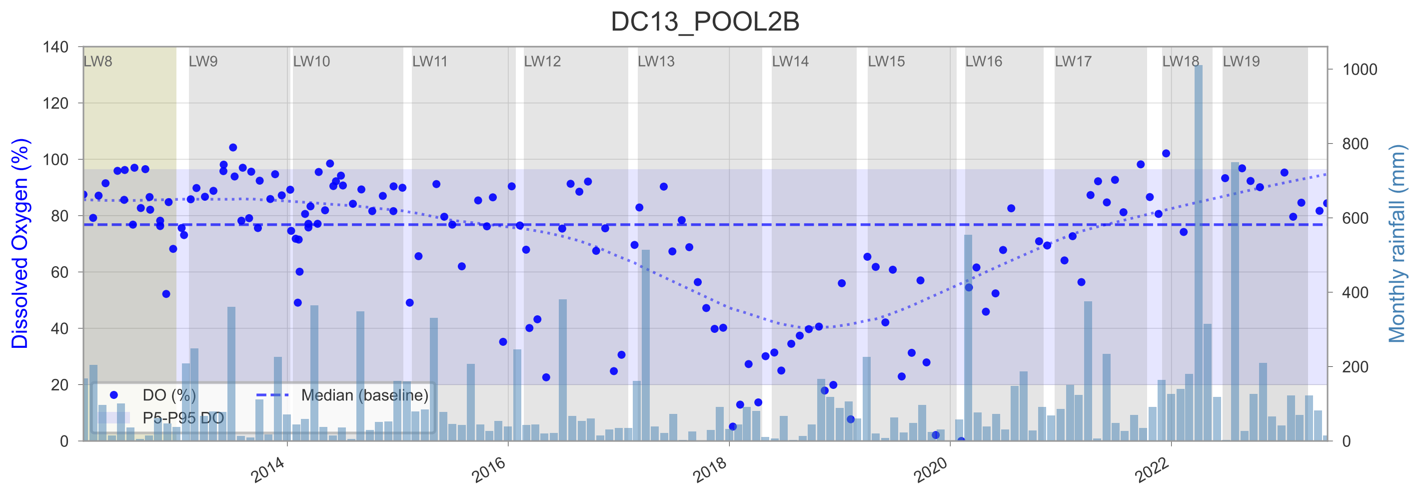

DC13_POOL10
pH units
Monthly rainfall (mm)
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH
P5-P95 pH
Median (baseline)
2014
2016
2018
2020
2022

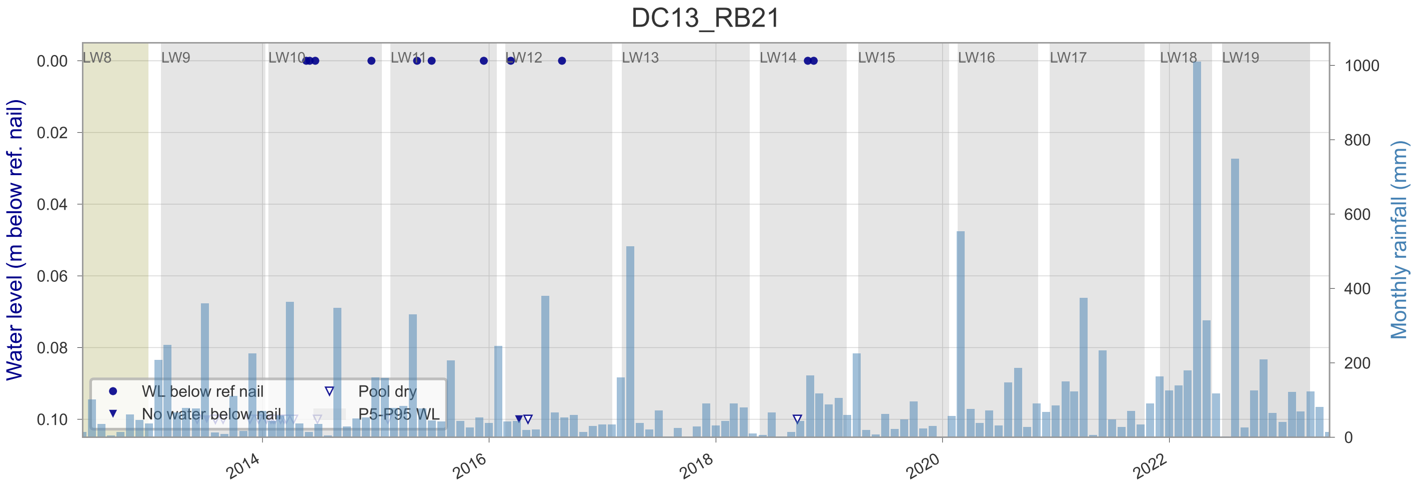

DC13_POOL10
Dissolved Oxygen (%)
Monthly rainfall (mm)
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
DO (%)
P5-P95 DO
Median (baseline)
2014
2016
2018
2020
2022


DC13S1
Stream flow (ML/day)
Monthly rainfall (mm)
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Flow (ML/d)
P5-P95 flow
2014
2016
2018
2020
2022

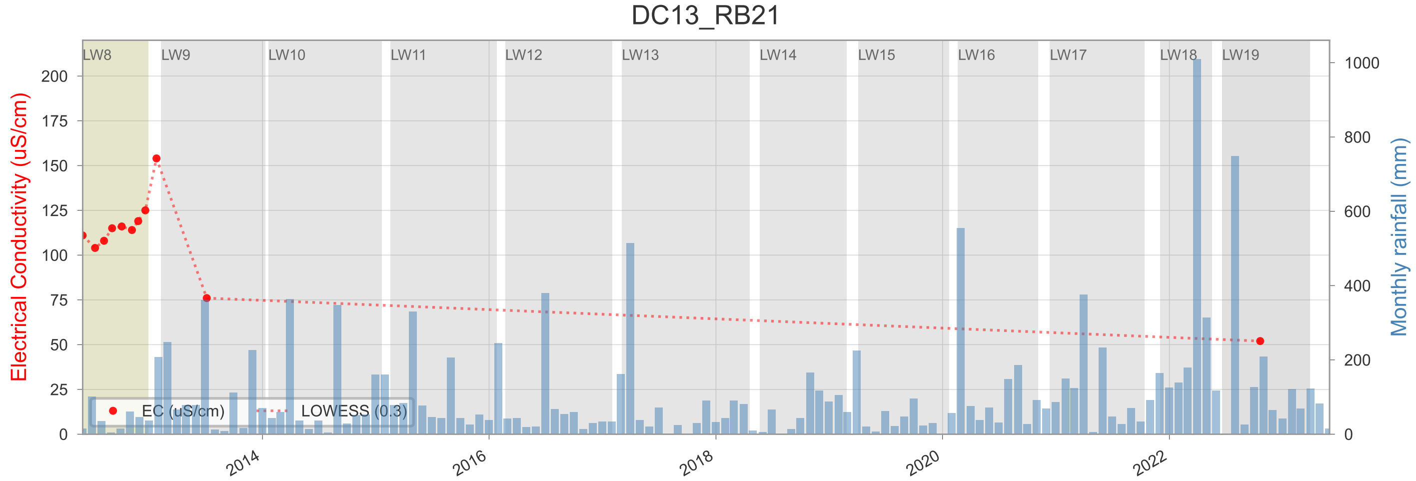

DC13_POOL2B
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)
2014
2016
2018
2020
2022


DC13_POOL2B
pH units
Monthly rainfall (mm)
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH
P5-P95 pH
Median (baseline)
2014
2016
2018
2020
2022

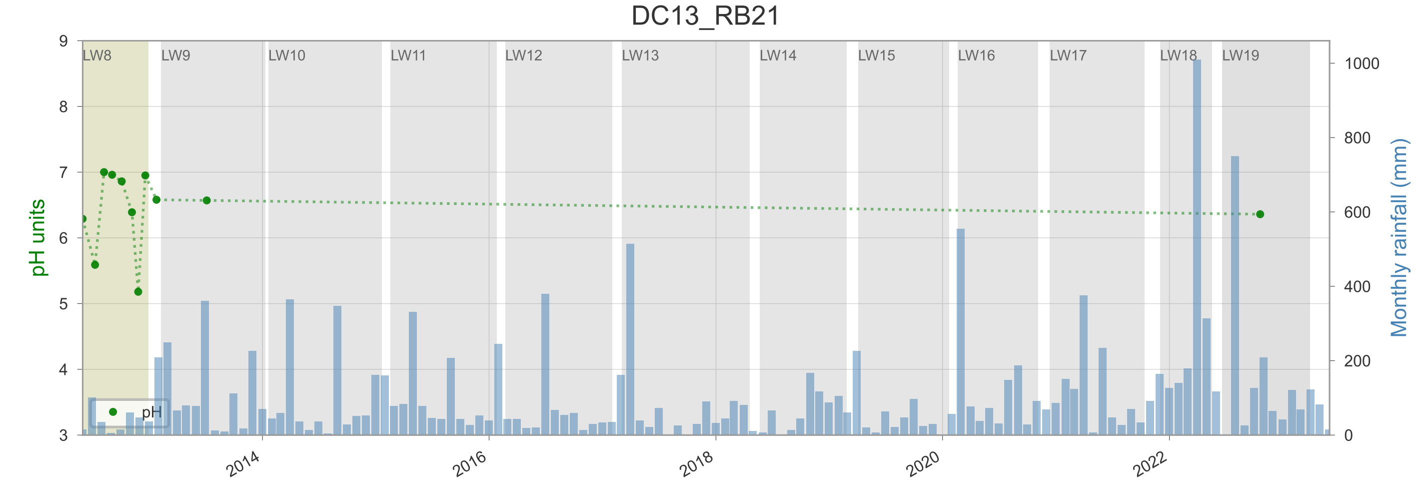

DC13_POOL2B
Dissolved Oxygen (%)
Monthly rainfall (mm)
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
DO (%)
P5-P95 DO
Median (baseline)
2014
2016
2018
2020
2022



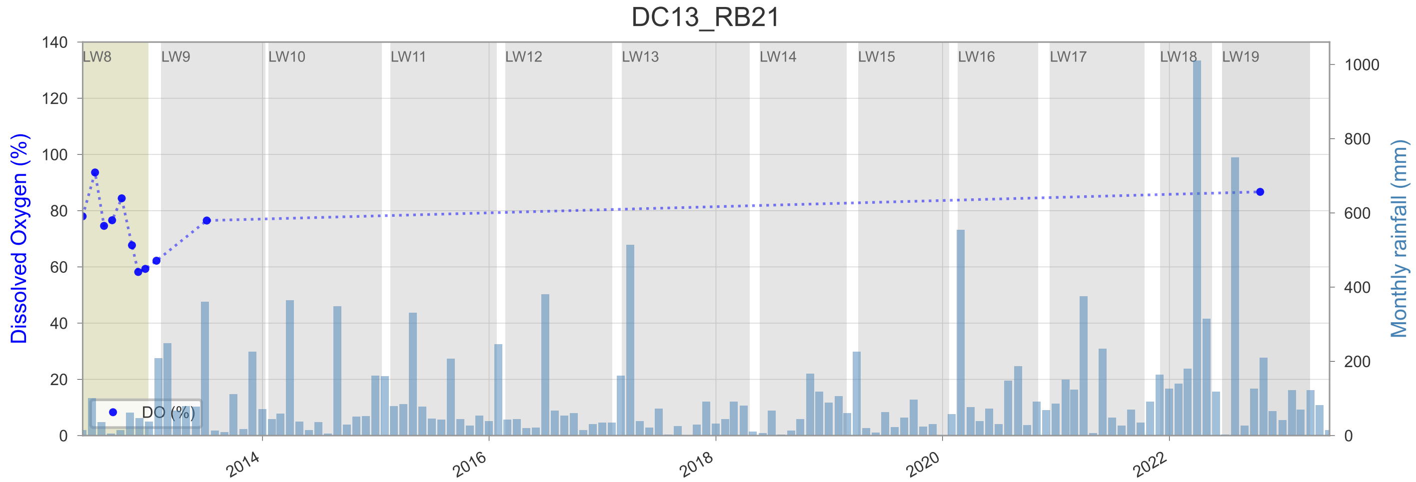
DC13_RB21
Water level (m below ref. nail)
Monthly rainfall (mm)
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
No water below nail
Pool dry
P5-P95 WL



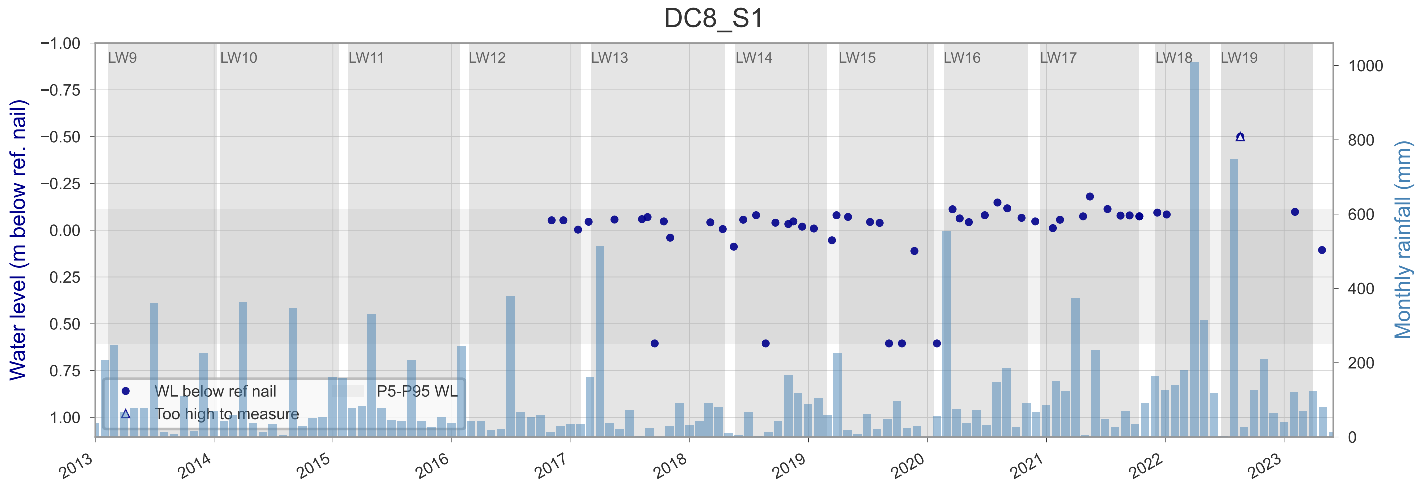
DC13_RB21
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
EC (uS/cm)
LOWESS (0.3)

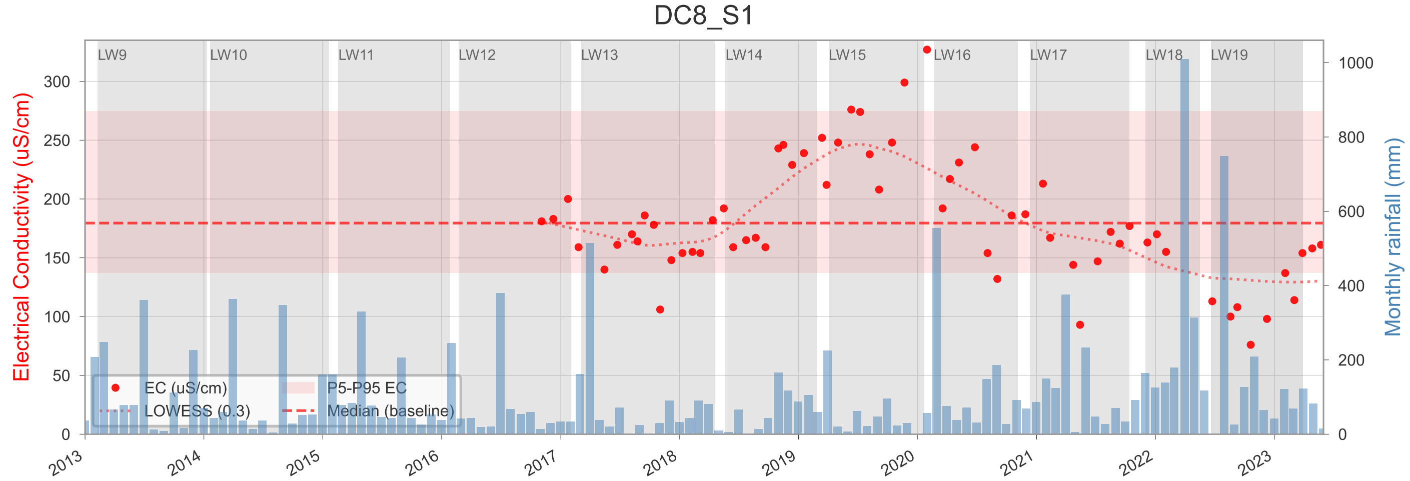


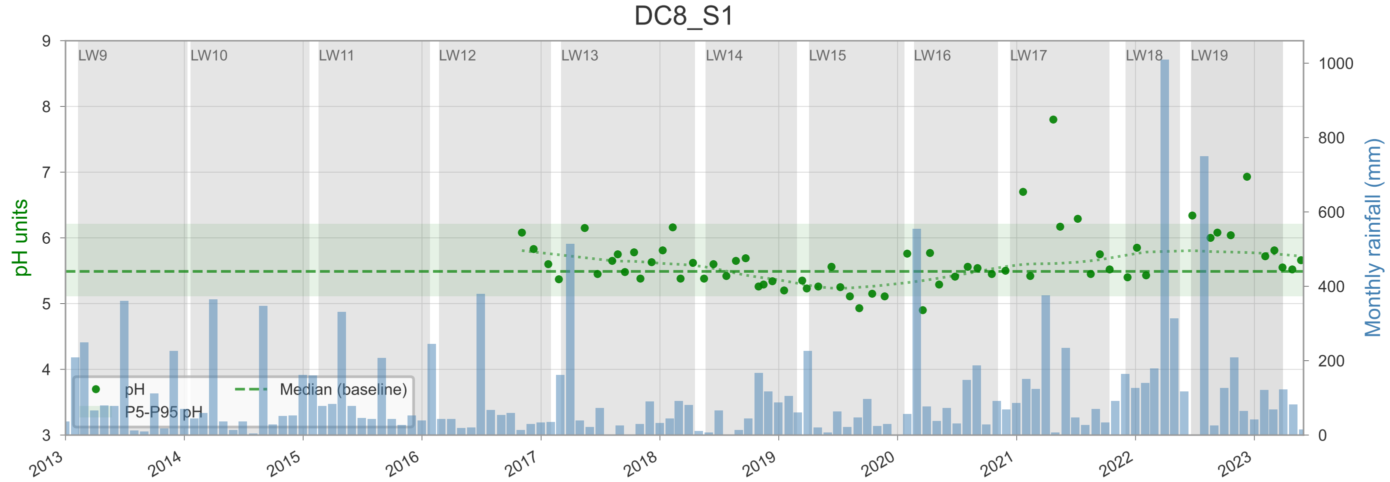
DC13_RB21
pH units
Monthly rainfall (mm)
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH

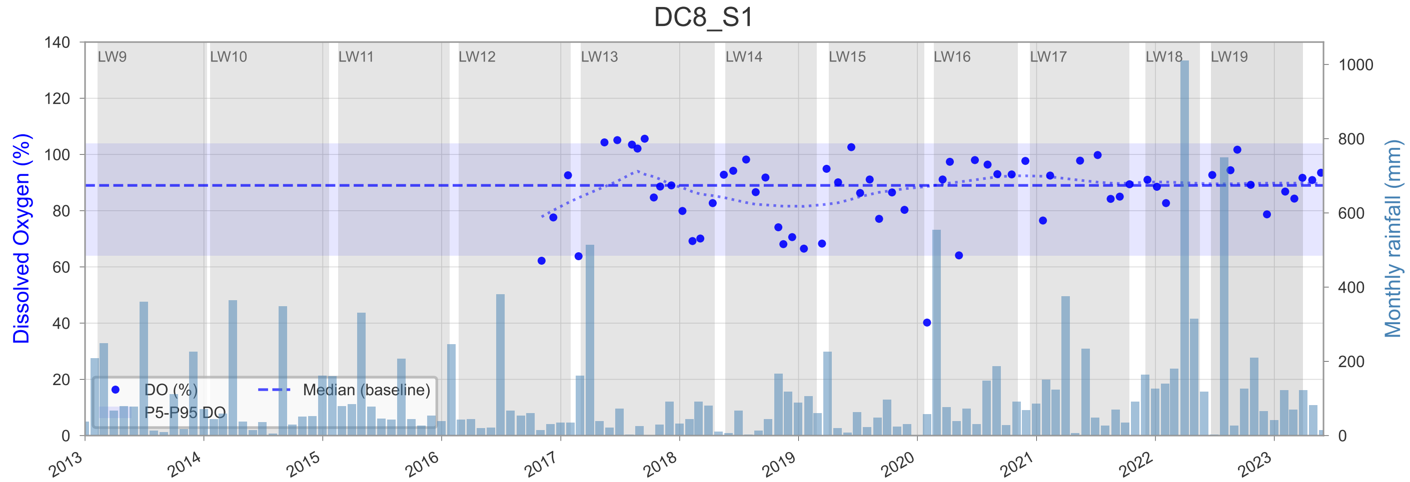


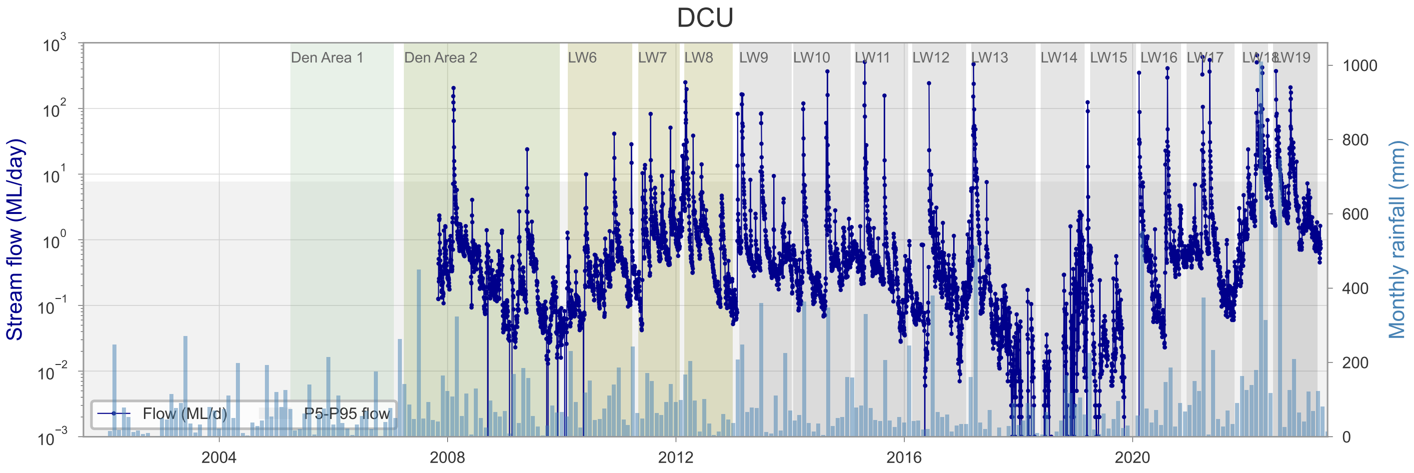
DC13_RB21
Dissolved Oxygen (%)
Monthly rainfall (mm)
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
DO (%)

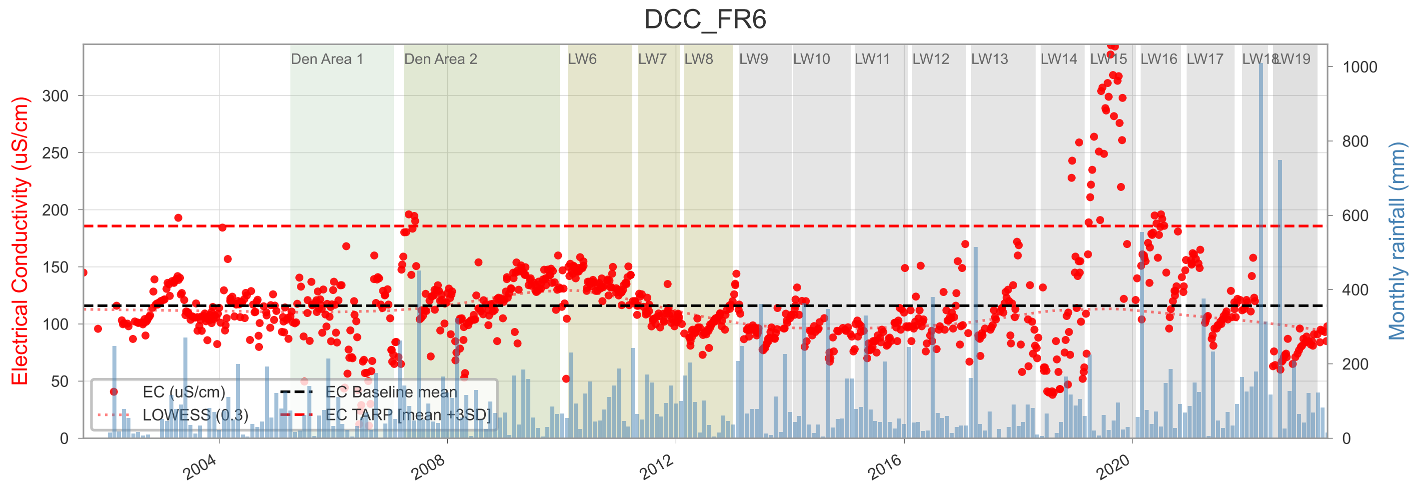

DC8_S1
Water level (m below ref. nail)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
Too high to measure
P5-P95 WL

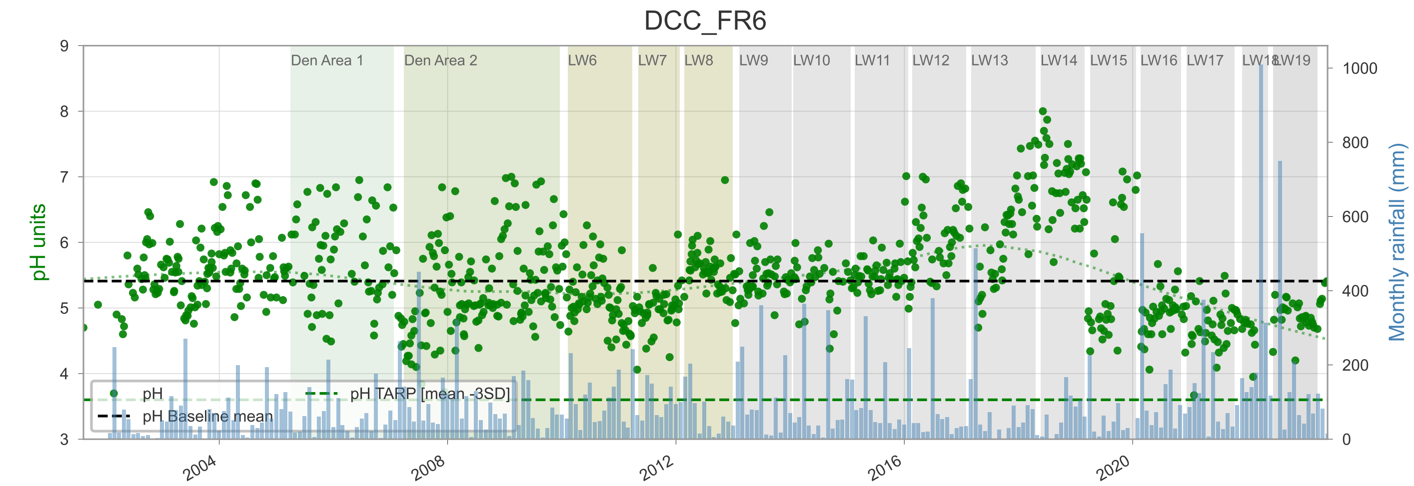

DC8_S1
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

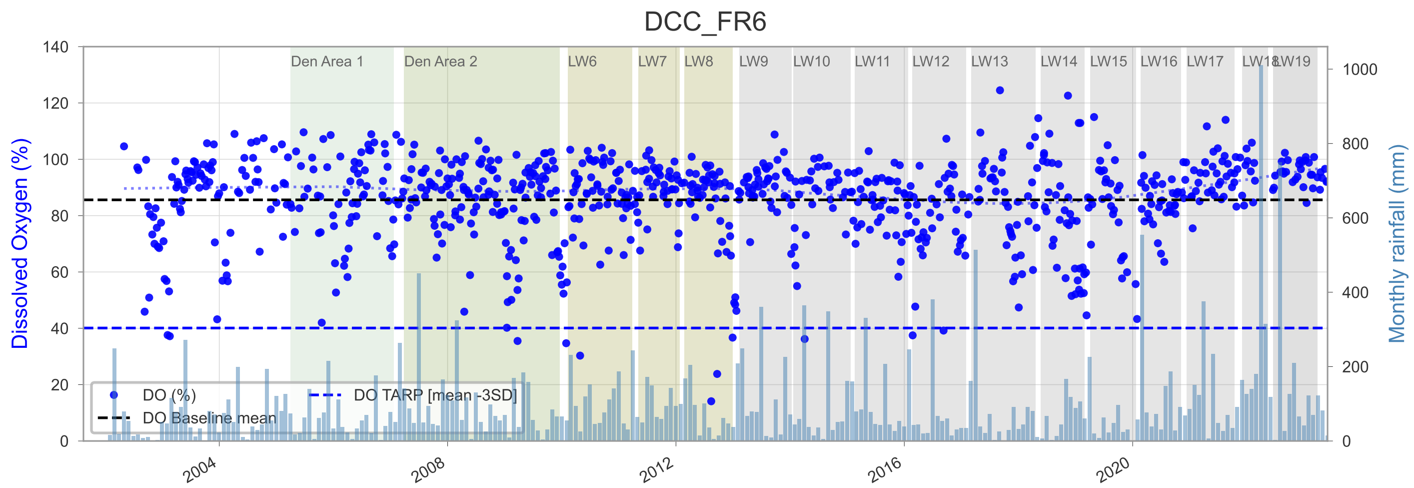

DC8_S1
pH units
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH
P5-P95 pH
Median (baseline)

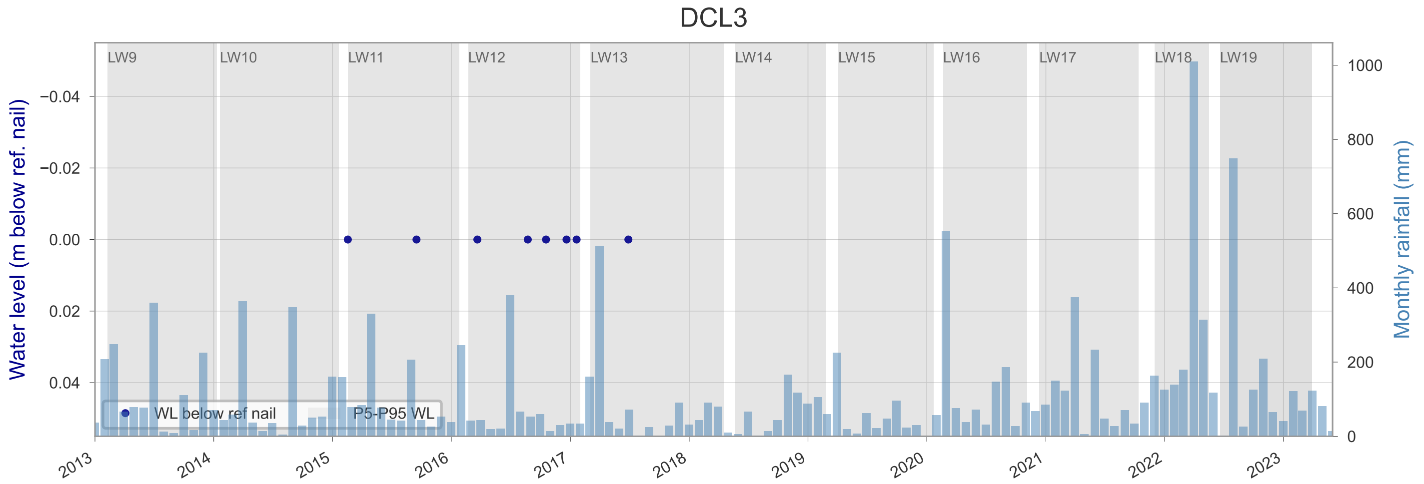

DC8_S1
Dissolved Oxygen (%)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
DO (%)
P5-P95 DO
Median (baseline)

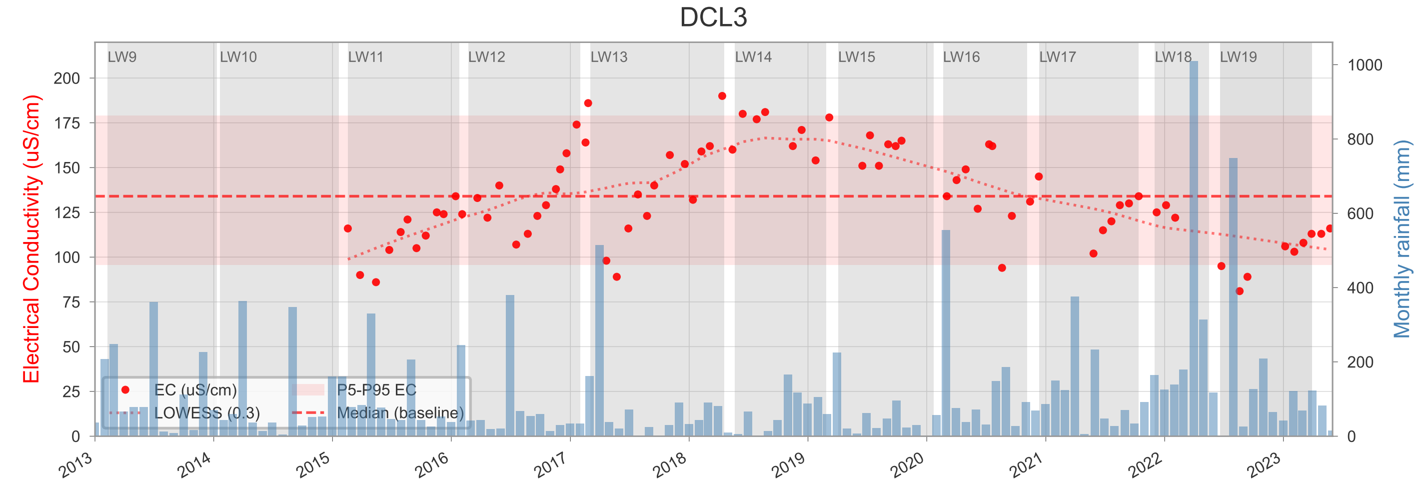

DCU
Stream flow (ML/day)
Monthly rainfall (mm)
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Flow (ML/d)
P5-P95 flow

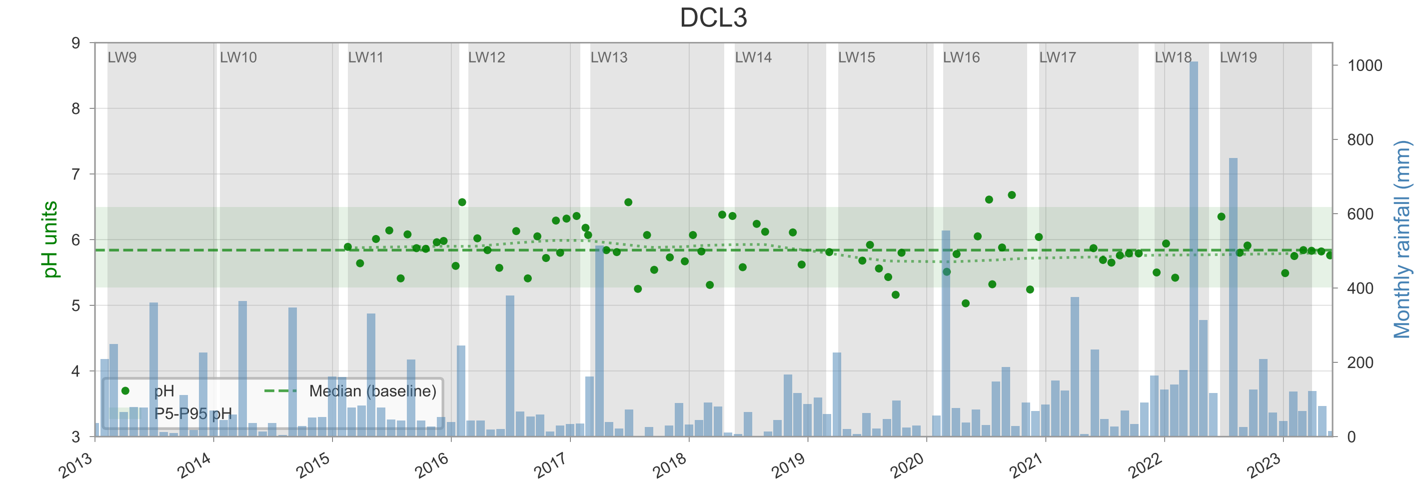

DCC_FR6
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
EC Baseline mean
EC TARP [mean +3SD]

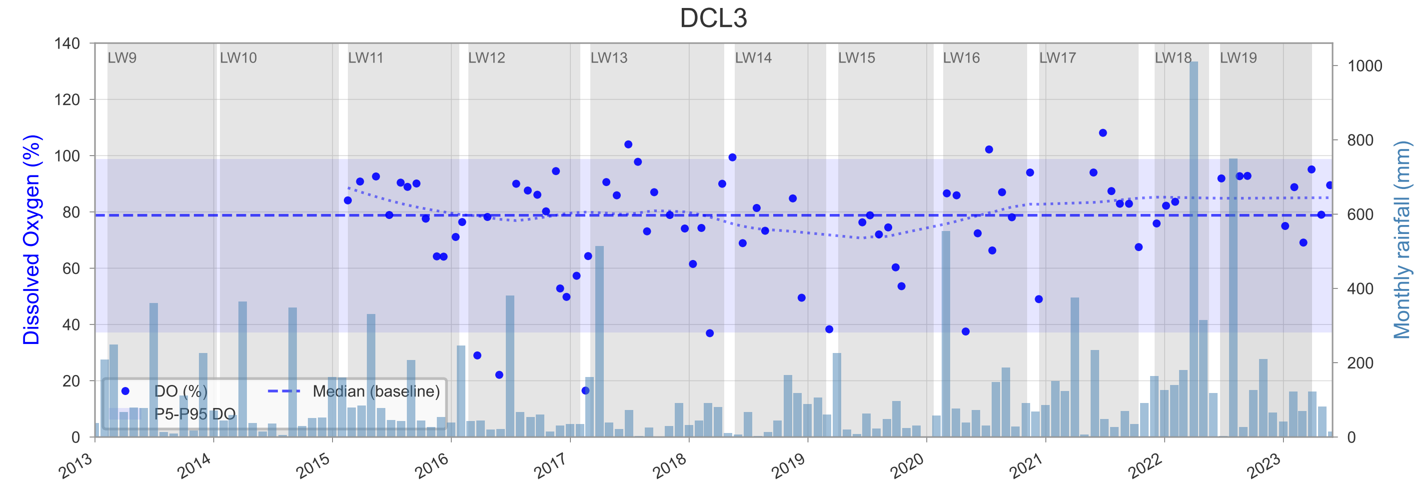

DCC_FR6
pH units
Monthly rainfall (mm)
pH
pH Baseline mean
pH TARP [mean -3SD]

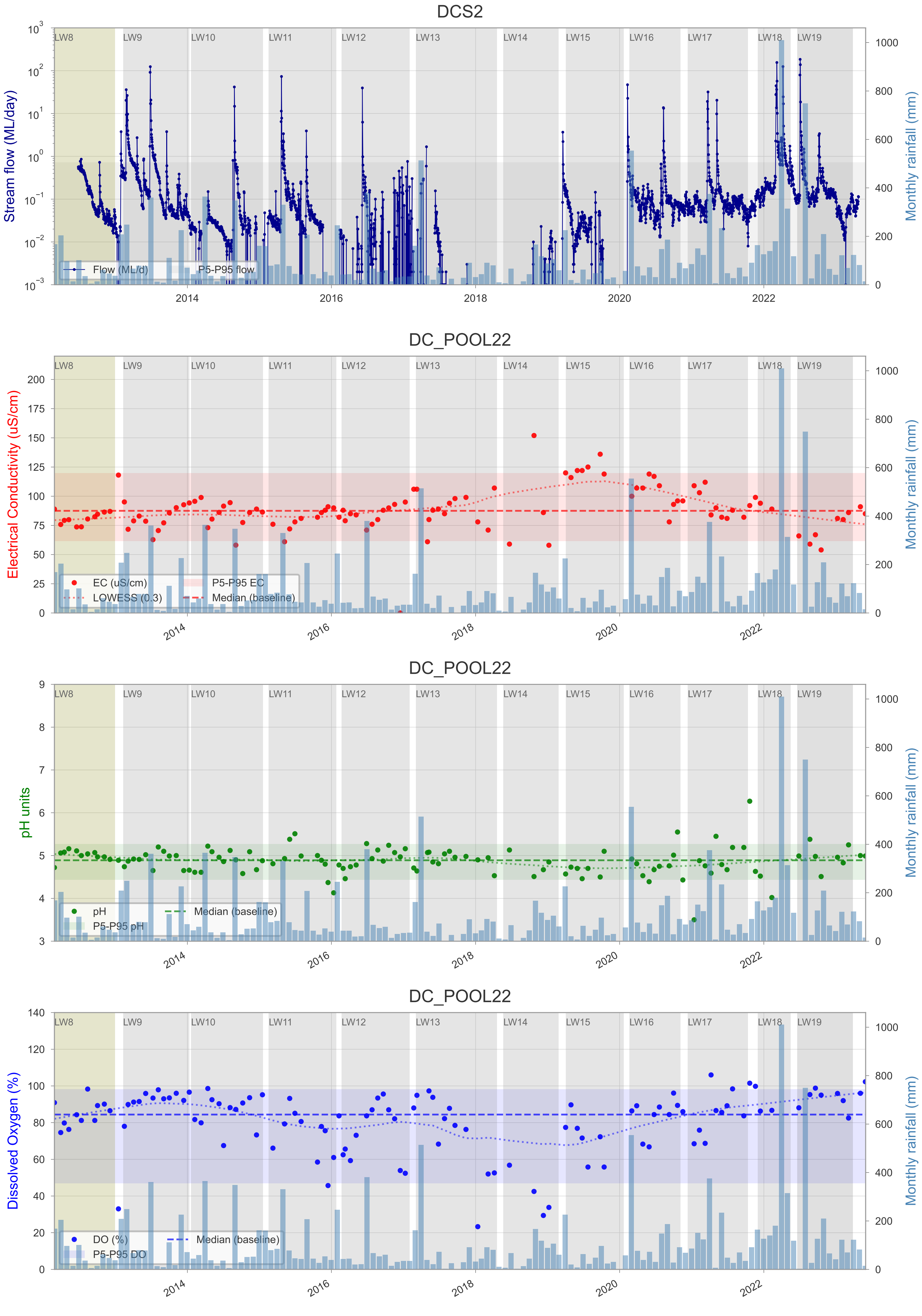

DCC_FR6
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
DO Baseline mean
DO TARP [mean -3SD]

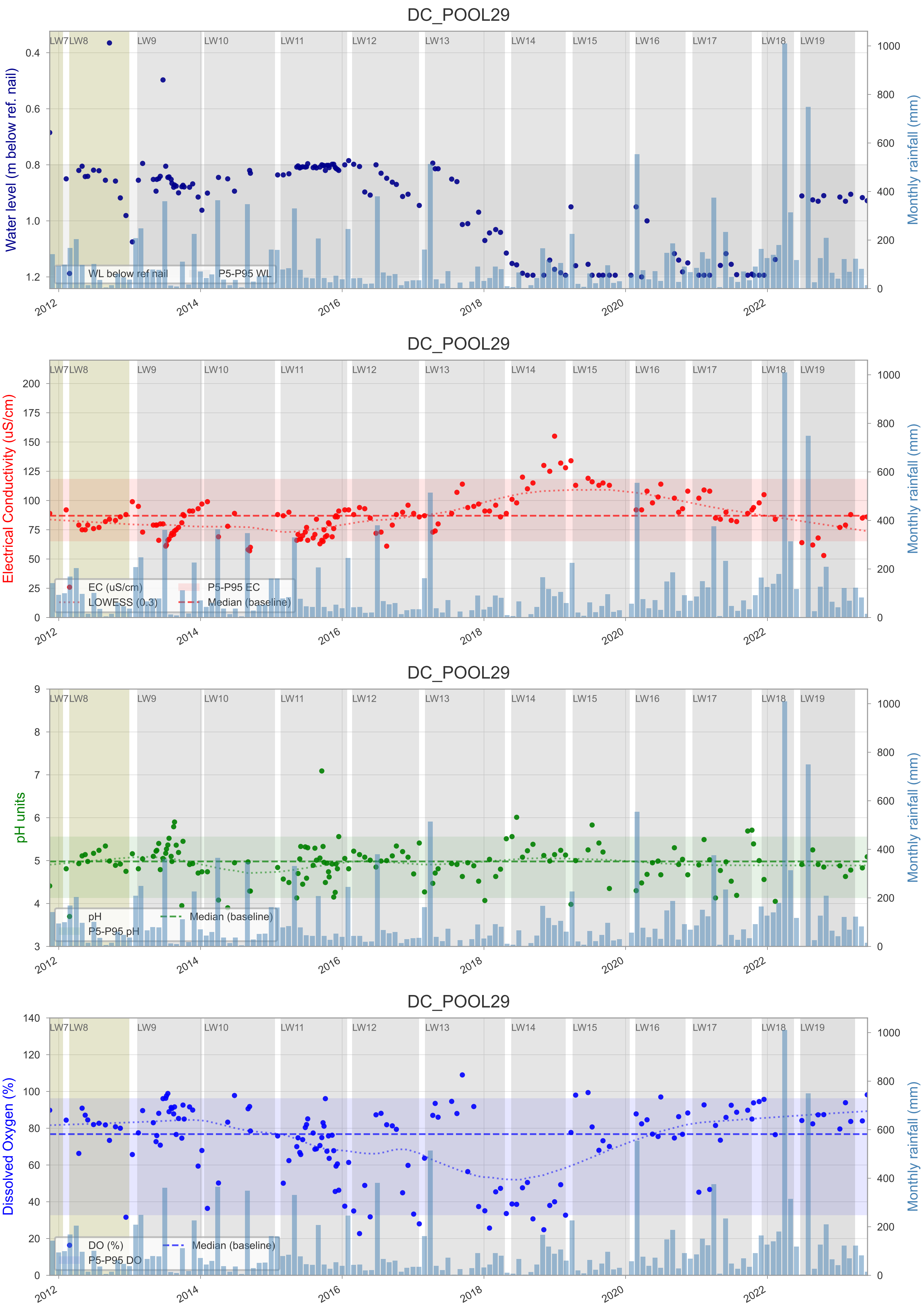

DCL3
Water level (m below ref. nail)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
P5-P95 WL

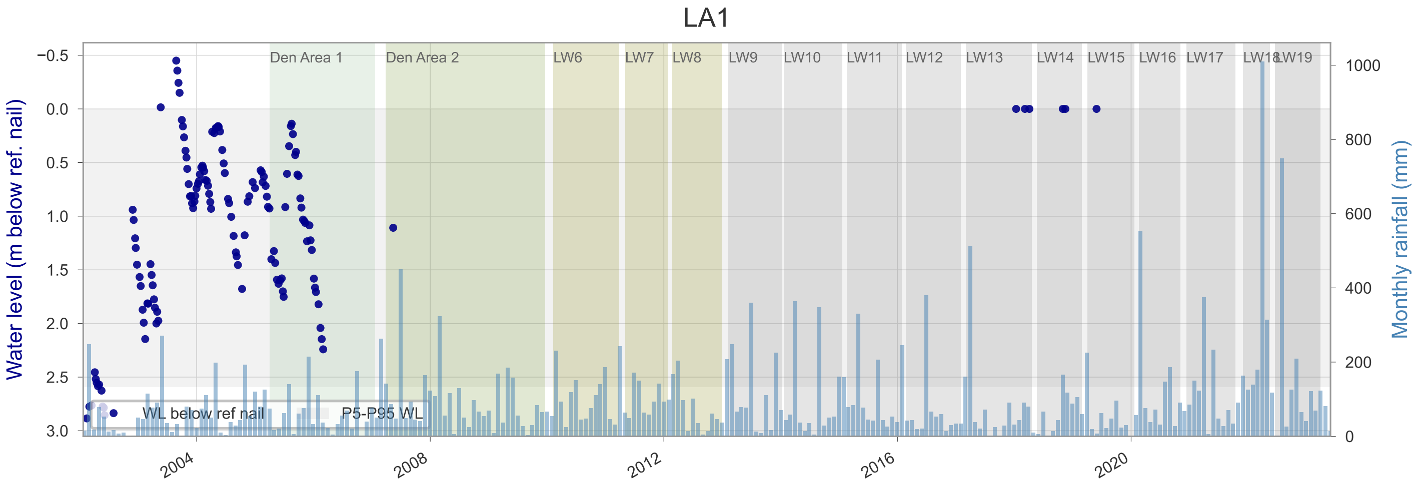

DCL3
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

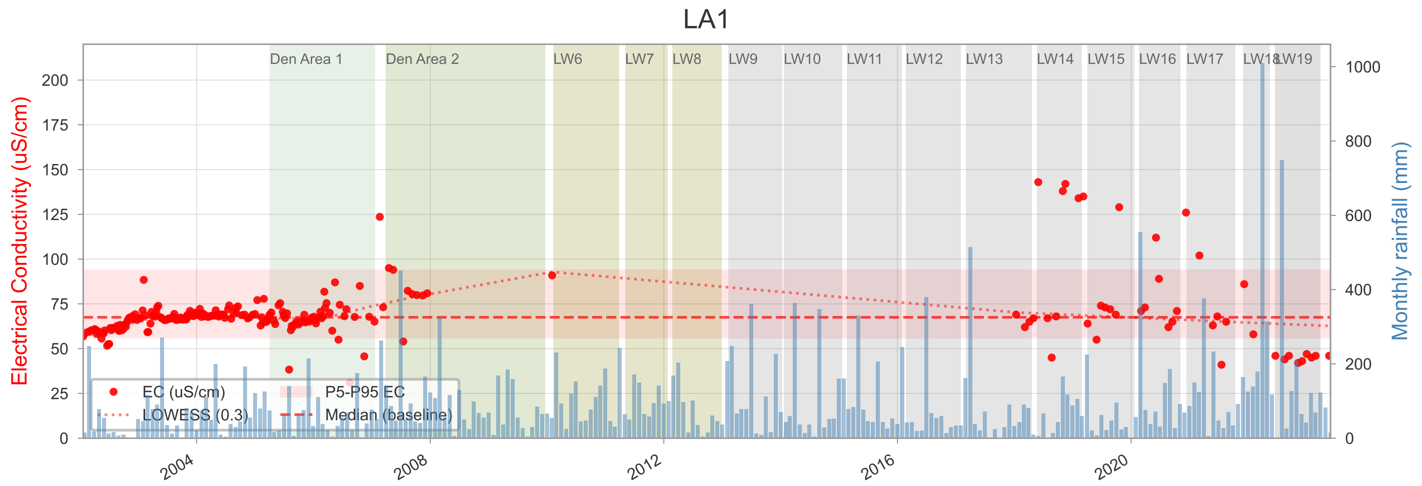

DCL3
pH units
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH
P5-P95 pH
Median (baseline)

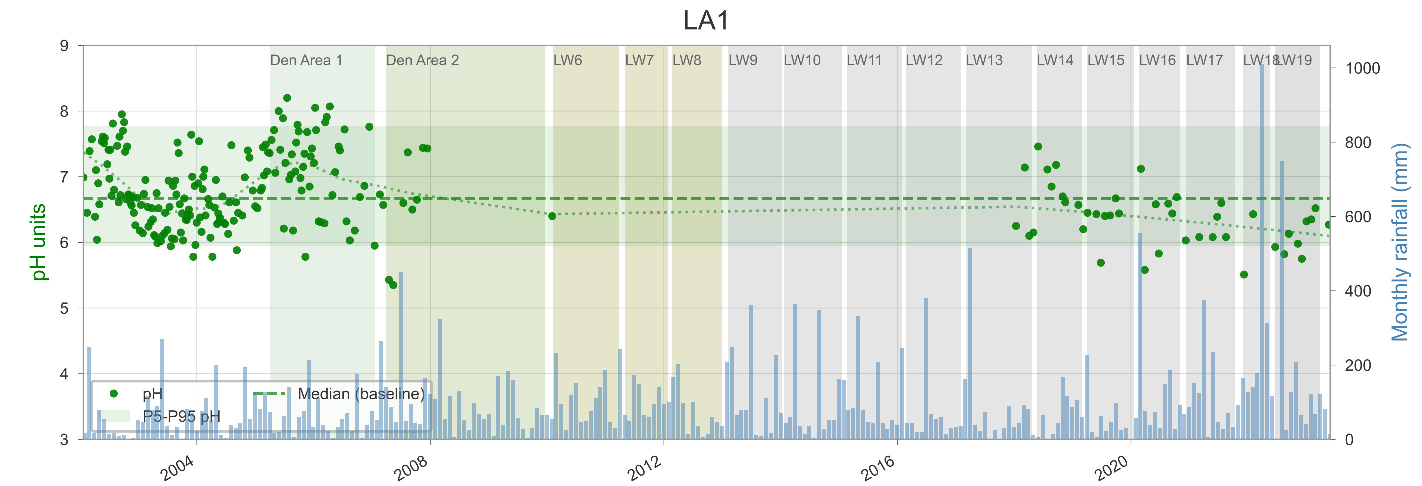

DCL3
Dissolved Oxygen (%)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
DO (%)
P5-P95 DO
Median (baseline)

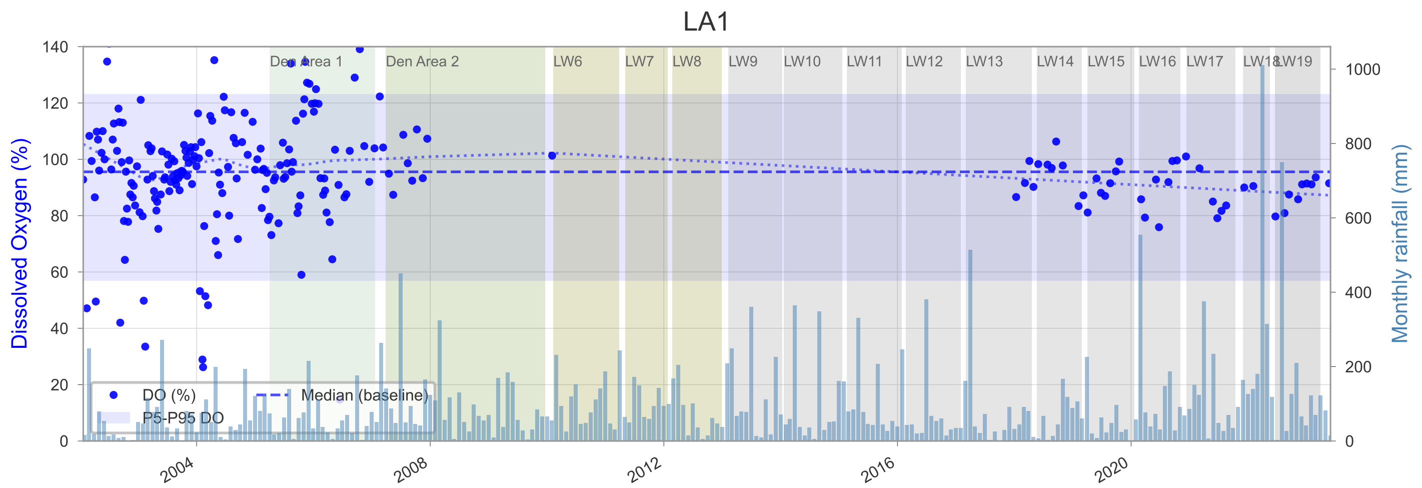

DCS2
Stream flow (ML/day)
Monthly rainfall (mm)
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Flow (ML/d)
P5-P95 flow
DC_POOL22
Electrical Conductivity (uS/cm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)
DC_POOL22
pH units
pH
P5-P95 pH
Median (baseline)
DC_POOL22
Dissolved Oxygen (%)
DO (%)
P5-P95 DO
Median (baseline)
2014
2016
2018
2020
2022

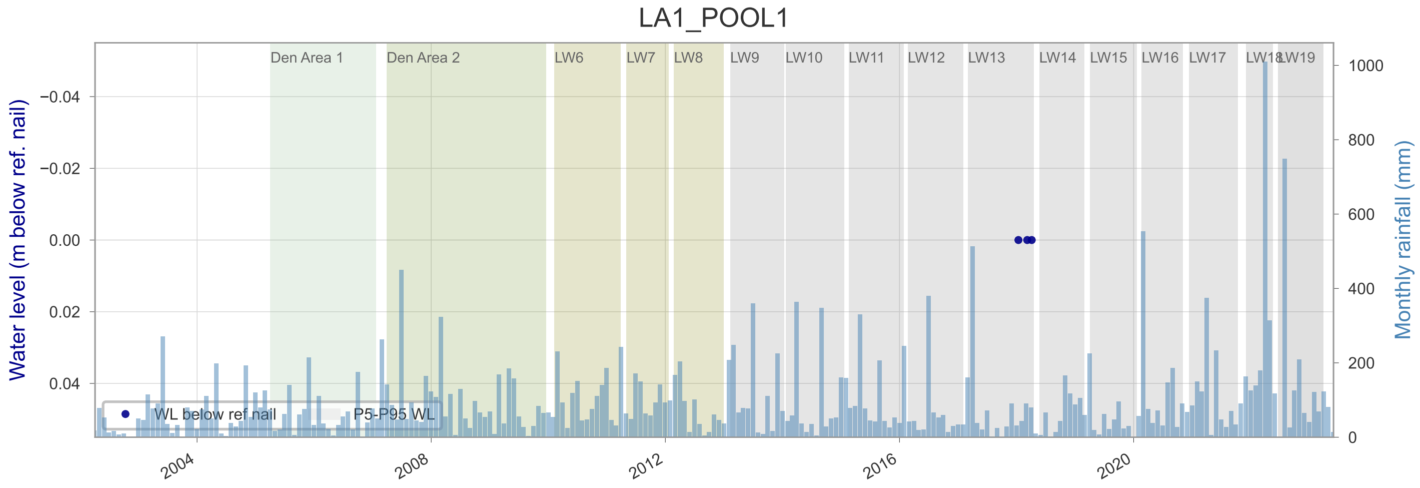

DC_POOL29
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
P5-P95 WL
DC_POOL29
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)
DC_POOL29
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)
DC_POOL29
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)
LW7 LW8 LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17 LW18 LW19
2012 2014 2016 2018 2020 2022

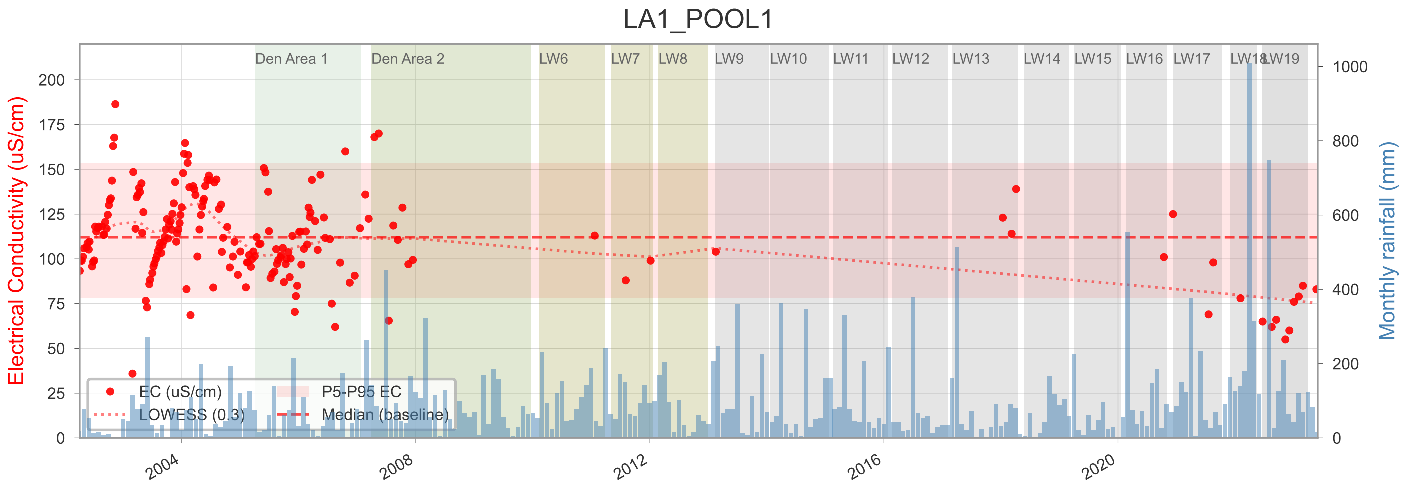

LA1
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
P5-P95 WL
2004
2008
2012
2016
2020

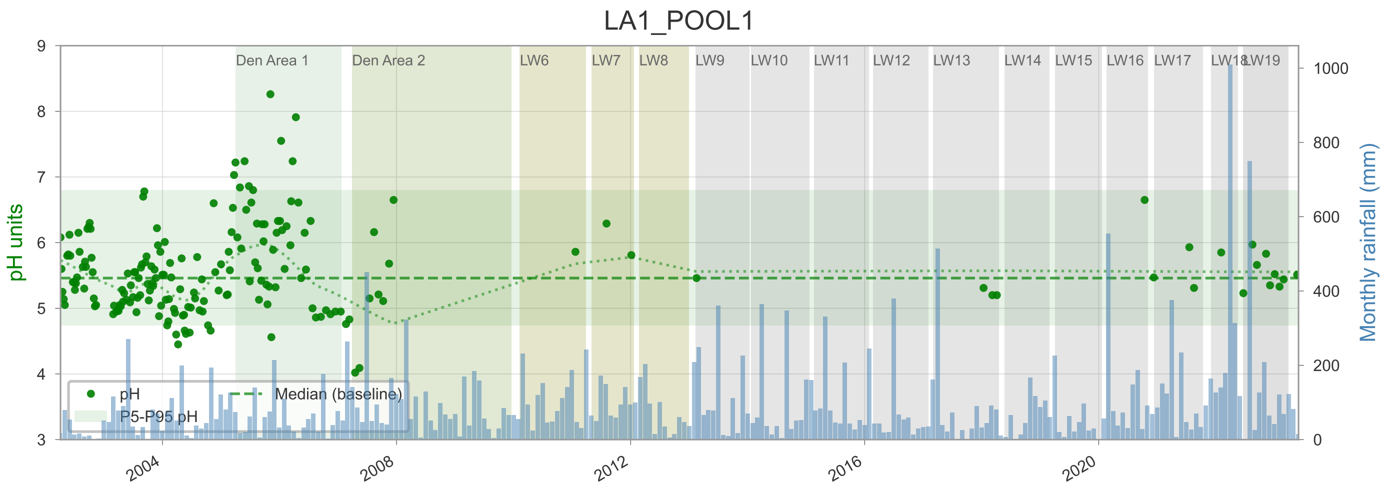

LA1
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
P5-P95 EC
LOWESS (0.3)
Median (baseline)
2004
2008
2012
2016
2020

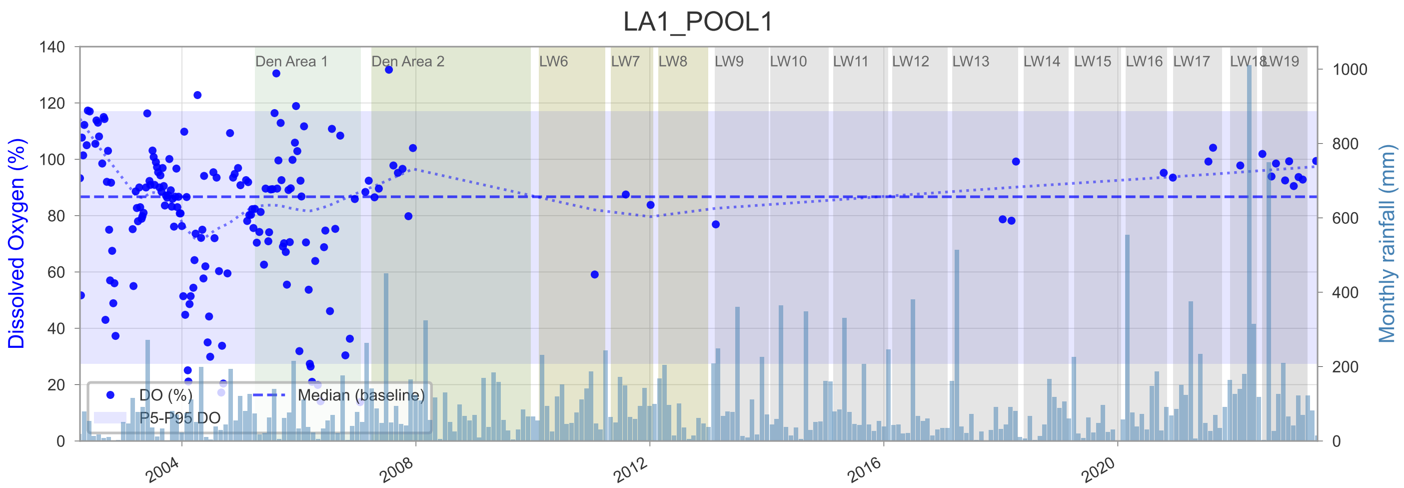

LA1
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH units
Monthly rainfall (mm)
pH
Median (baseline)
P5-P95 pH
2004
2008
2012
2016
2020

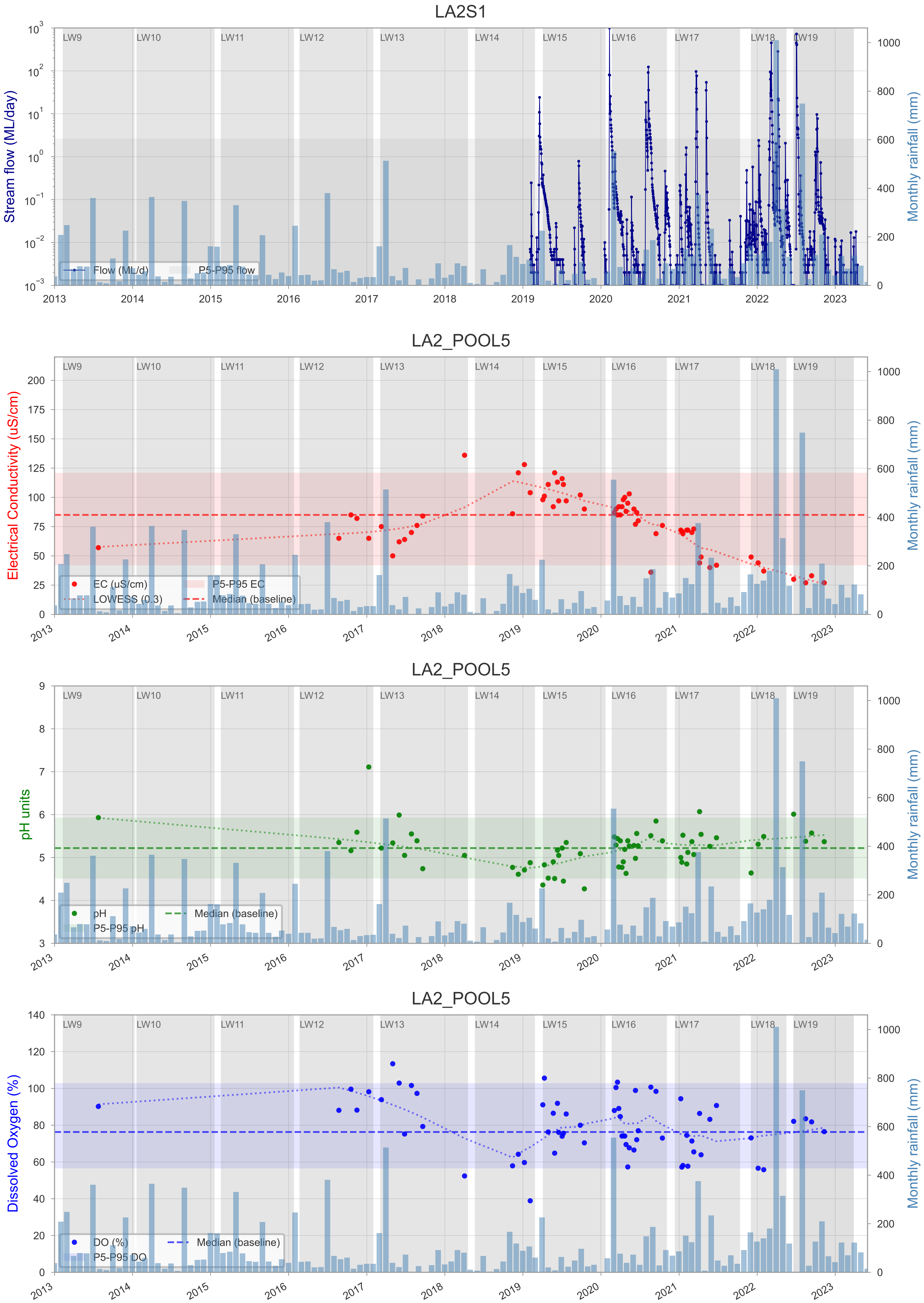

LA1
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
Median (baseline)
P5-P95 DO
2004
2008
2012
2016
2020

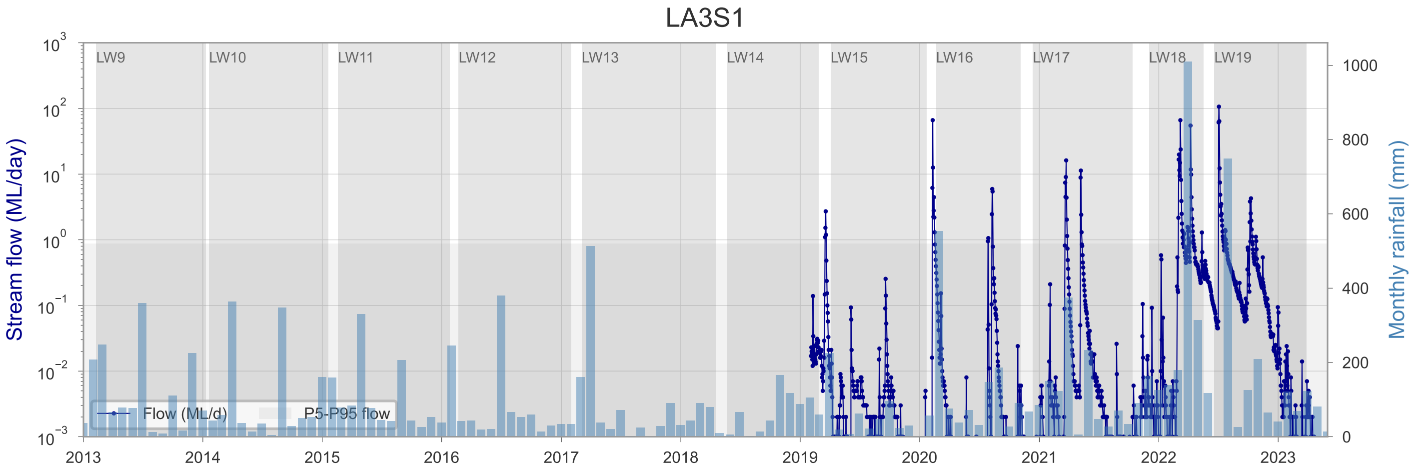

LA1_POOL1
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
P5-P95 WL

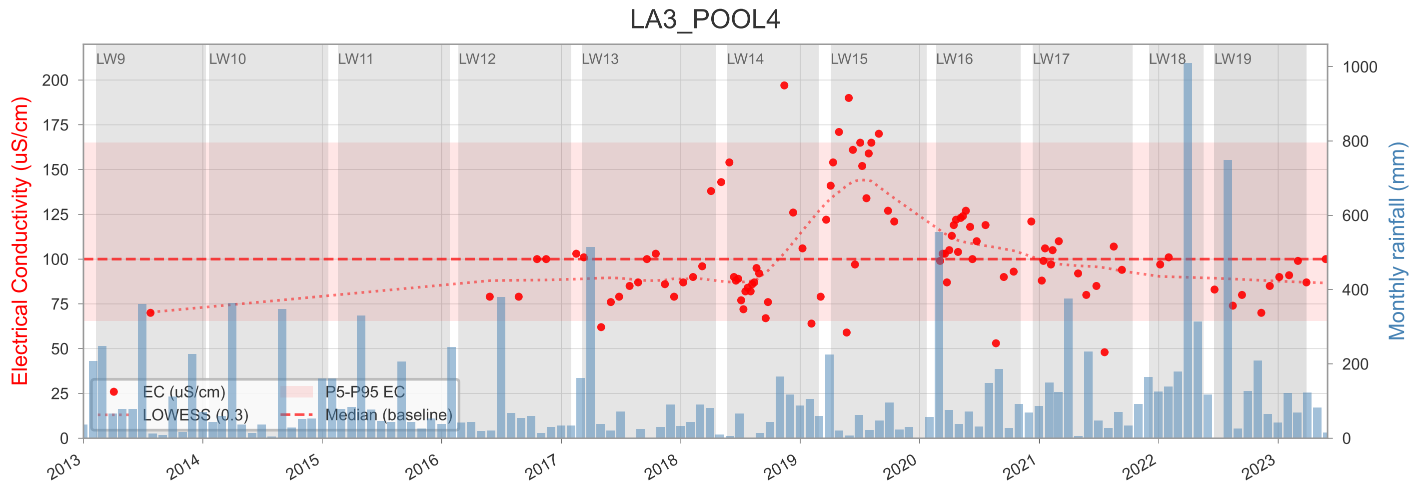

LA1_POOL1
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

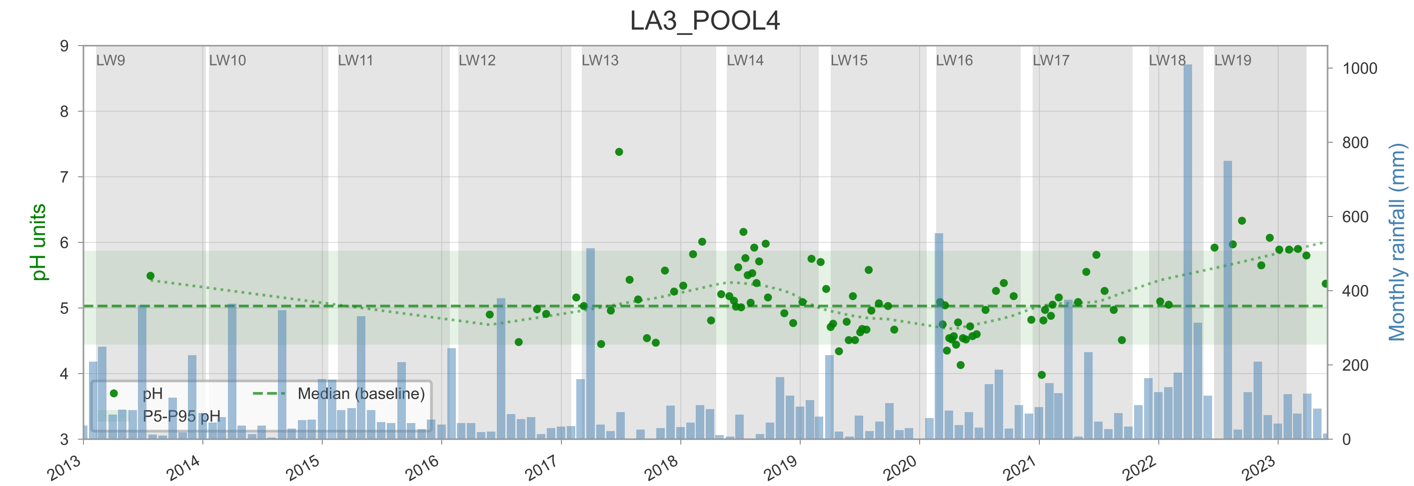

LA1_POOL1
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)

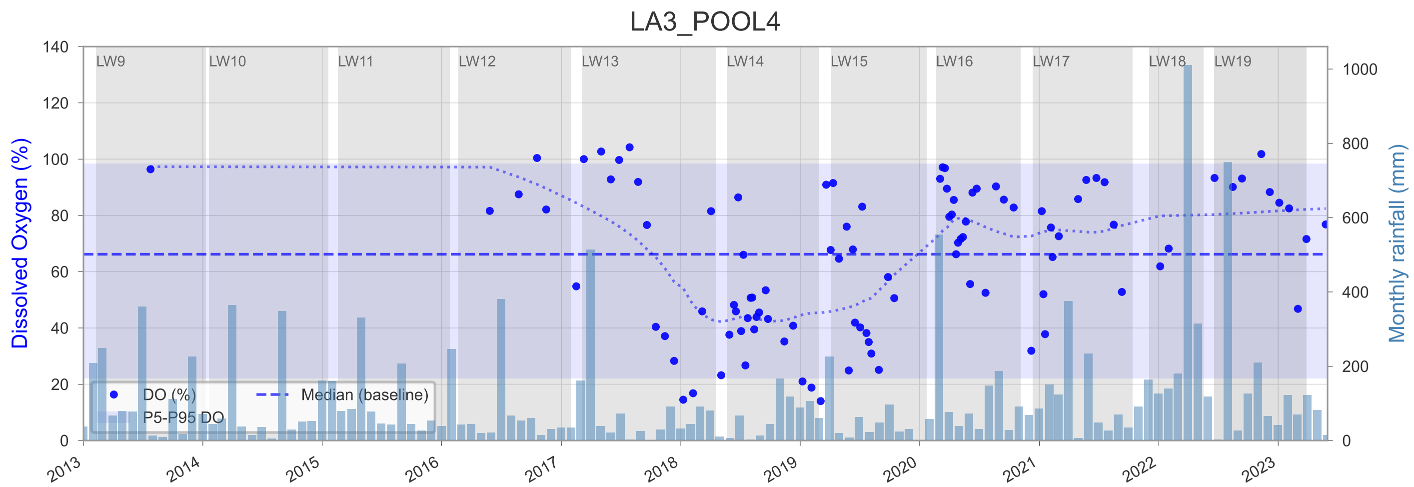

LA1_POOL1
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)

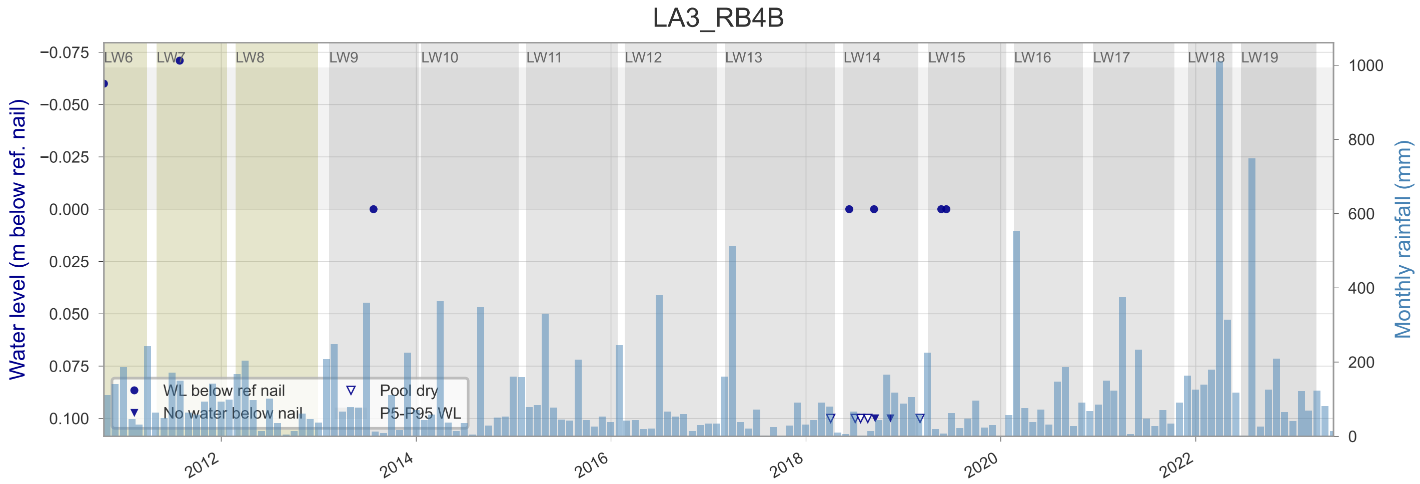

LA2S1
Stream flow (ML/day)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Flow (ML/d)
P5-P95 flow
LA2_POOL5
Electrical Conductivity (uS/cm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)
LA2_POOL5
pH units
pH
P5-P95 pH
Median (baseline)
LA2_POOL5
Dissolved Oxygen (%)
DO (%)
P5-P95 DO
Median (baseline)

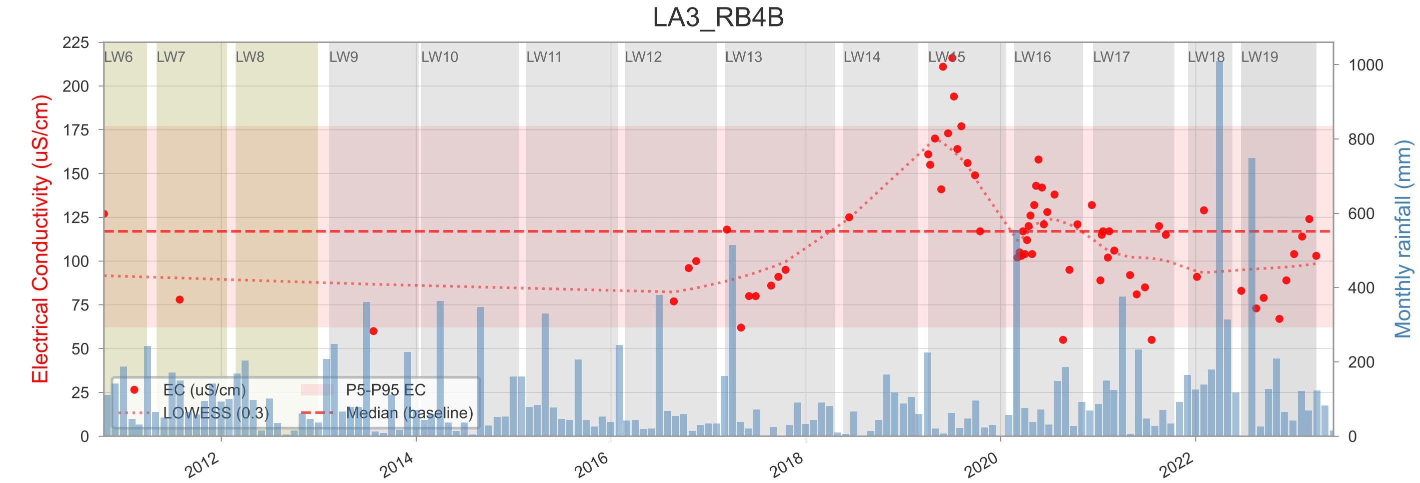

LA3S1
Stream flow (ML/day)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Flow (ML/d)
P5-P95 flow

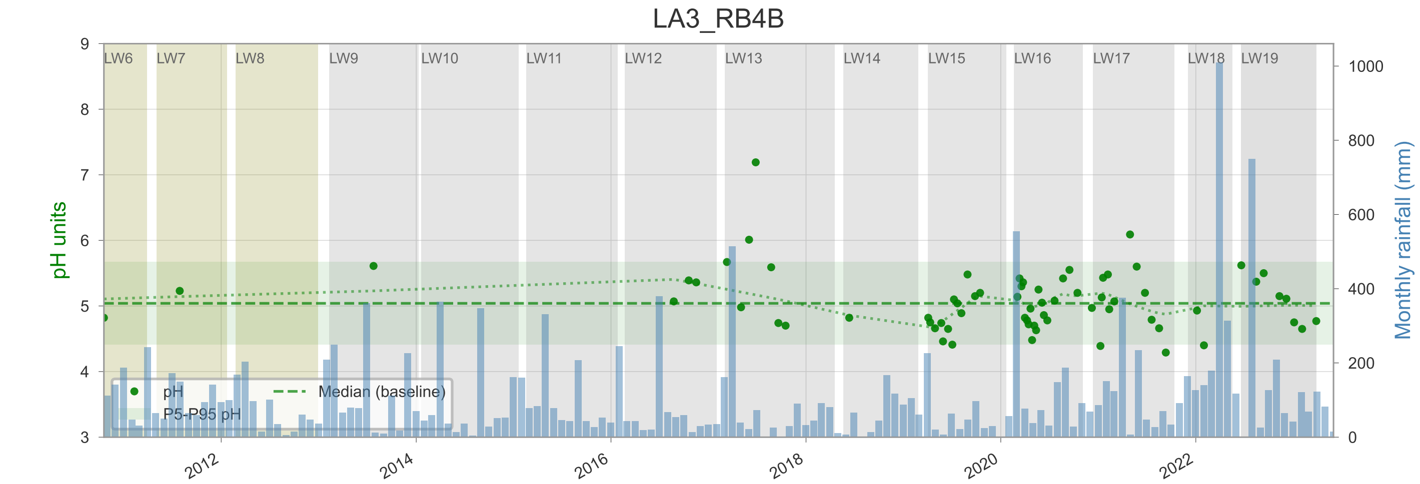

LA3_POOL4
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

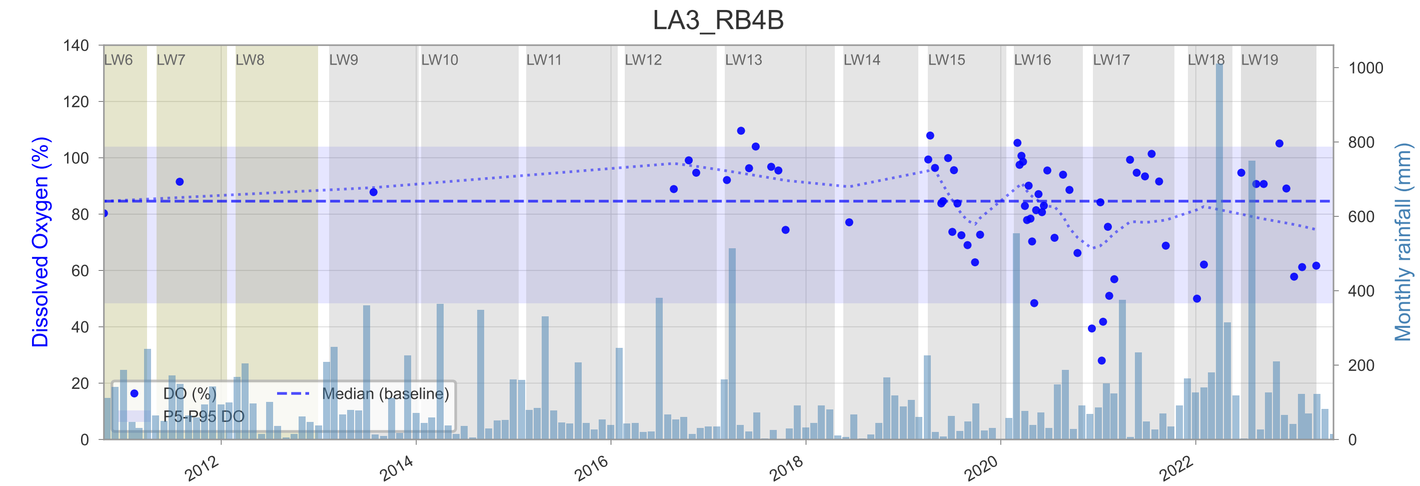

LA3_POOL4
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)

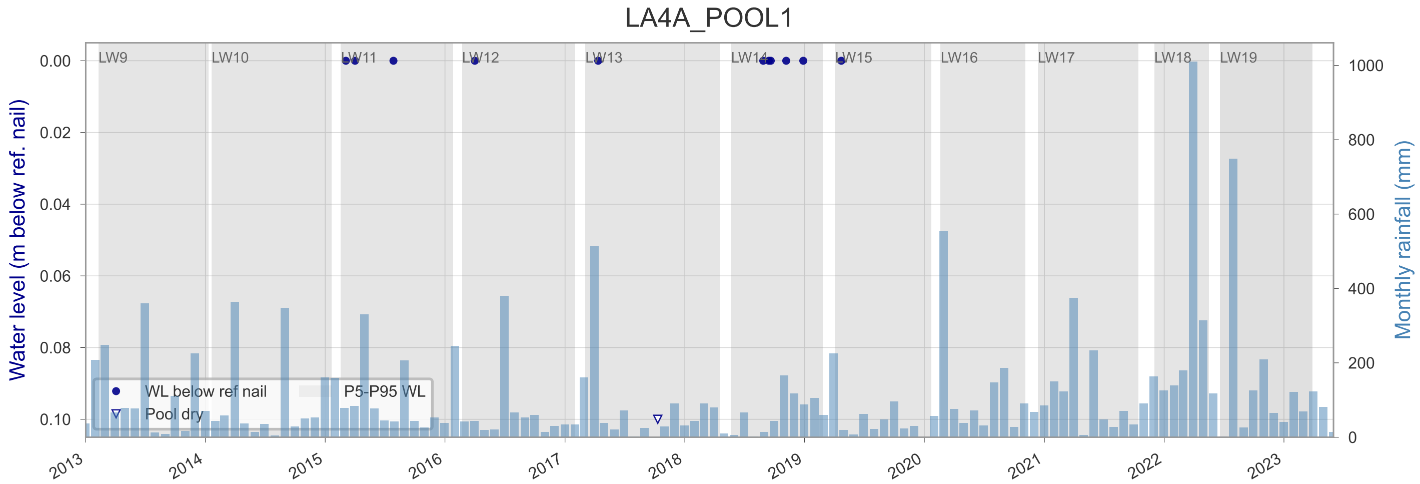

LA3_POOL4
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)

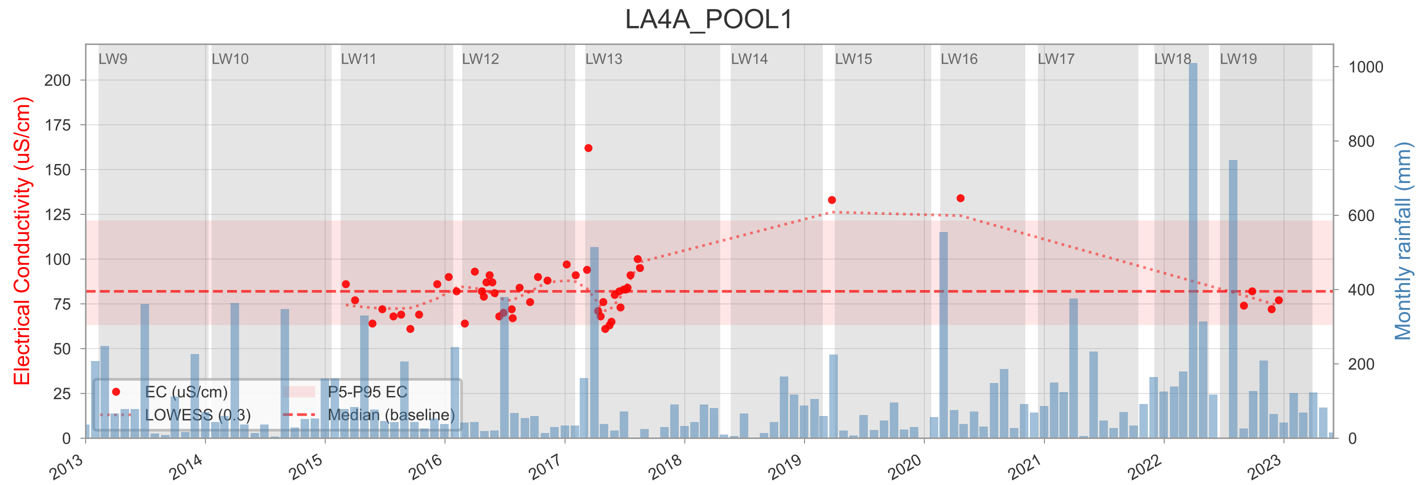

LA3_RB4B
LW6 LW7 LW8 LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17 LW18 LW19
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
No water below nail
Pool dry
P5-P95 WL
2012 2014 2016 2018 2020 2022

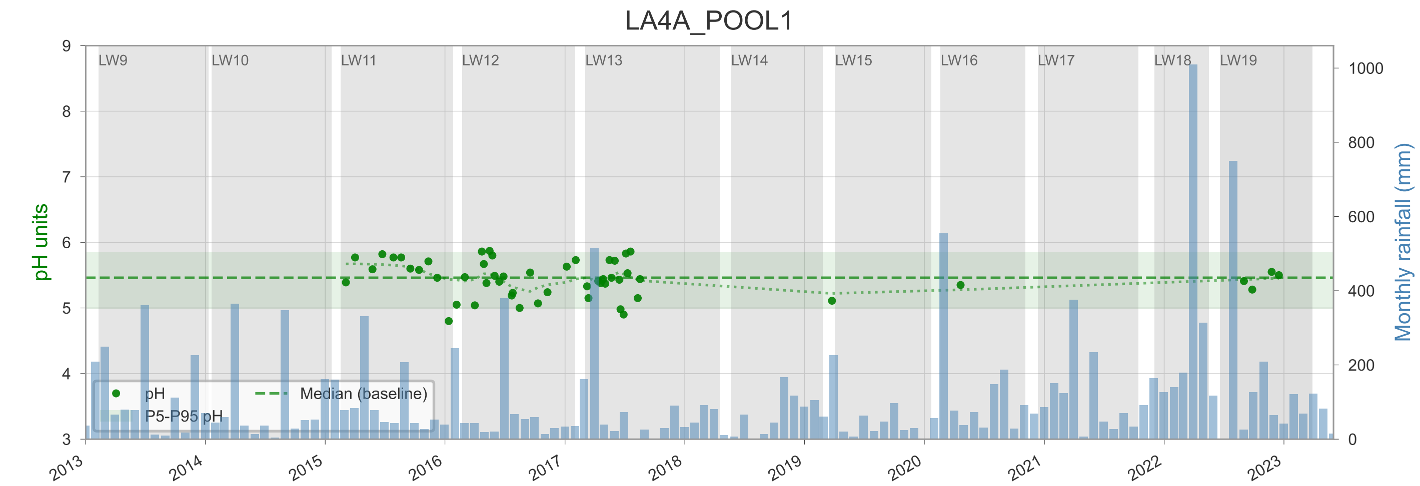

LA3_RB4B
LW6 LW7 LW8 LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17 LW18 LW19
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)
2012 2014 2016 2018 2020 2022

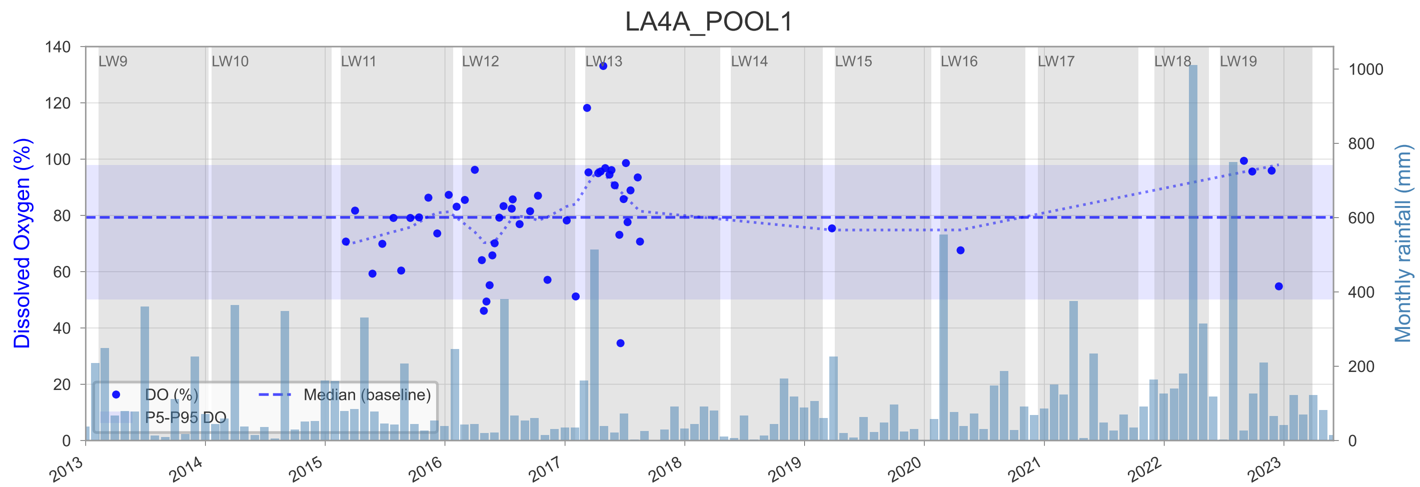

LA3_RB4B
LW6 LW7 LW8 LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17 LW18 LW19
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)
2012 2014 2016 2018 2020 2022

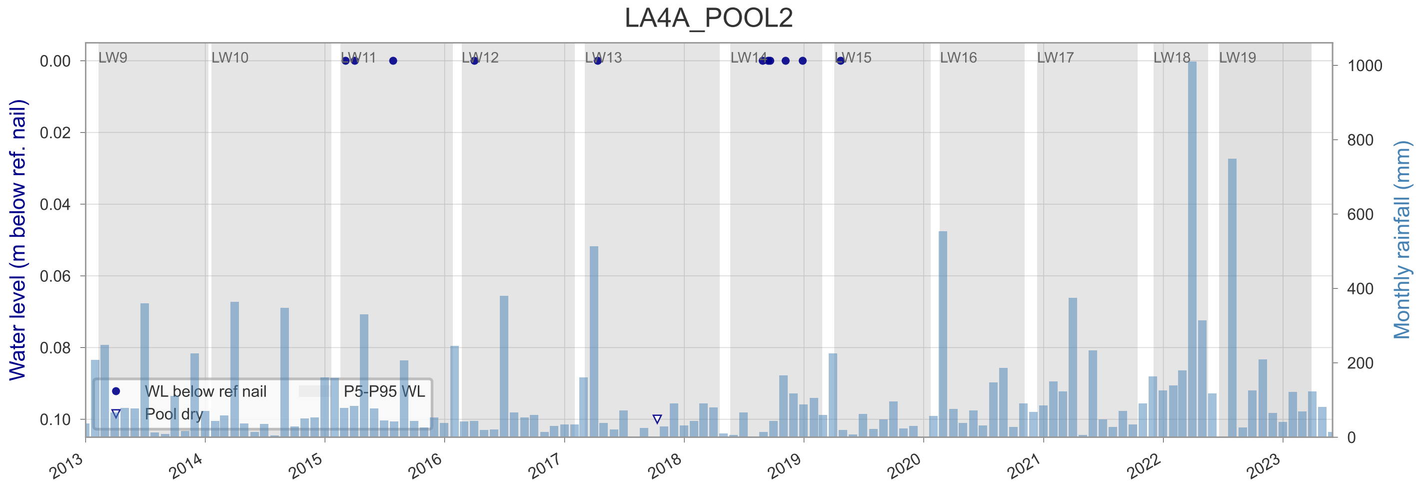

LA3_RB4B
LW6 LW7 LW8 LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17 LW18 LW19
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)
2012 2014 2016 2018 2020 2022

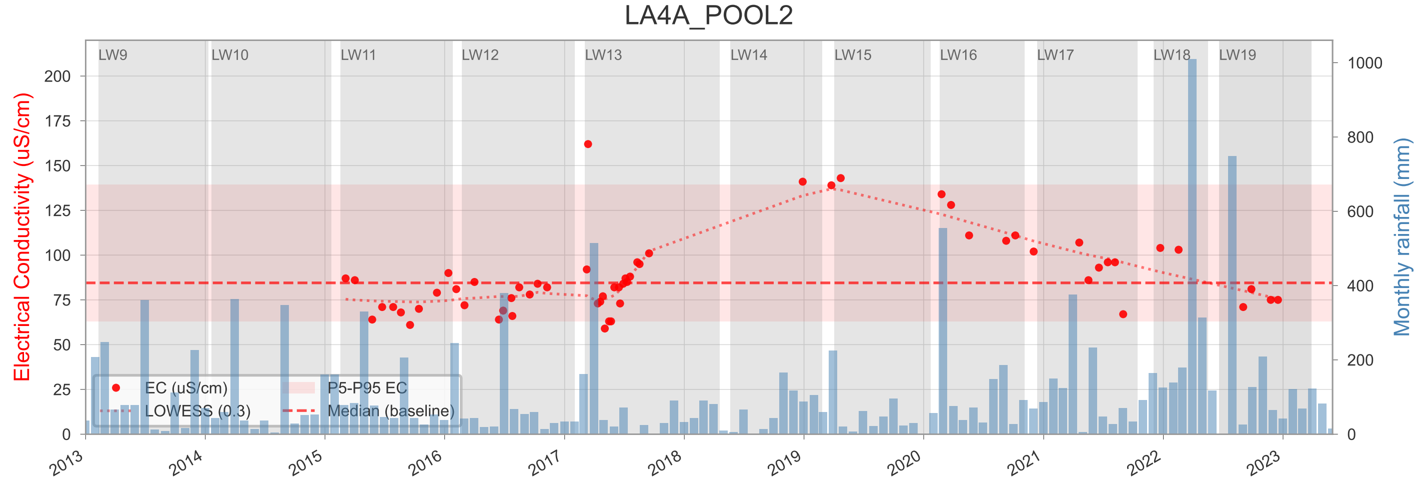

LA4A_POOL1
Water level (m below ref. nail)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
Pool dry
P5-P95 WL

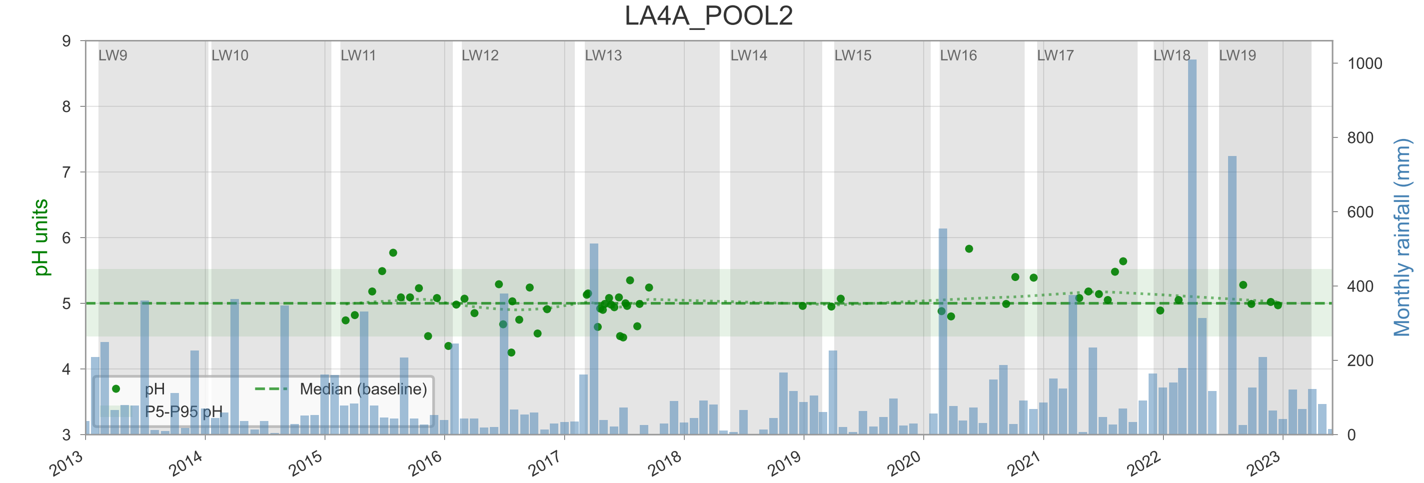

LA4A_POOL1
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

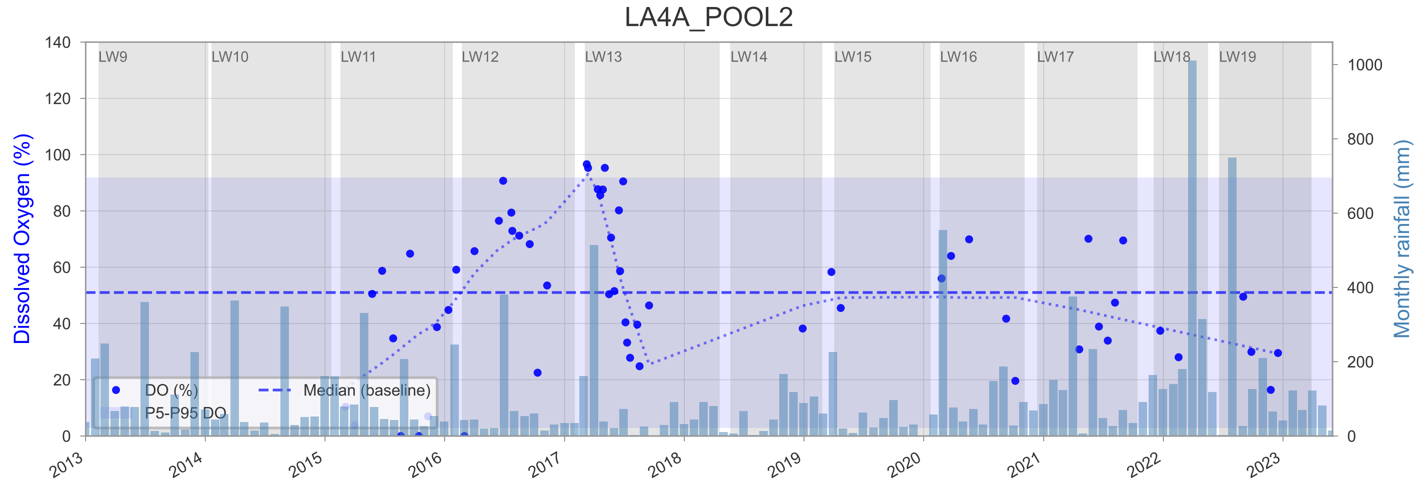

LA4A_POOL1
pH units
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH
P5-P95 pH
Median (baseline)

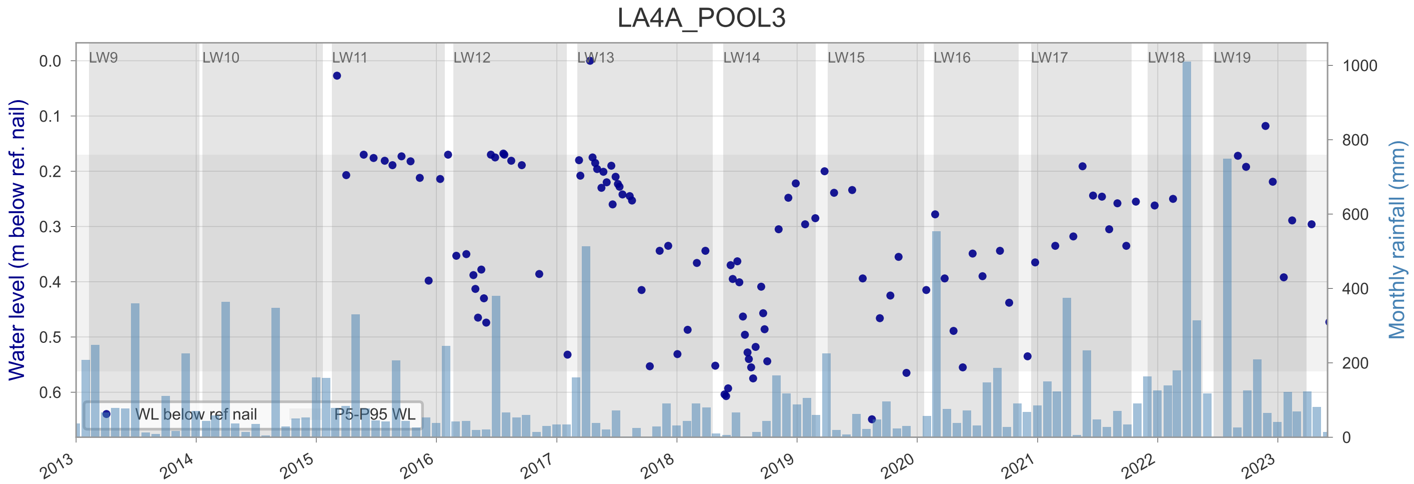

LA4A_POOL1
Dissolved Oxygen (%)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
DO (%)
P5-P95 DO
Median (baseline)

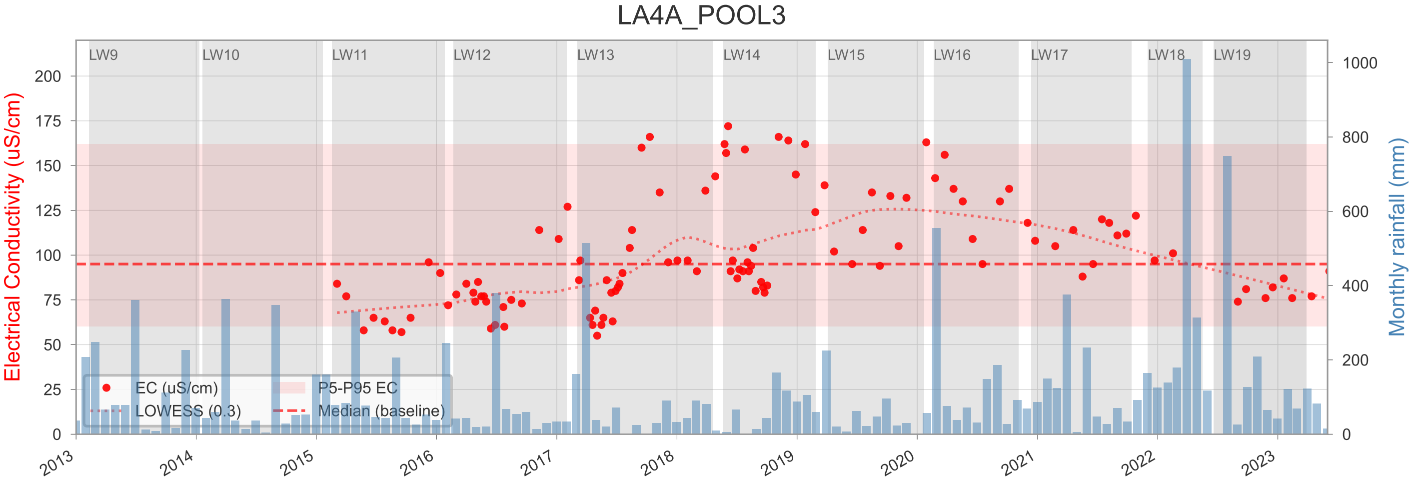

LA4A_POOL2
Water level (m below ref. nail)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
Pool dry
P5-P95 WL

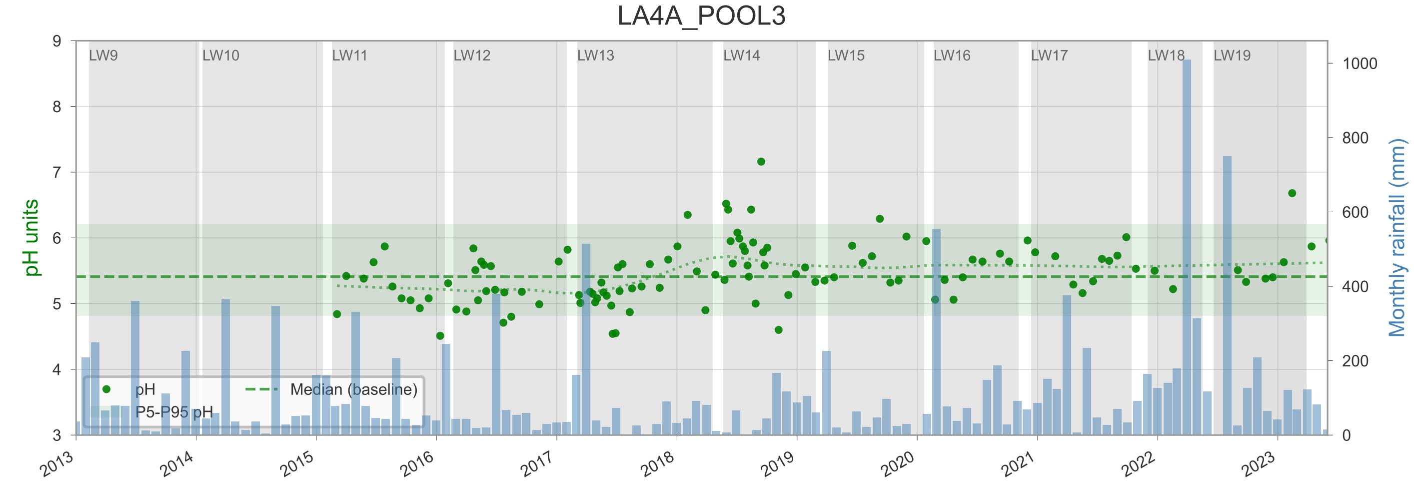

LA4A_POOL2
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

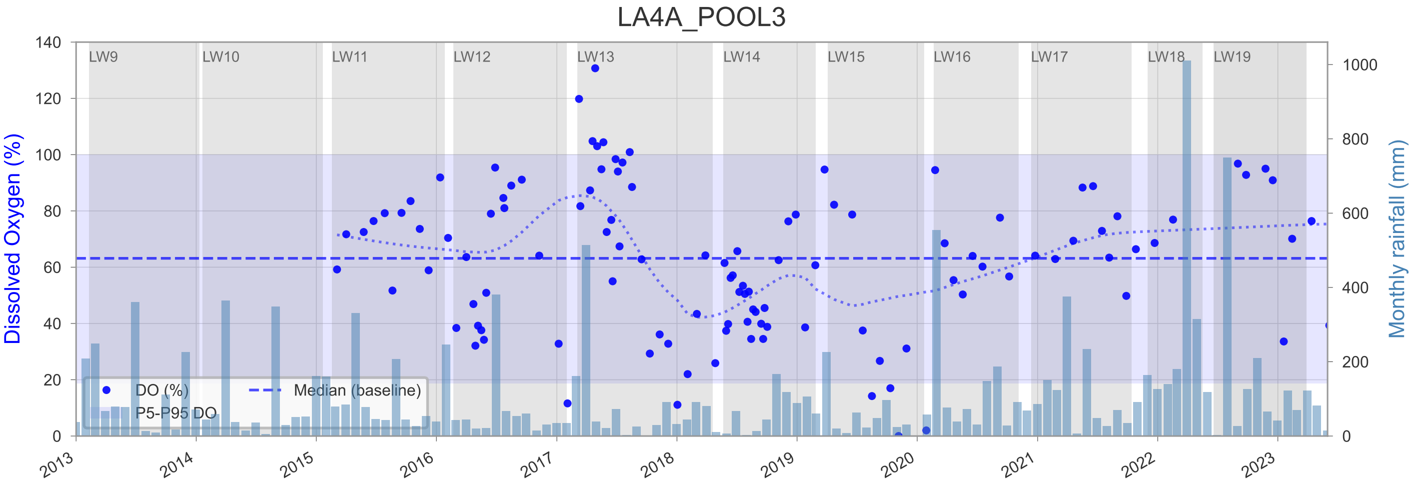

LA4A_POOL2
pH units
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH
P5-P95 pH
Median (baseline)

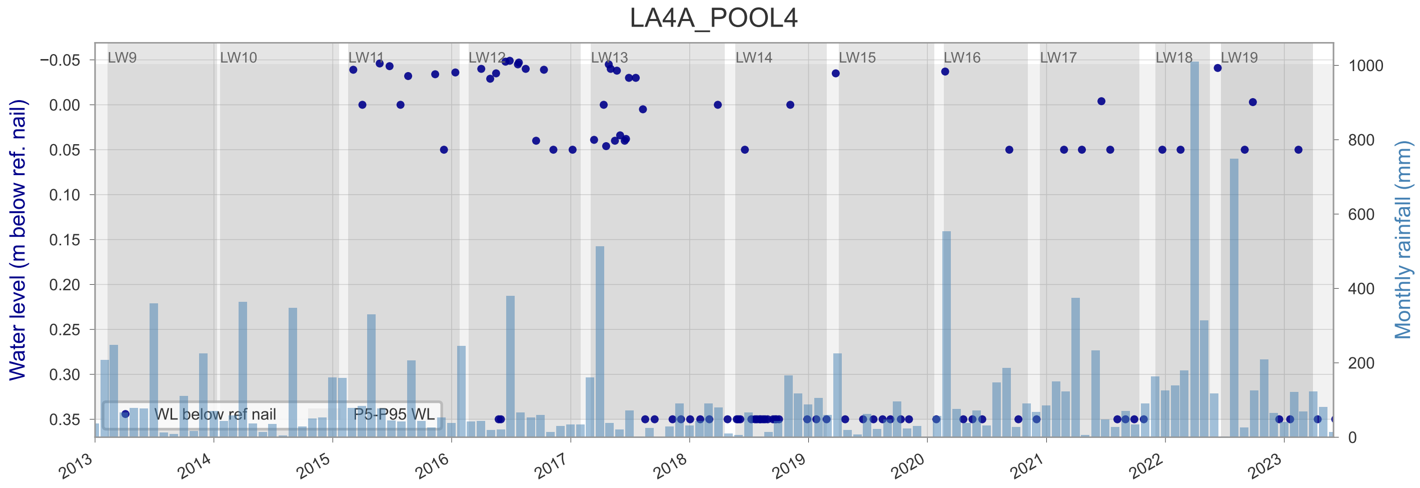

LA4A_POOL2
Dissolved Oxygen (%)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
DO (%)
P5-P95 DO
Median (baseline)

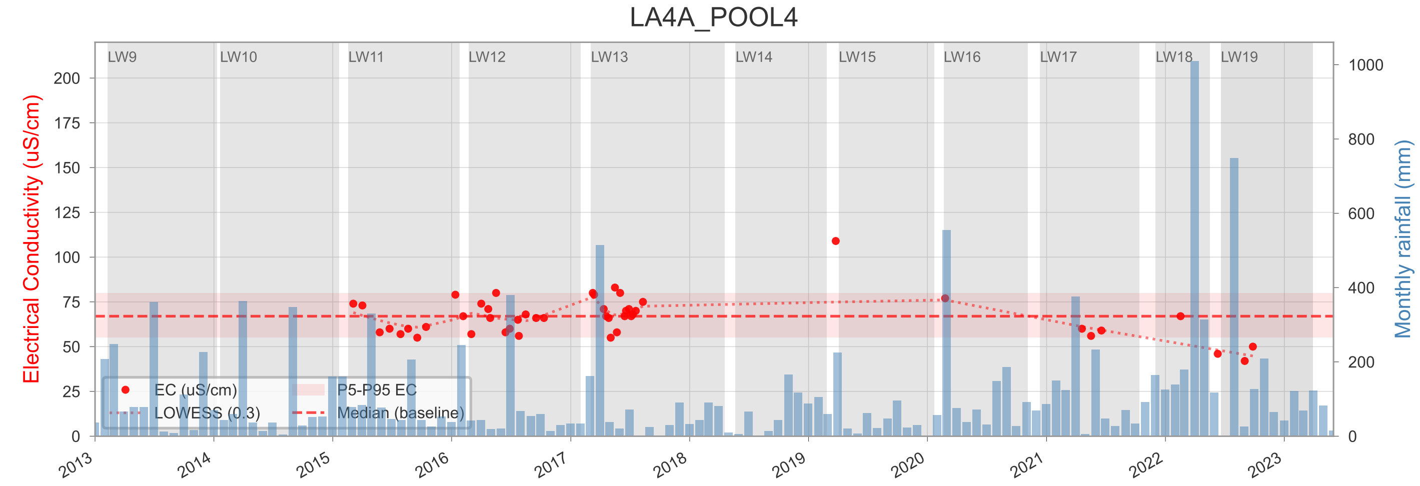

LA4A_POOL3
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
P5-P95 WL
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

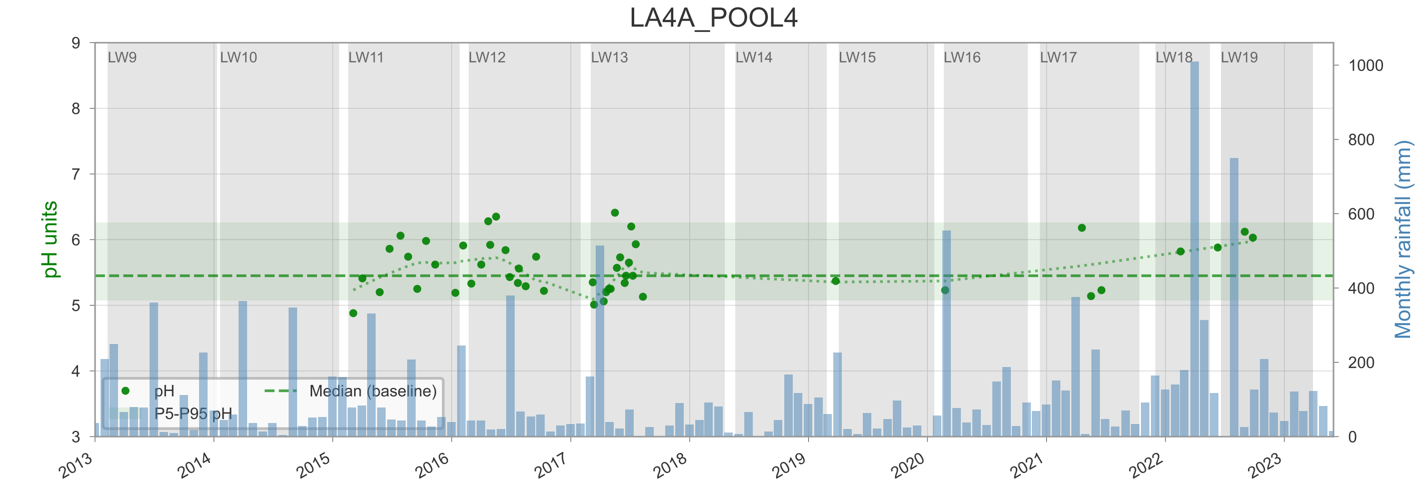

LA4A_POOL3
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

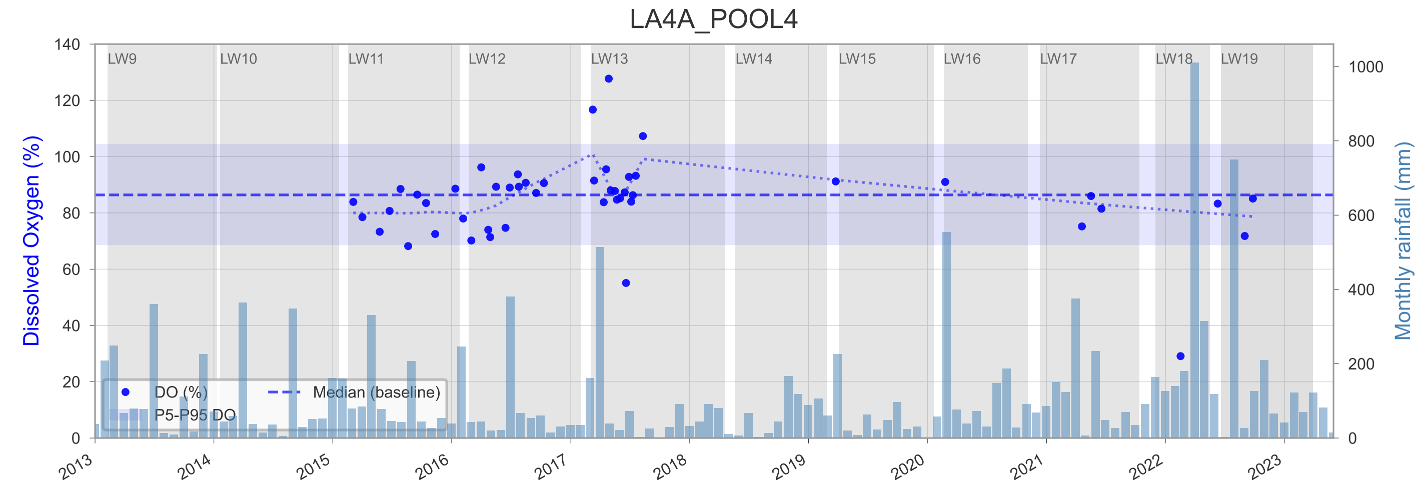

LA4A_POOL3
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)

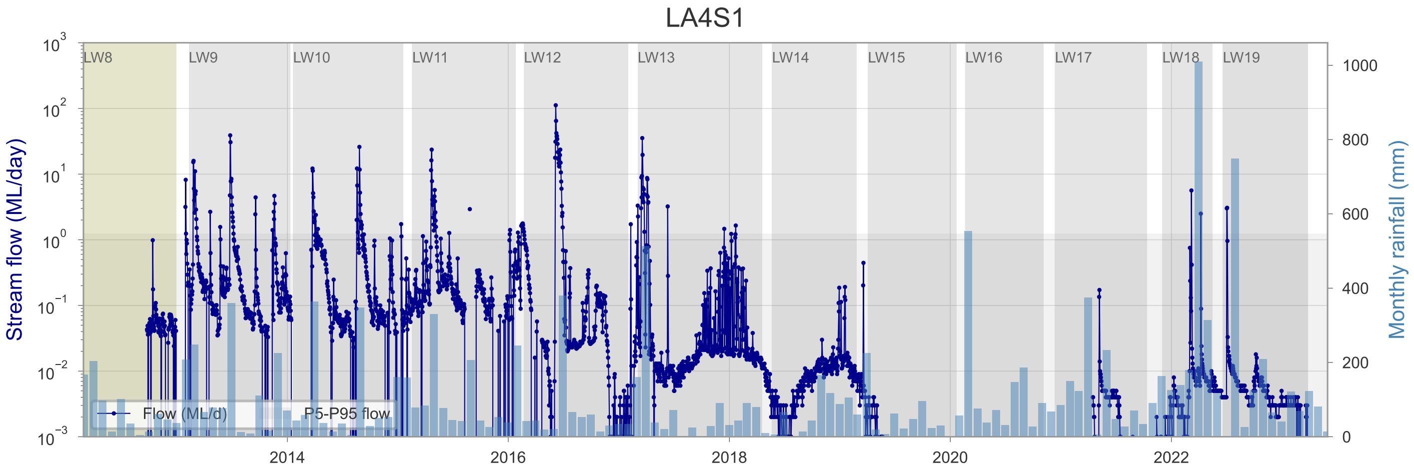

LA4A_POOL3
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)

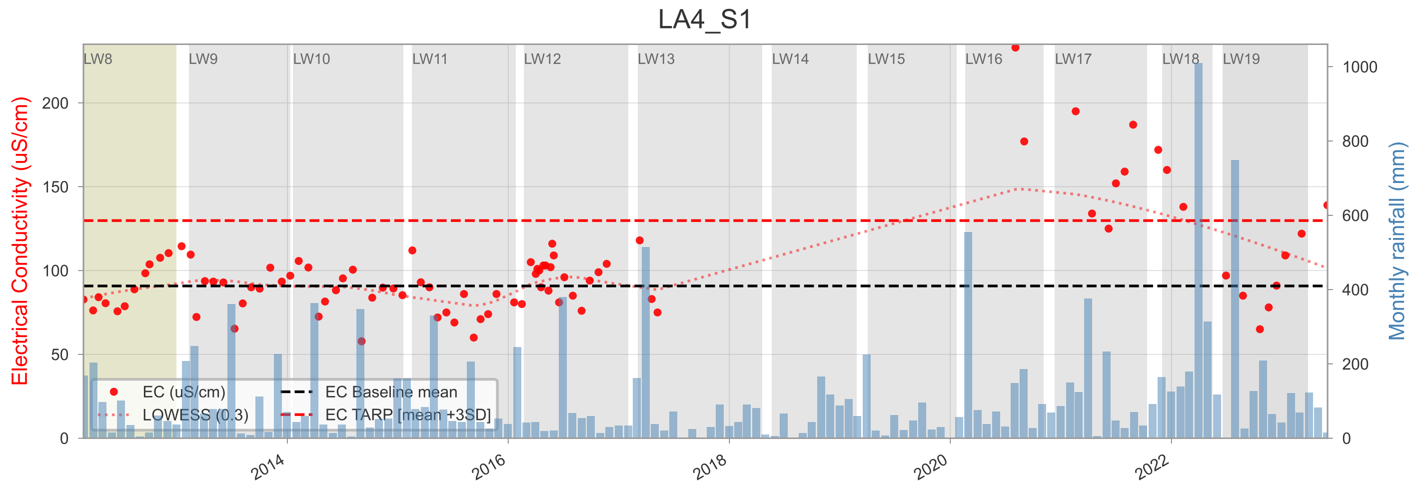

LA4A_POOL4
Water level (m below ref. nail)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
P5-P95 WL
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

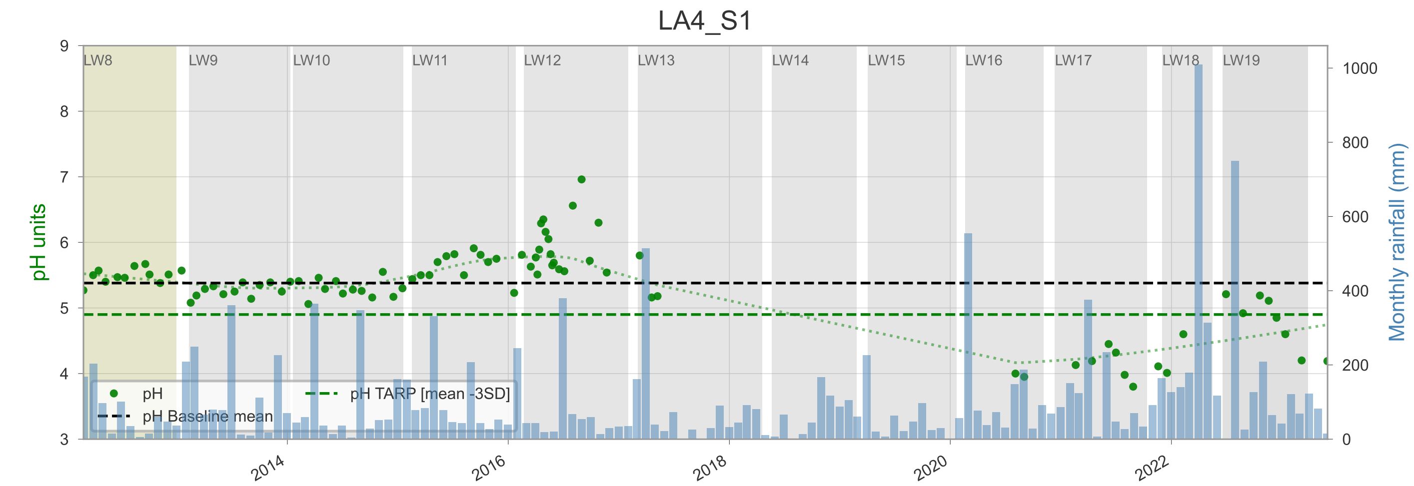

LA4A_POOL4
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

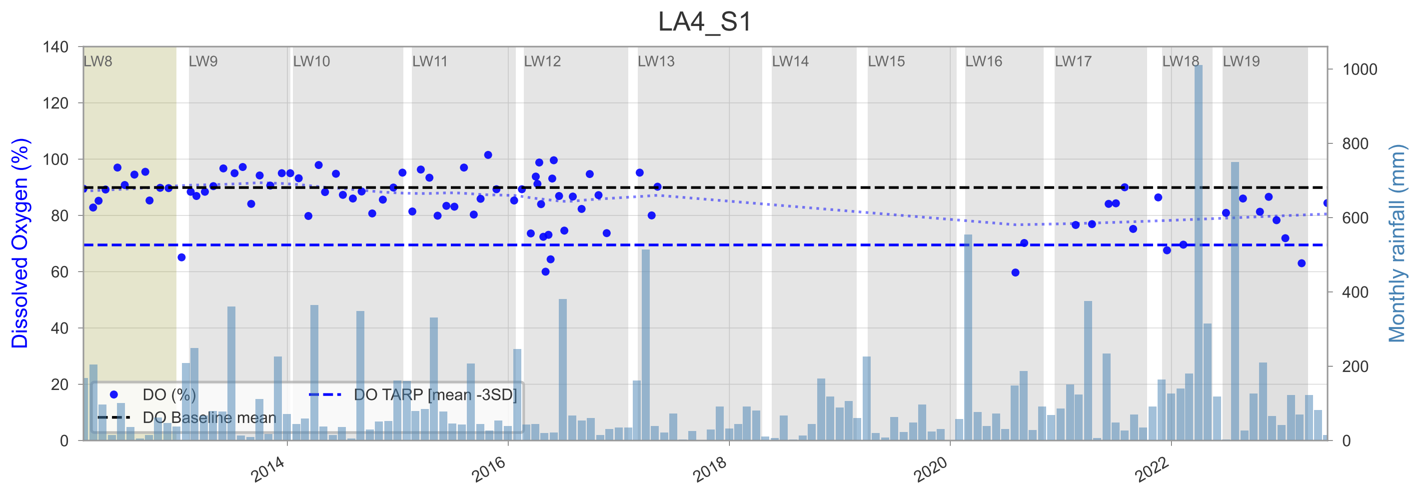

LA4A_POOL4
pH units
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH
P5-P95 pH
Median (baseline)
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

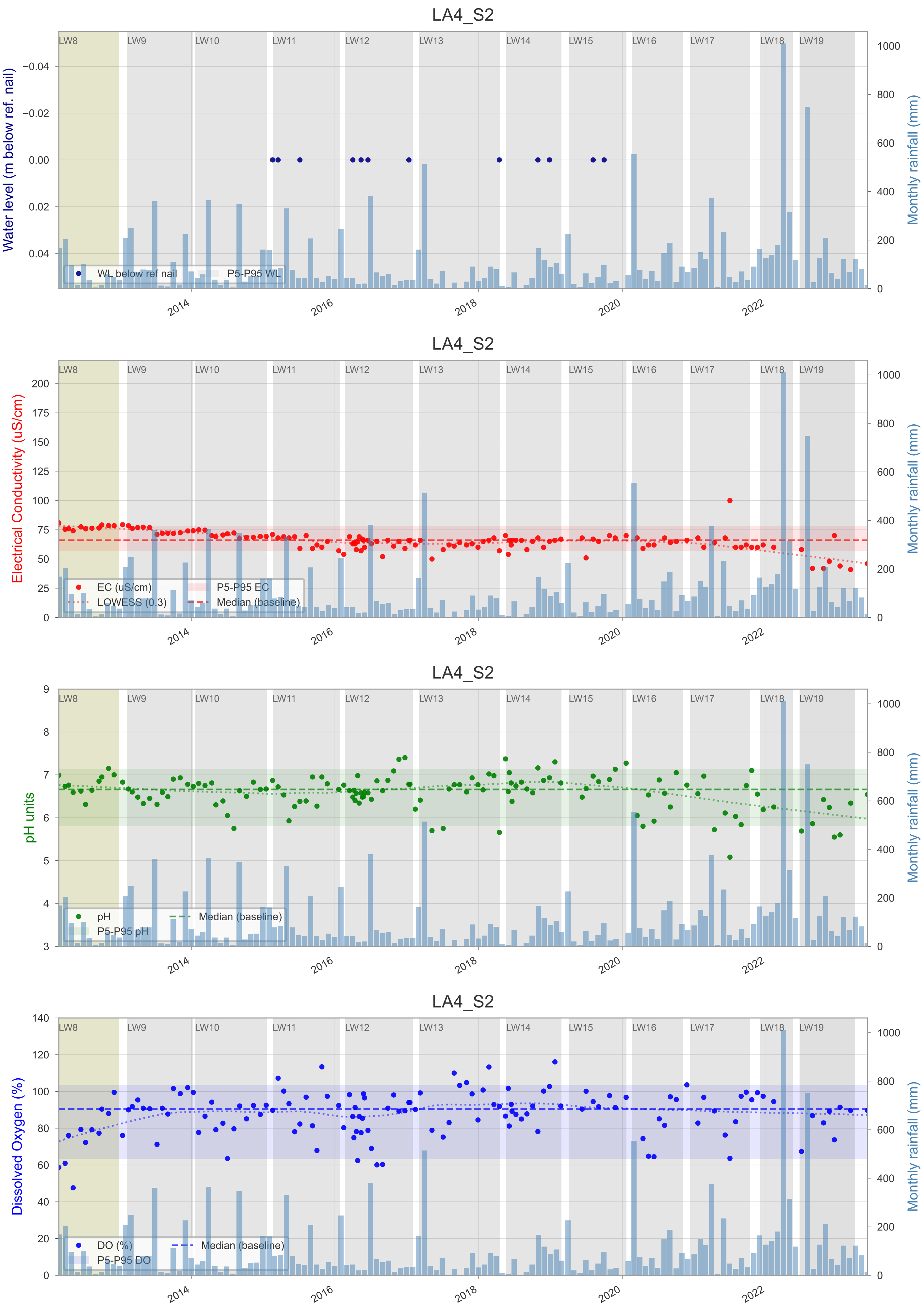

LA4A_POOL4
Dissolved Oxygen (%)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
DO (%)
P5-P95 DO
Median (baseline)
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

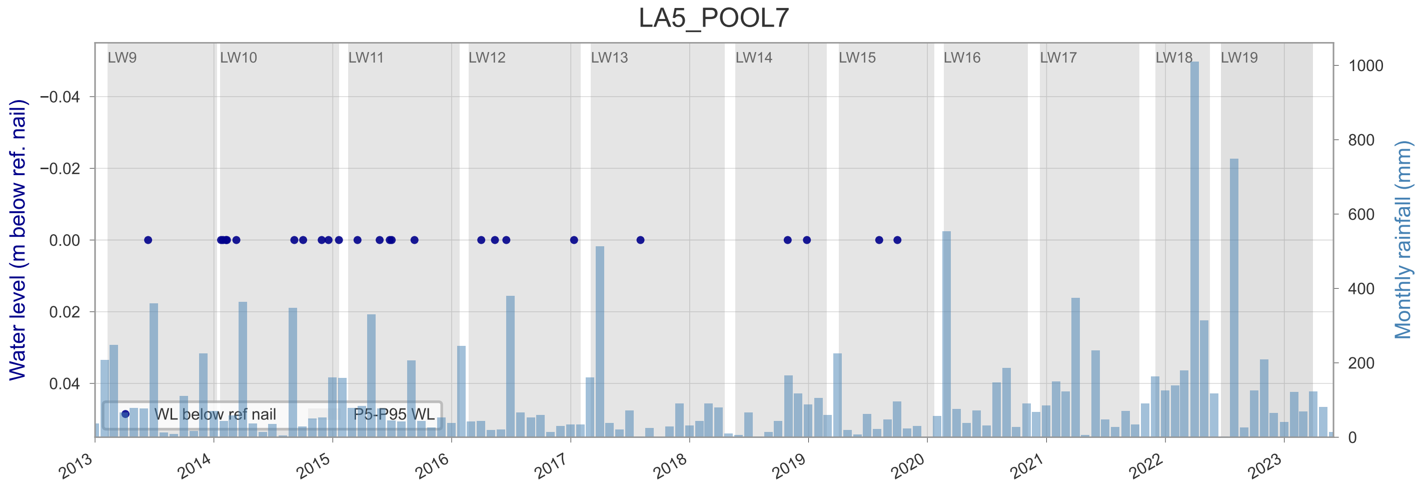

LA4S1
Stream flow (ML/day)
Monthly rainfall (mm)
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Flow (ML/d)
P5-P95 flow

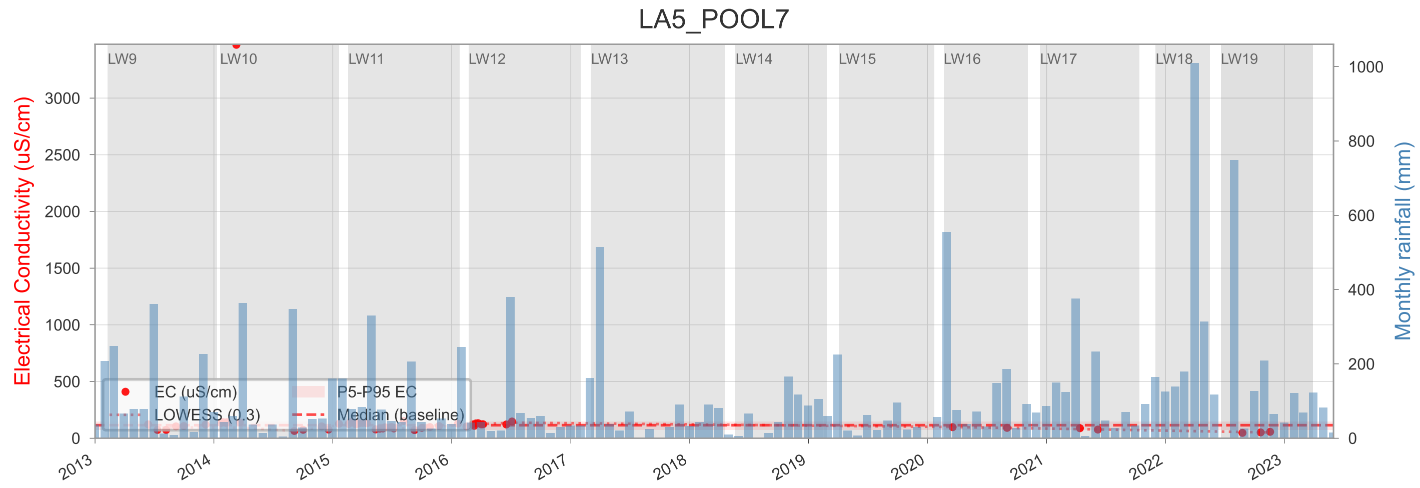

LA4_S1
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
EC Baseline mean
EC TARP [mean +3SD]

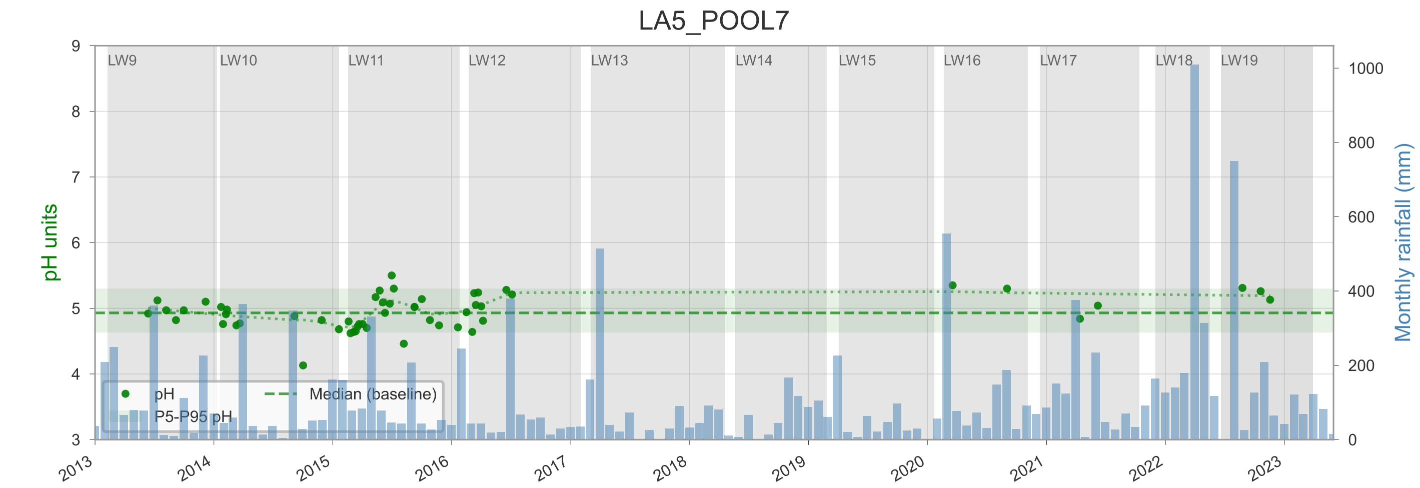

LA4_S1
pH units
Monthly rainfall (mm)
pH
pH Baseline mean
pH TARP [mean -3SD]

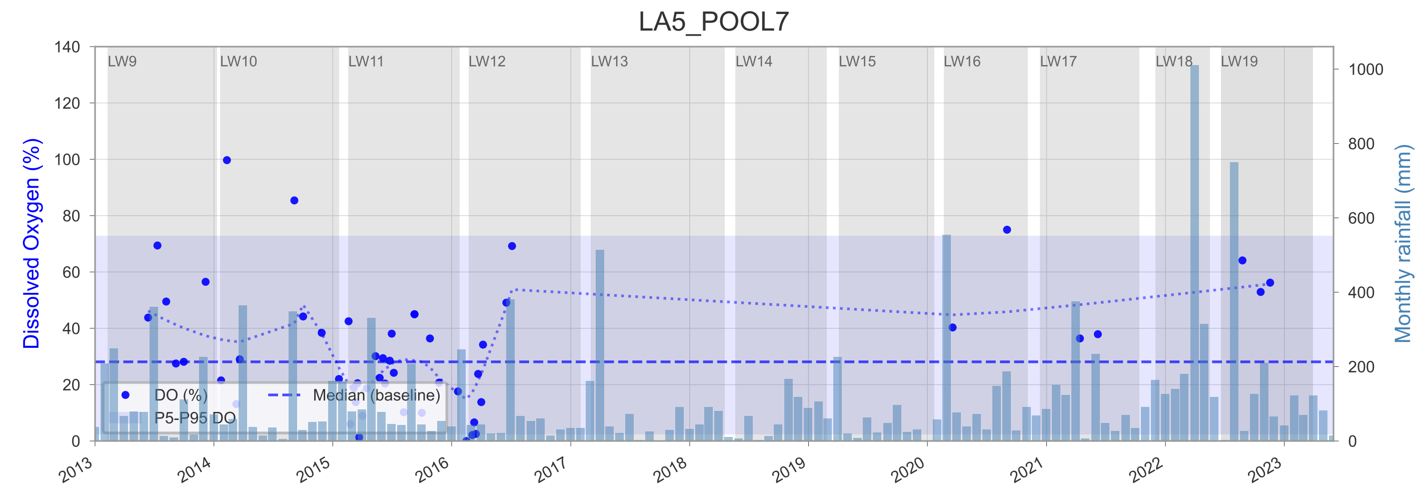

LA4_S1
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
DO Baseline mean
DO TARP [mean -3SD]

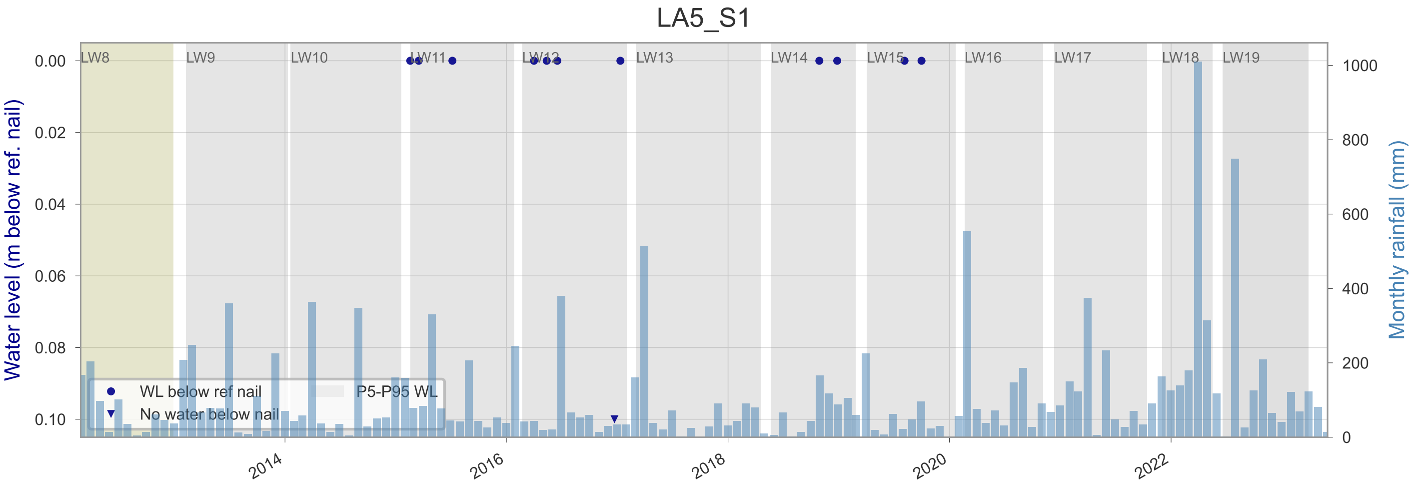

LA4_S2
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
P5-P95 WL
LA4_S2
Electrical Conductivity (uS/cm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)
LA4_S2
pH units
pH
P5-P95 pH
Median (baseline)
LA4_S2
Dissolved Oxygen (%)
DO (%)
P5-P95 DO
Median (baseline)
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
2014
2016
2018
2020
2022

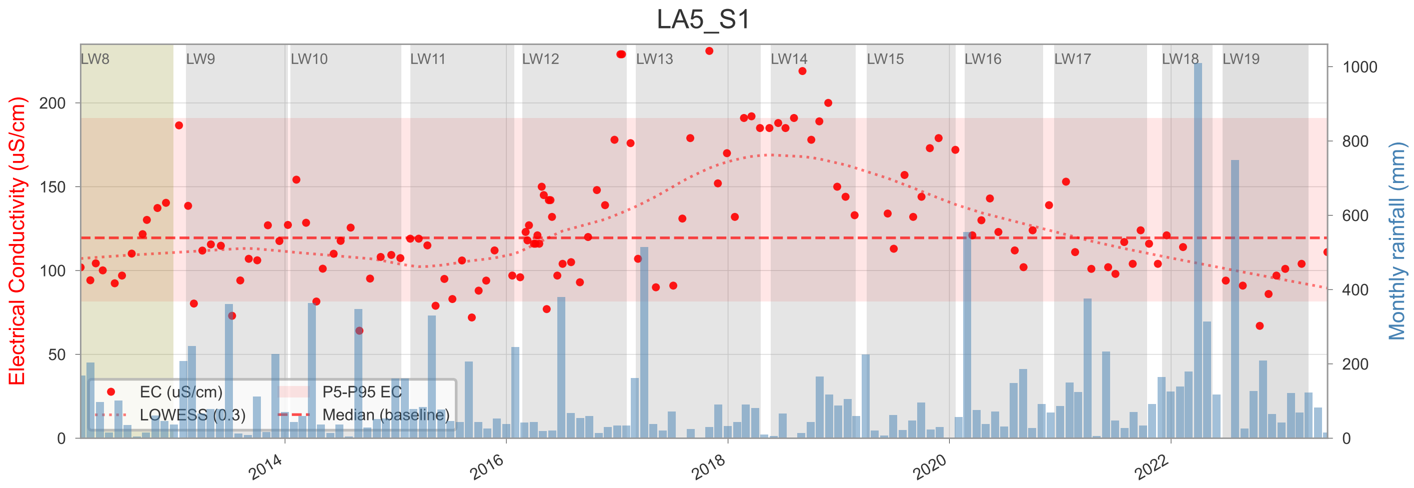

LA5_POOL7
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
P5-P95 WL

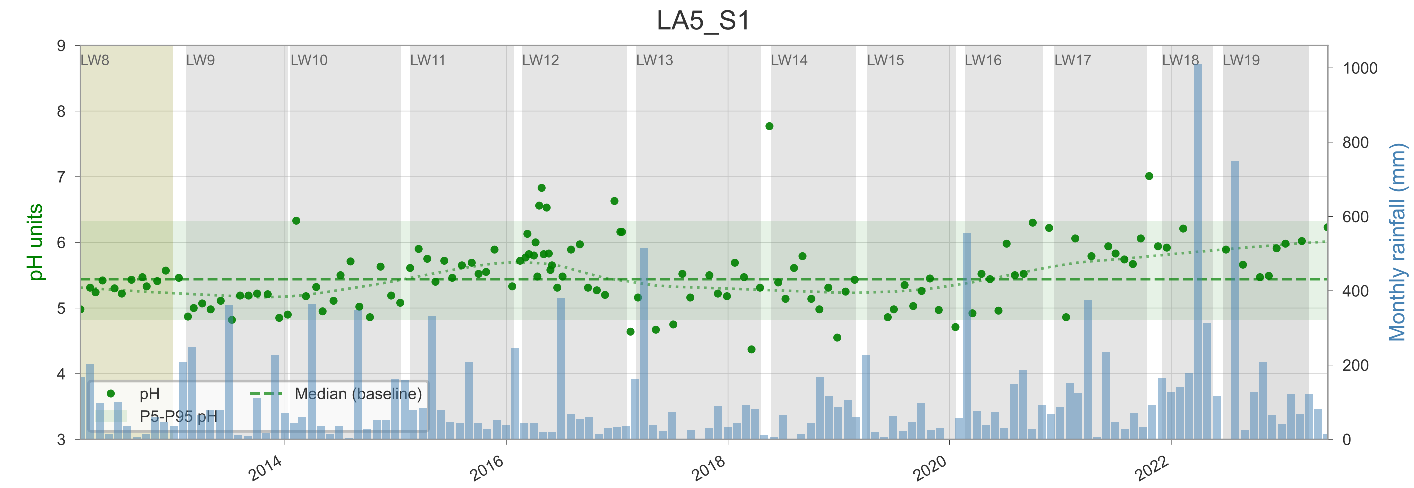

LA5_POOL7
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

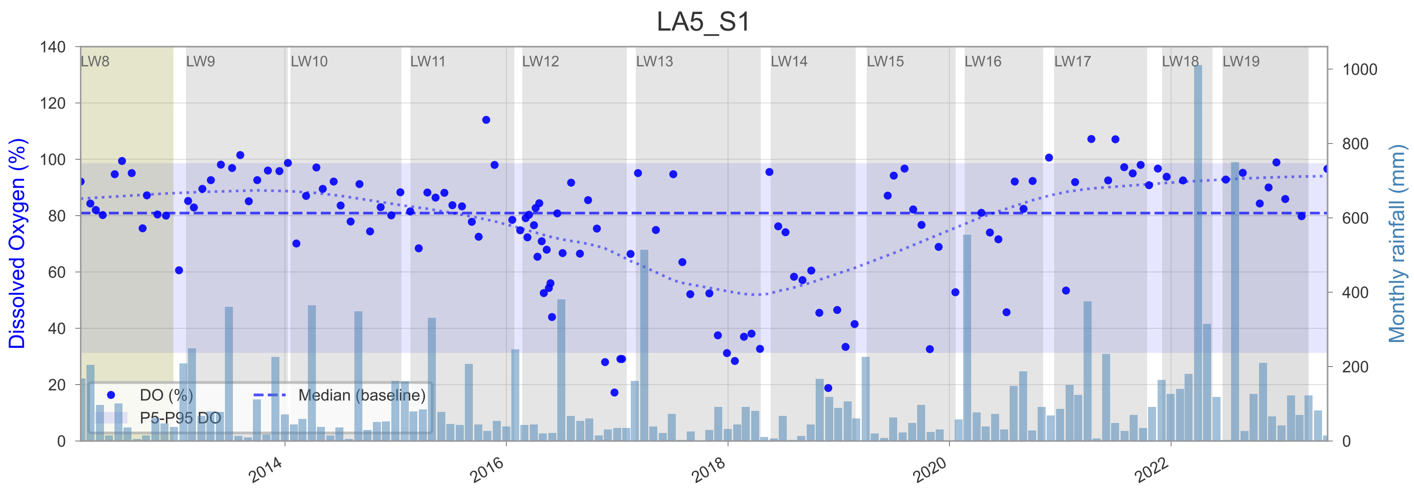

LA5_POOL7
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)

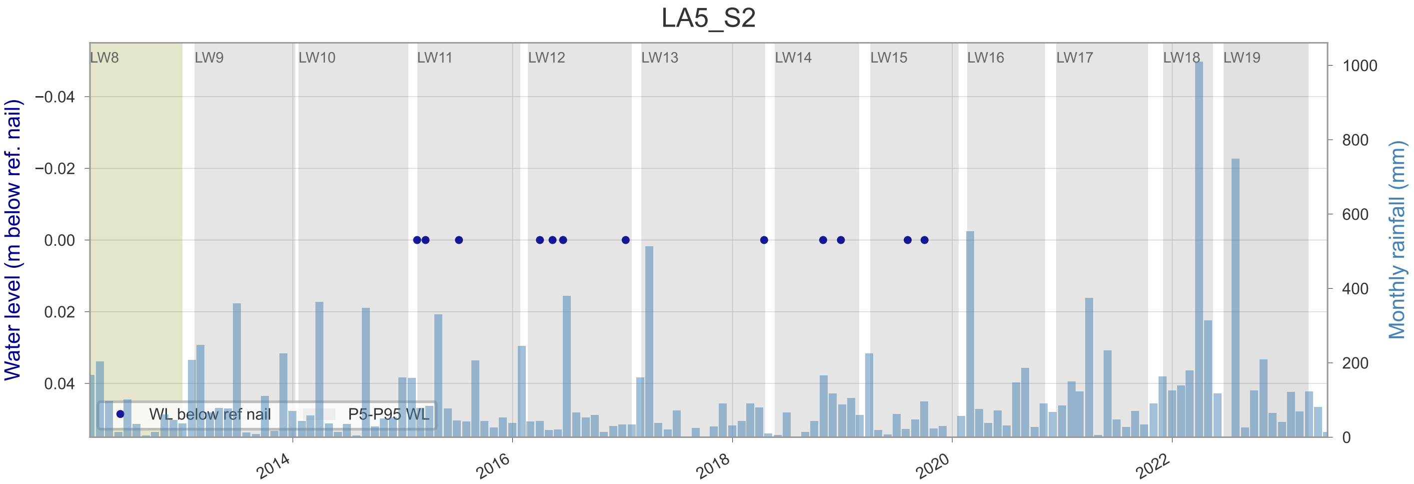

LA5_POOL7
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)

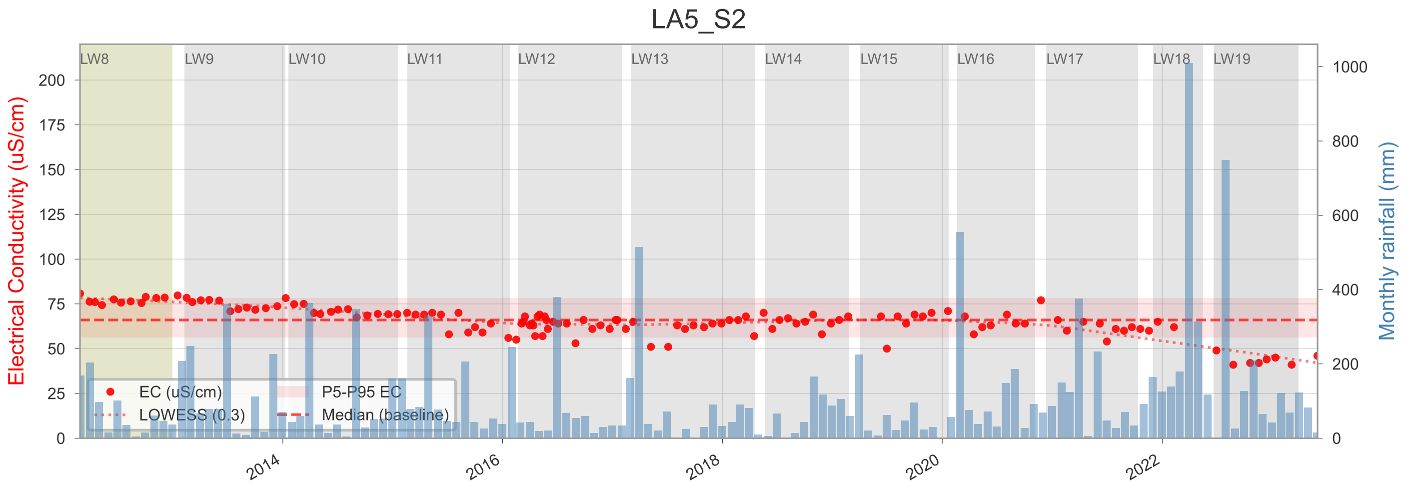

LA5_S1
Water level (m below ref. nail)
Monthly rainfall (mm)
LW8 LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17 LW18 LW19
WL below ref nail
No water below nail
P5-P95 WL
2014 2016 2018 2020 2022

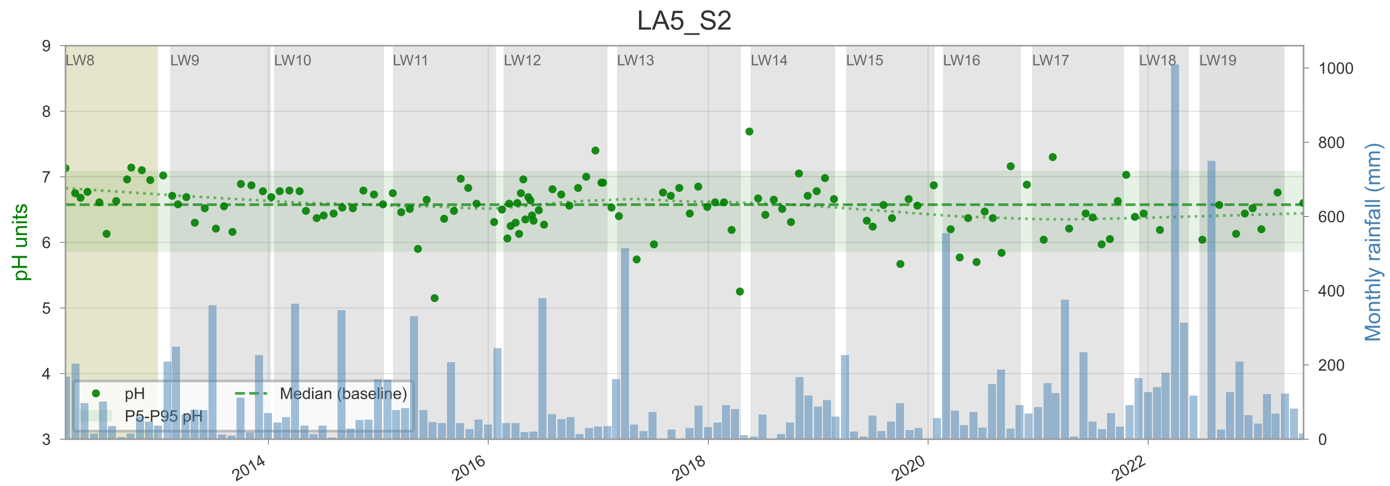

LA5_S1
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
LW8 LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17 LW18 LW19
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)
2014 2016 2018 2020 2022

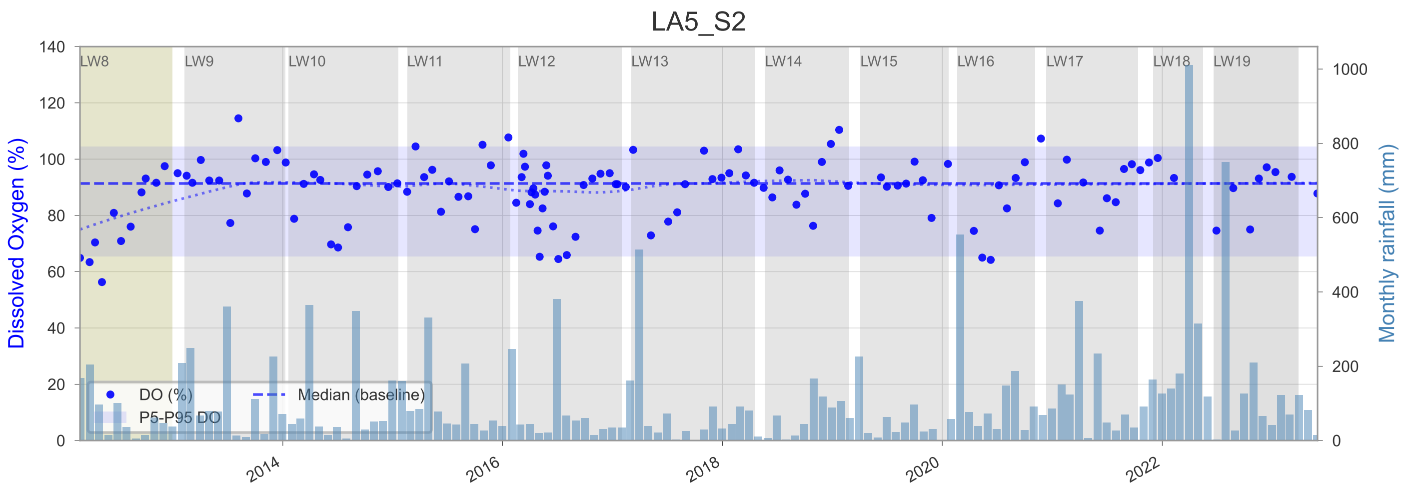

LA5_S1
pH units
Monthly rainfall (mm)
LW8 LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17 LW18 LW19
pH
P5-P95 pH
Median (baseline)
2014 2016 2018 2020 2022

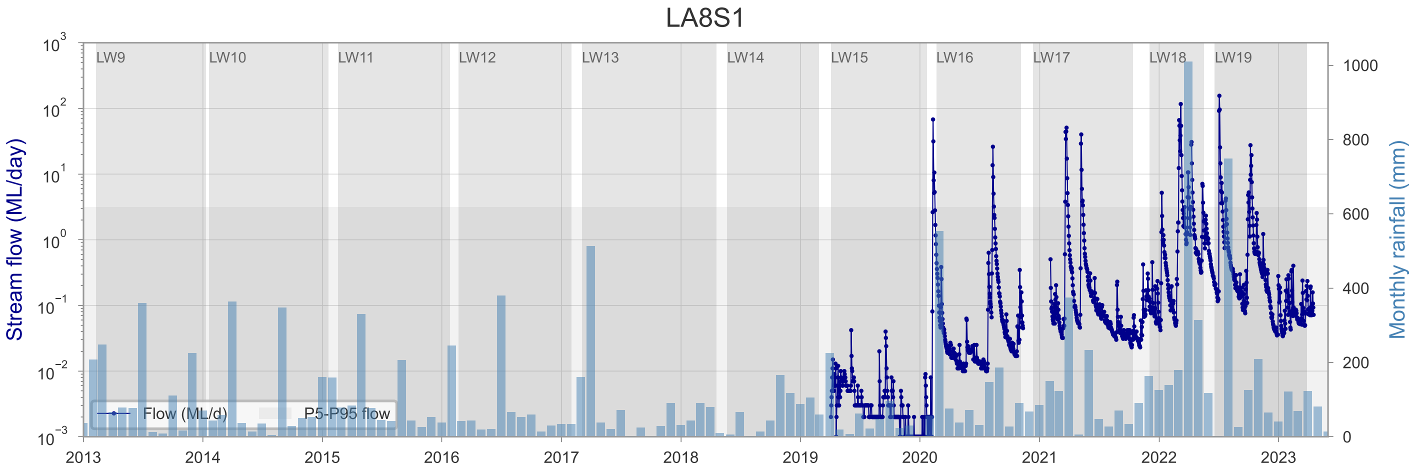

LA5_S1
Dissolved Oxygen (%)
Monthly rainfall (mm)
LW8 LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17 LW18 LW19
DO (%)
P5-P95 DO
Median (baseline)
2014 2016 2018 2020 2022

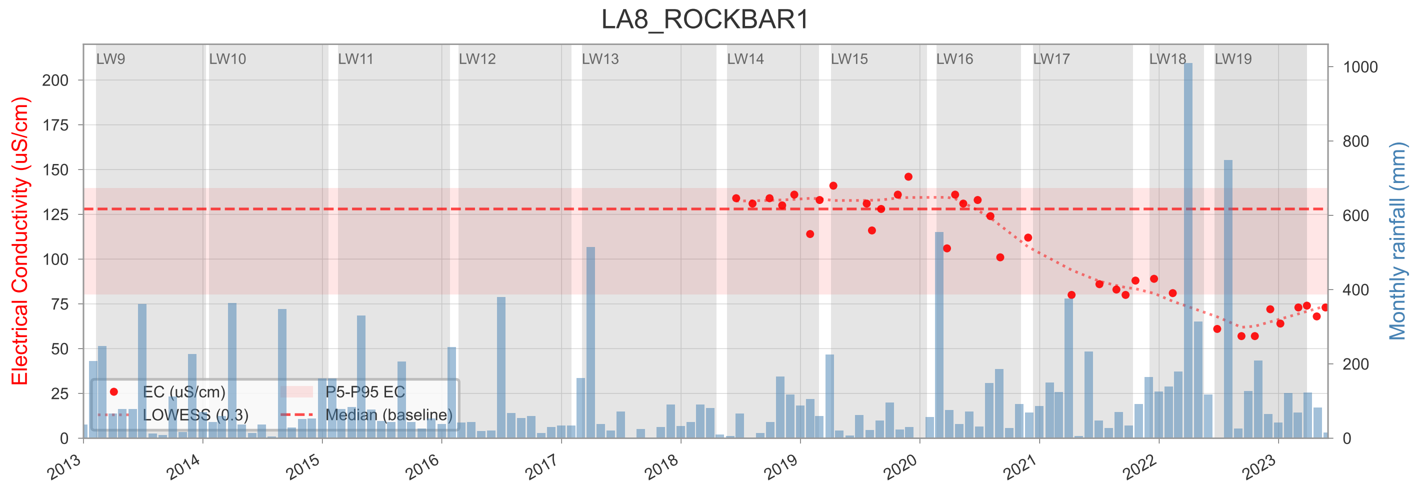

LA5_S2
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
P5-P95 WL
2014
2016
2018
2020
2022

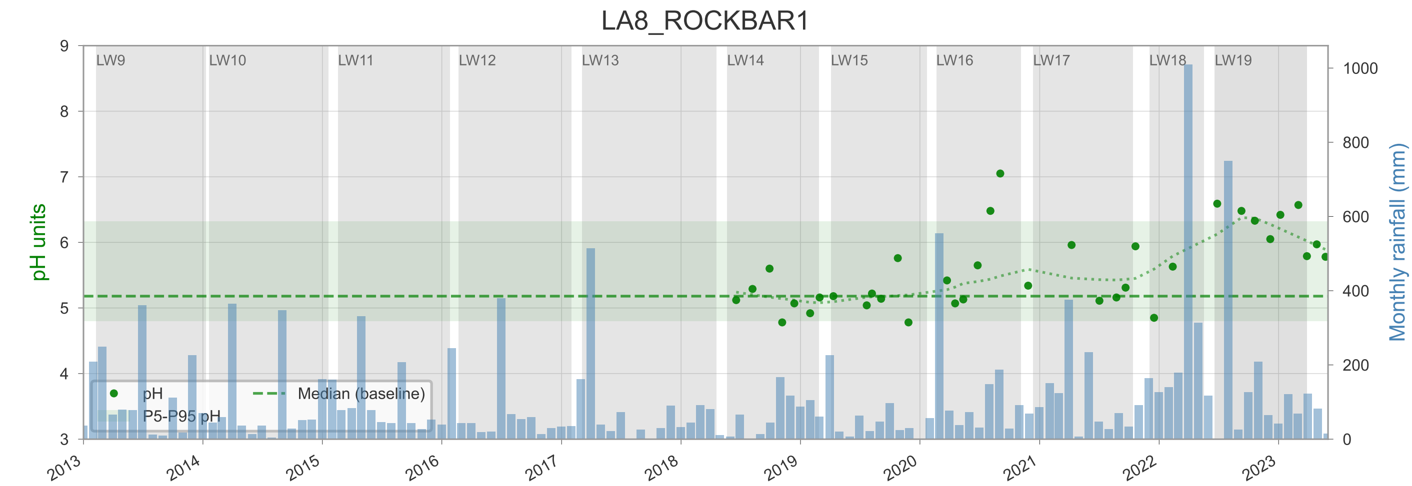

LA5_S2
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)
2014
2016
2018
2020
2022

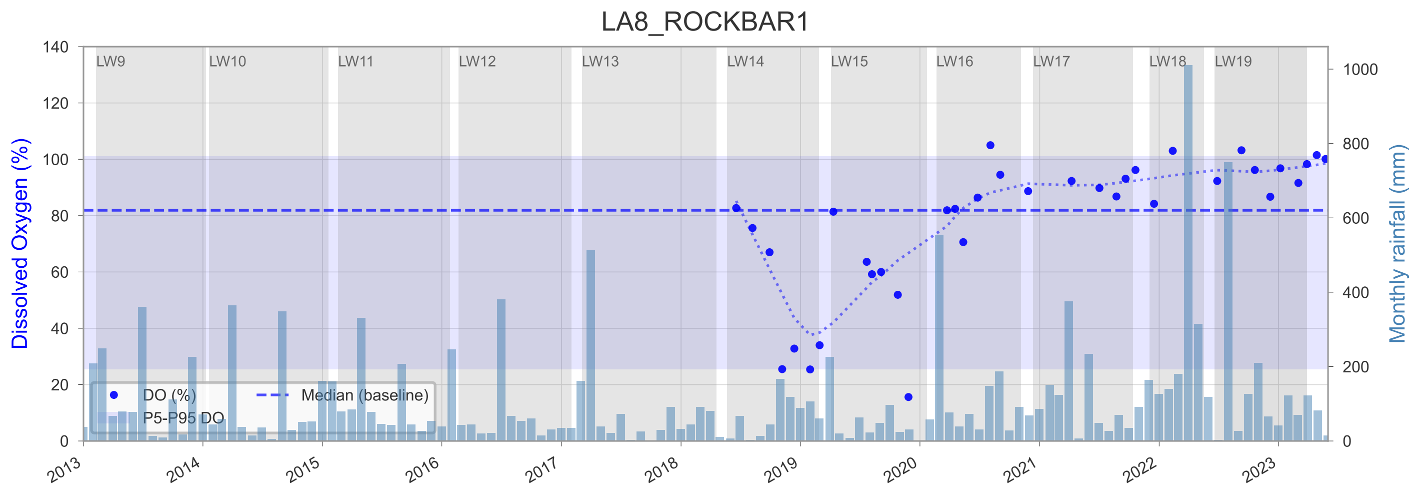

LA5_S2
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)
2014
2016
2018
2020
2022

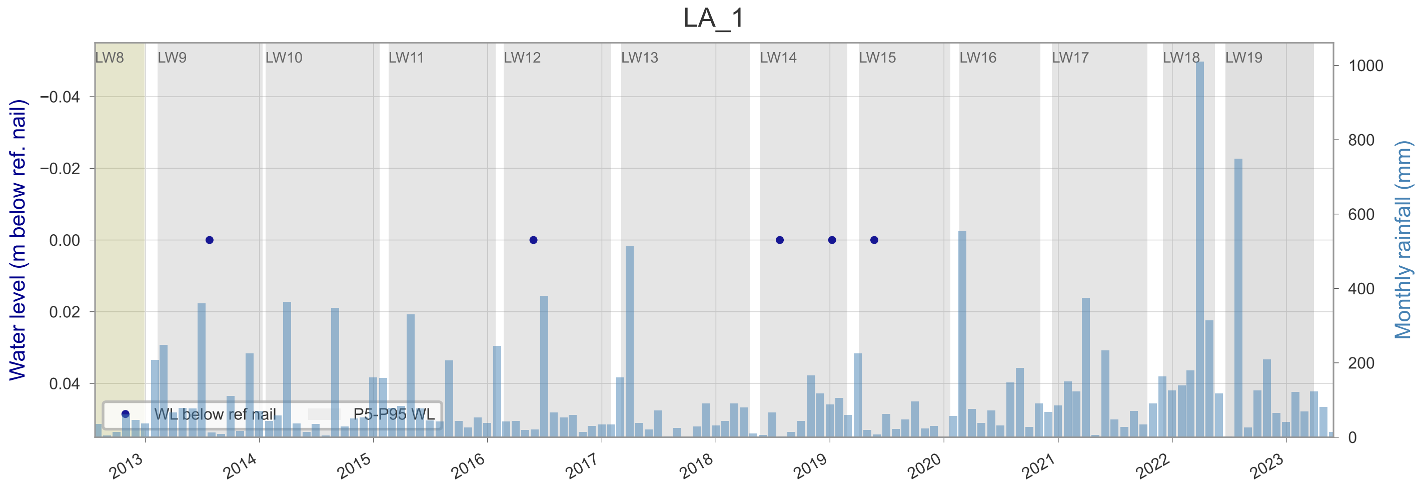

LA5_S2
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)
2014
2016
2018
2020
2022

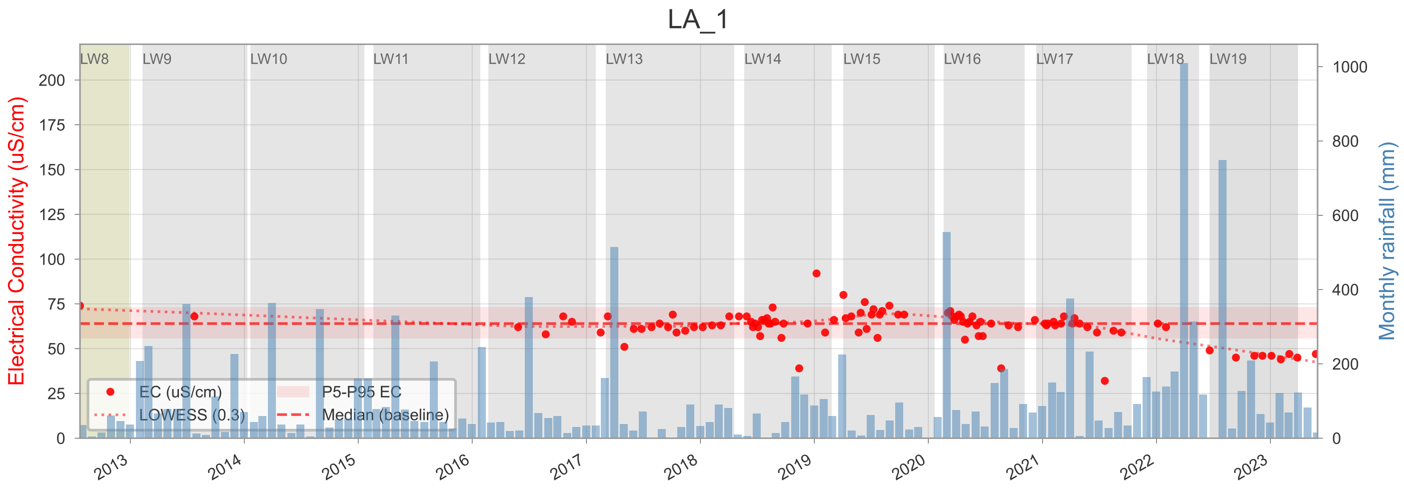

LA8S1
Stream flow (ML/day)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Flow (ML/d)
P5-P95 flow
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

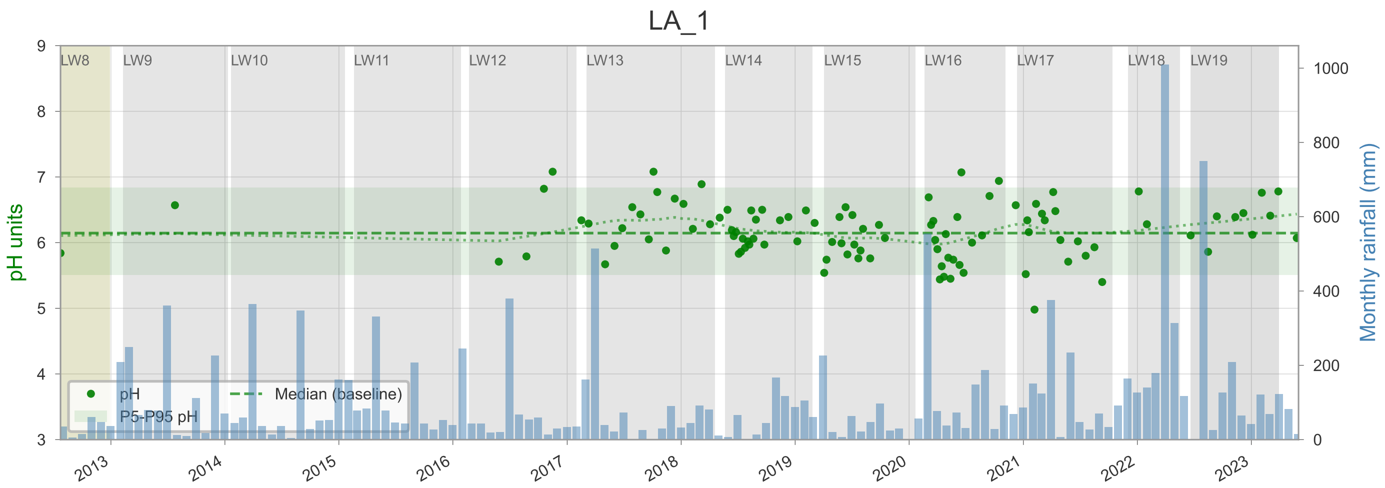

LA8_ROCKBAR1
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

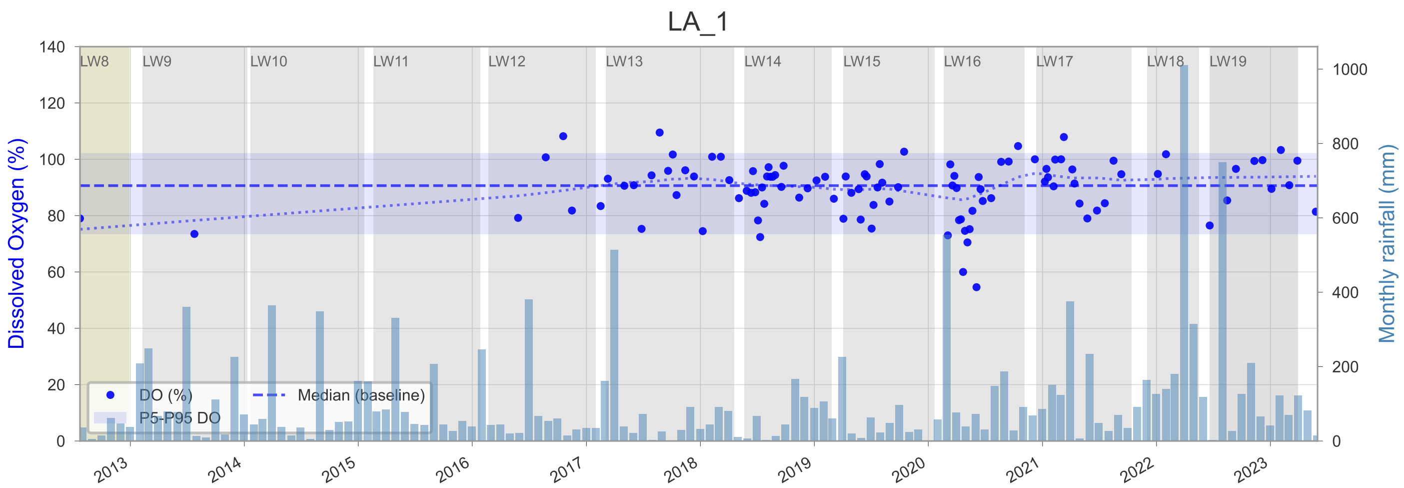

LA8_ROCKBAR1
pH units
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH
P5-P95 pH
Median (baseline)

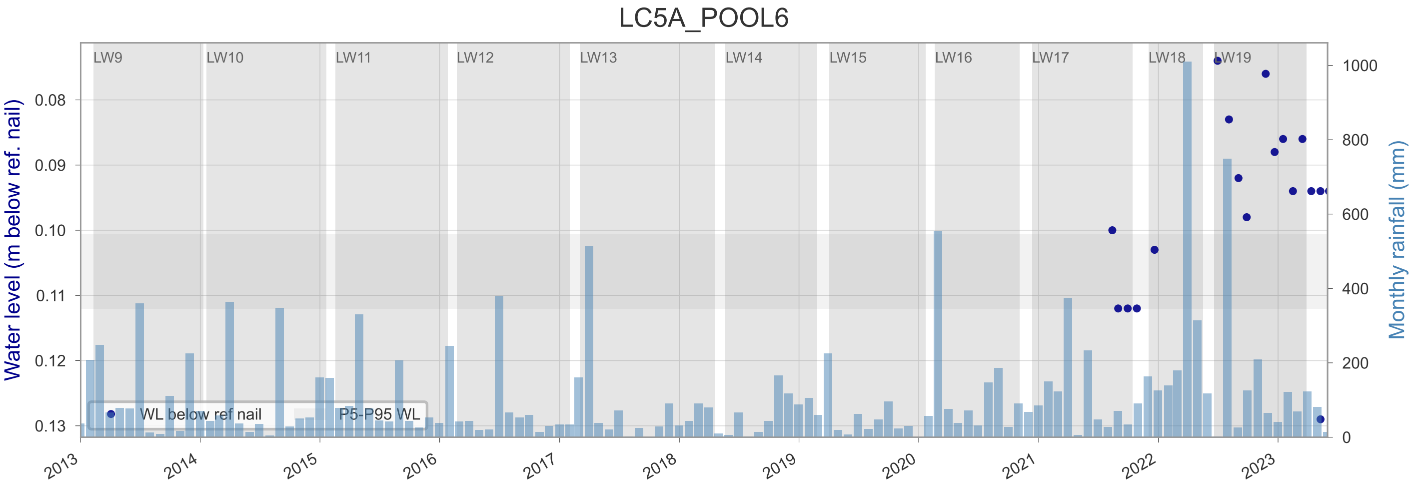

LA8_ROCKBAR1
Dissolved Oxygen (%)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
DO (%)
P5-P95 DO
Median (baseline)

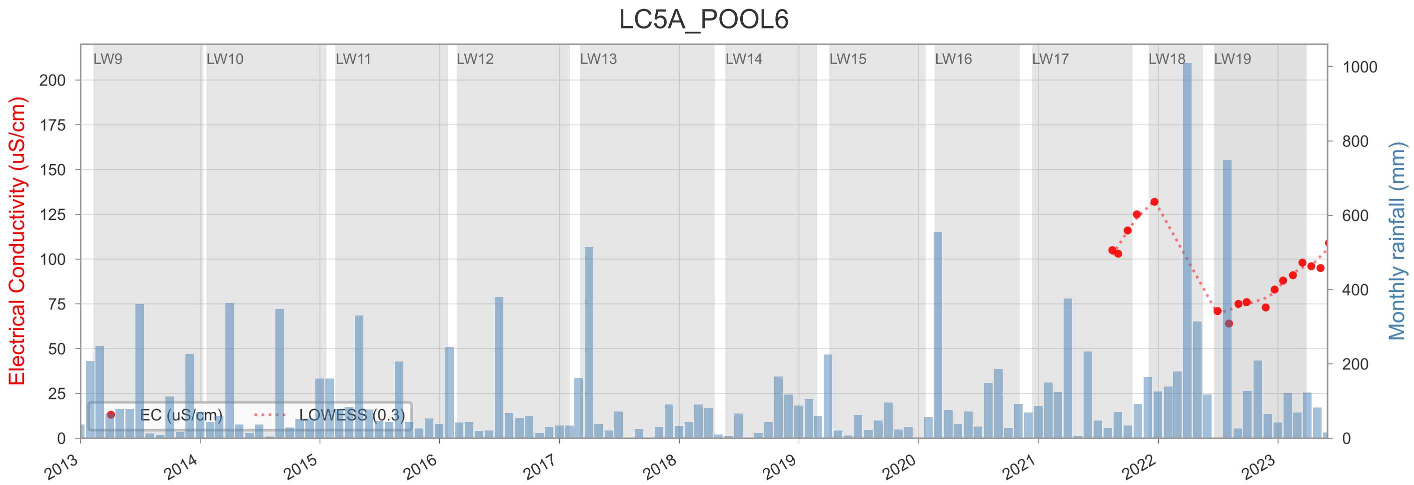

LA_1
Water level (m below ref. nail)
Monthly rainfall (mm)
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
P5-P95 WL

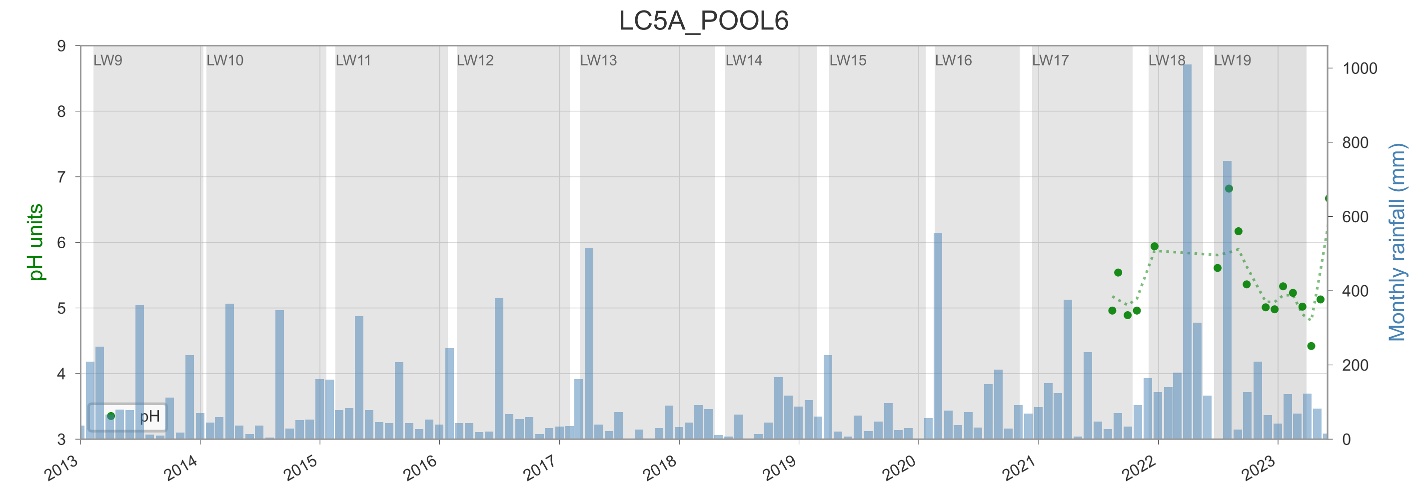

LA_1
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

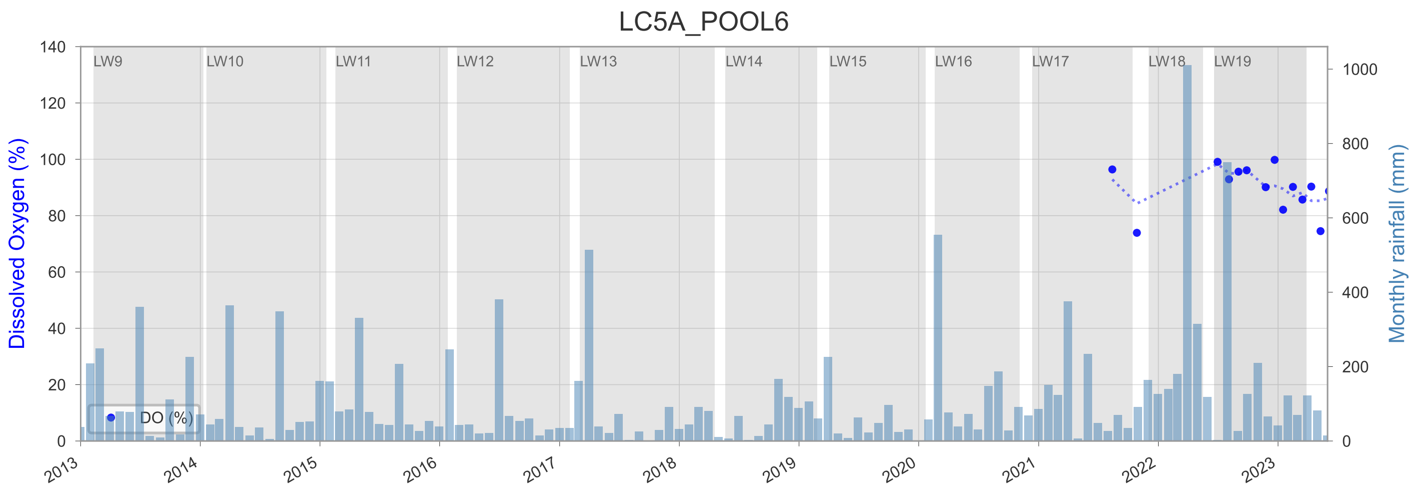

LA_1
pH units
Monthly rainfall (mm)
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH
P5-P95 pH
Median (baseline)

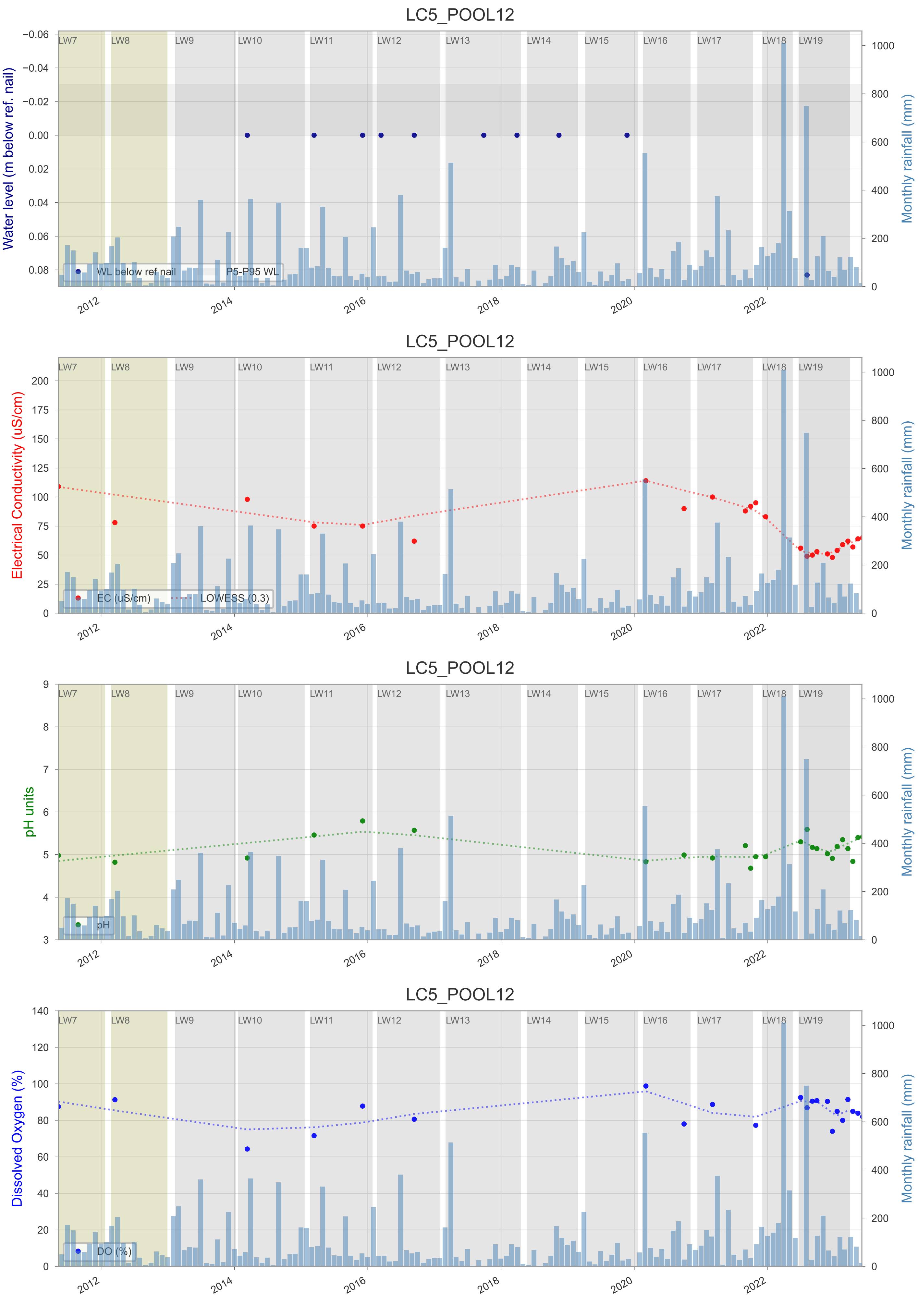

LA_1
Dissolved Oxygen (%)
Monthly rainfall (mm)
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
DO (%)
P5-P95 DO
Median (baseline)


LC5A_POOL6
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
P5-P95 WL
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

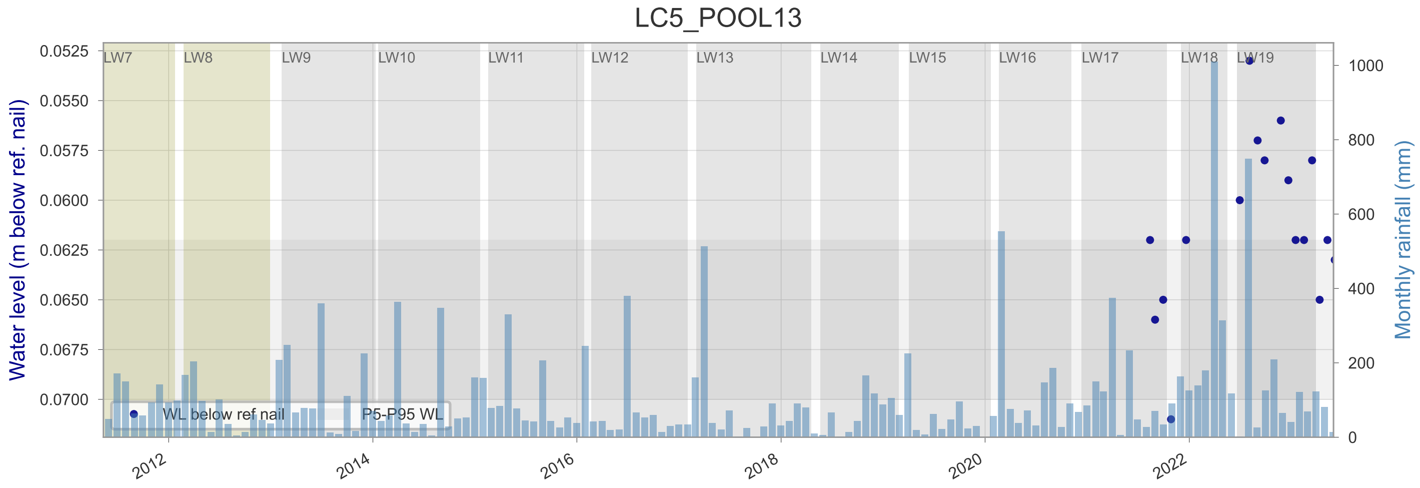

LC5A_POOL6
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

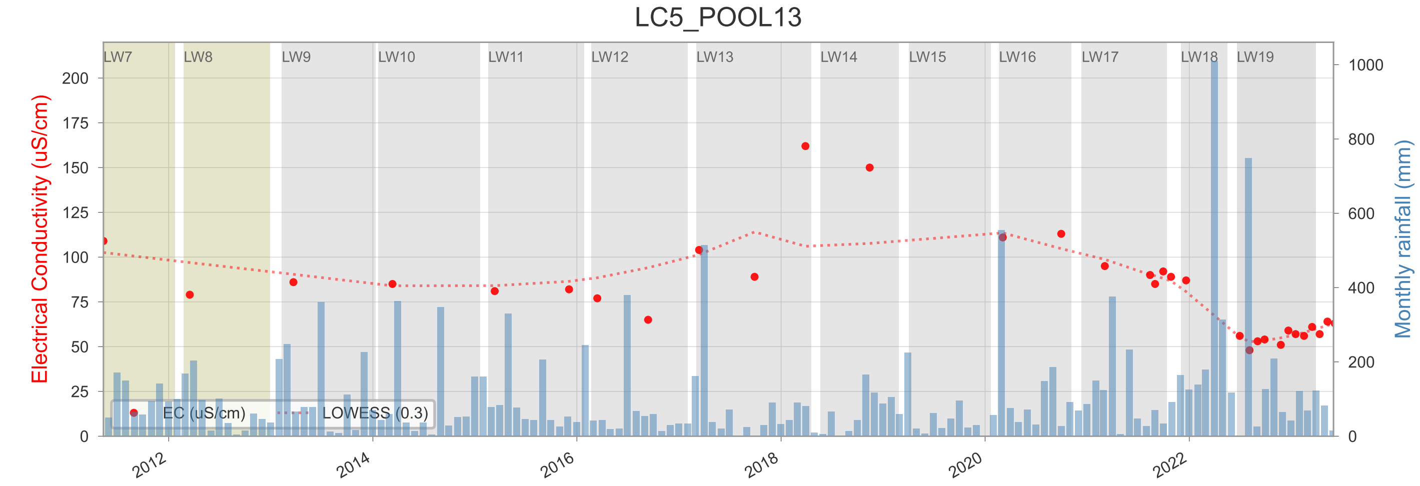

LC5A_POOL6
pH units
Monthly rainfall (mm)
pH
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

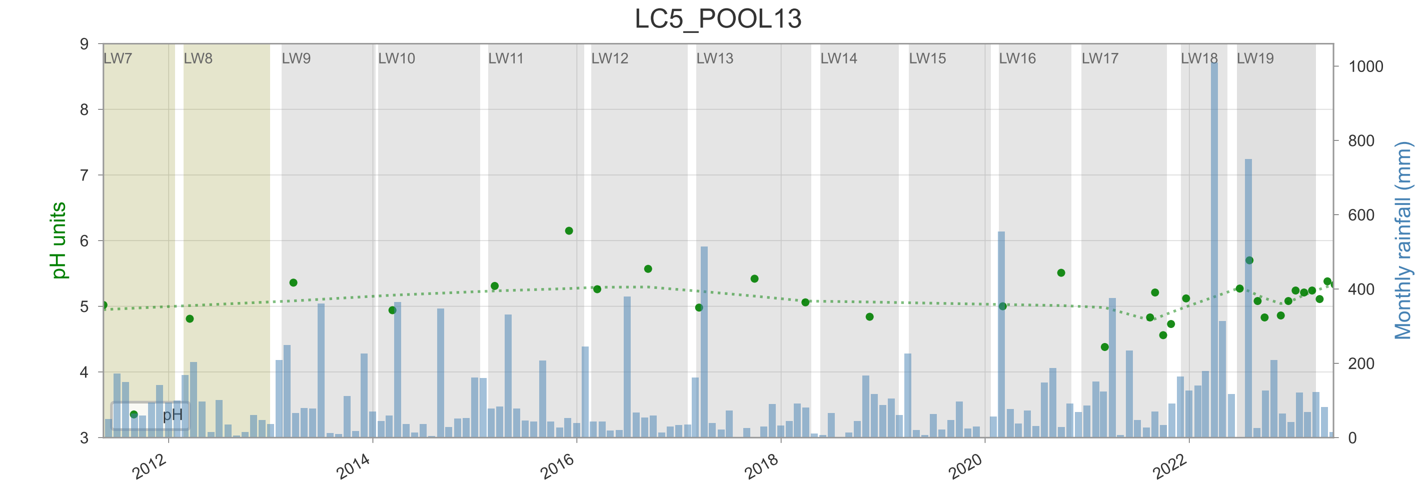

LC5A_POOL6
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

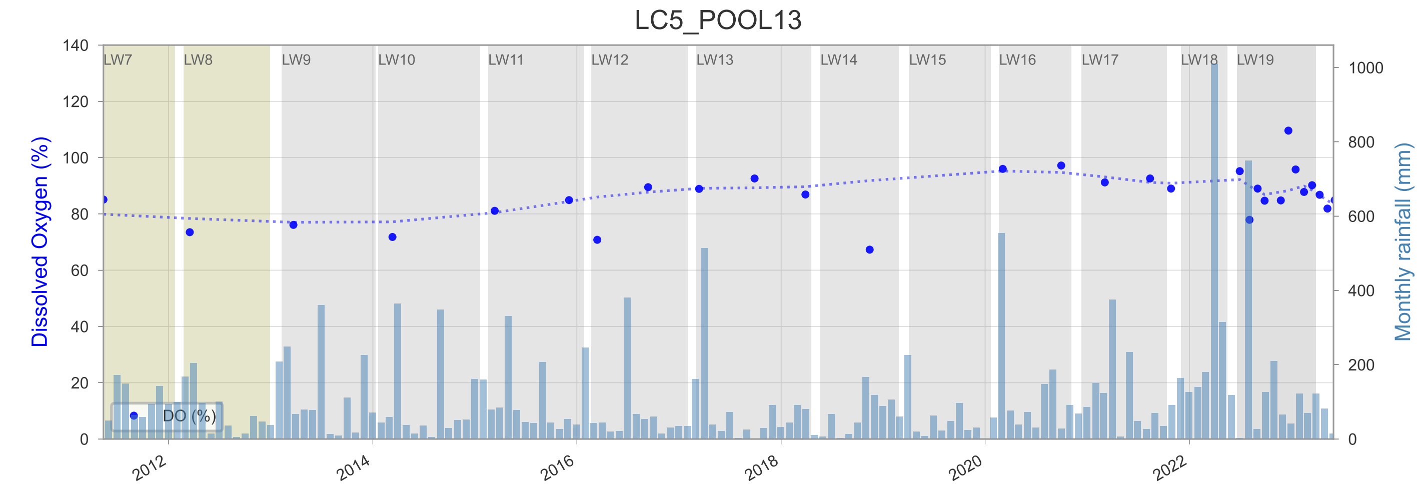


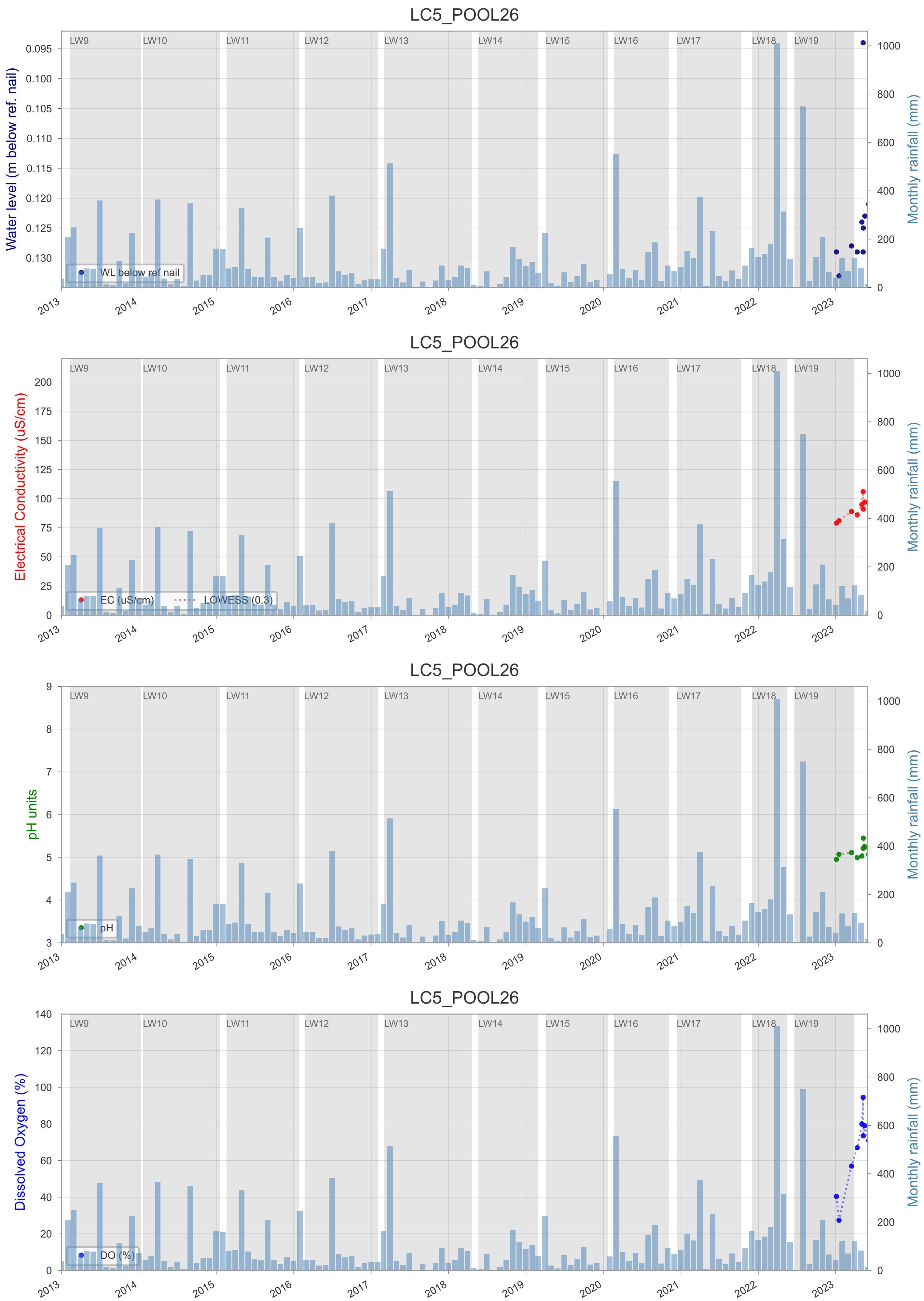
LC5_POOL12
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
P5-P95 WL
LC5_POOL12
Electrical Conductivity (uS/cm)
EC (uS/cm)
LOWESS (0.3)
LC5_POOL12
pH units
pH
LC5_POOL12
Dissolved Oxygen (%)
DO (%)
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19


LC5_POOL13
Water level (m below ref. nail)
Monthly rainfall (mm)
LW7 LW8 LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17 LW18 LW19
WL below ref nail
P5-P95 WL

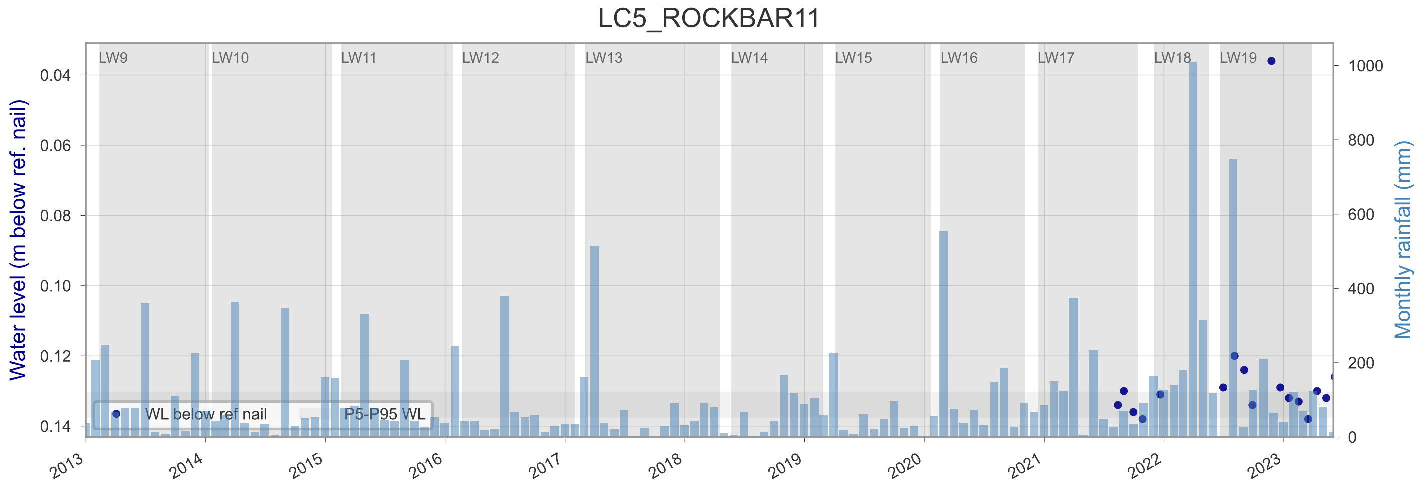

LC5_POOL13
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
LW7 LW8 LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17 LW18 LW19
EC (uS/cm)
LOWESS (0.3)

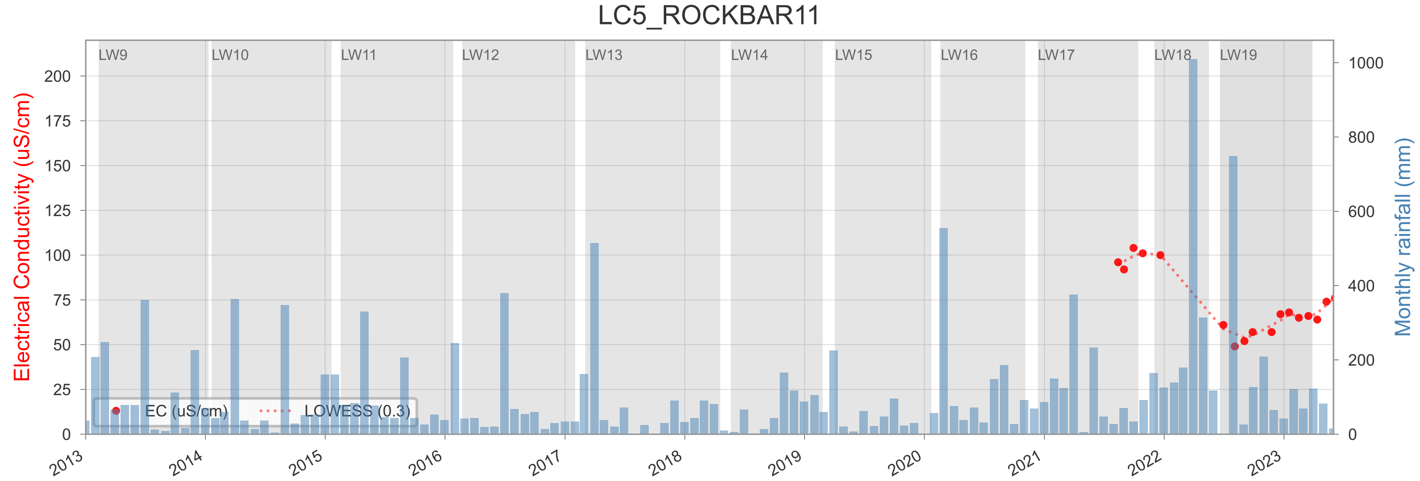

LC5_POOL13
pH units
Monthly rainfall (mm)
LW7 LW8 LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17 LW18 LW19
pH

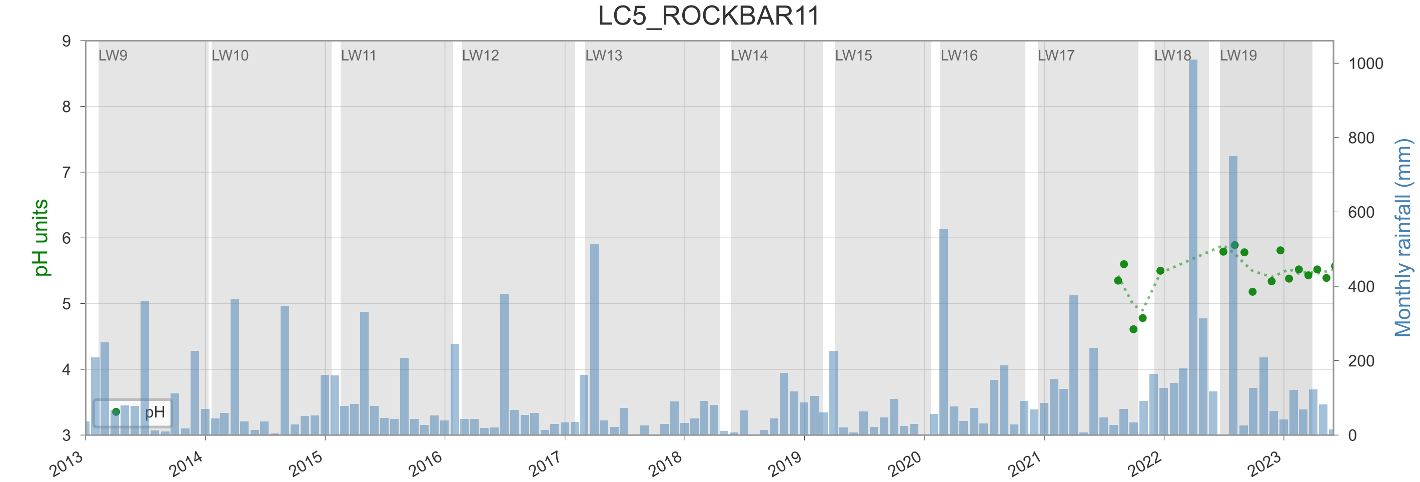

LC5_POOL13
Dissolved Oxygen (%)
Monthly rainfall (mm)
LW7 LW8 LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17 LW18 LW19
DO (%)

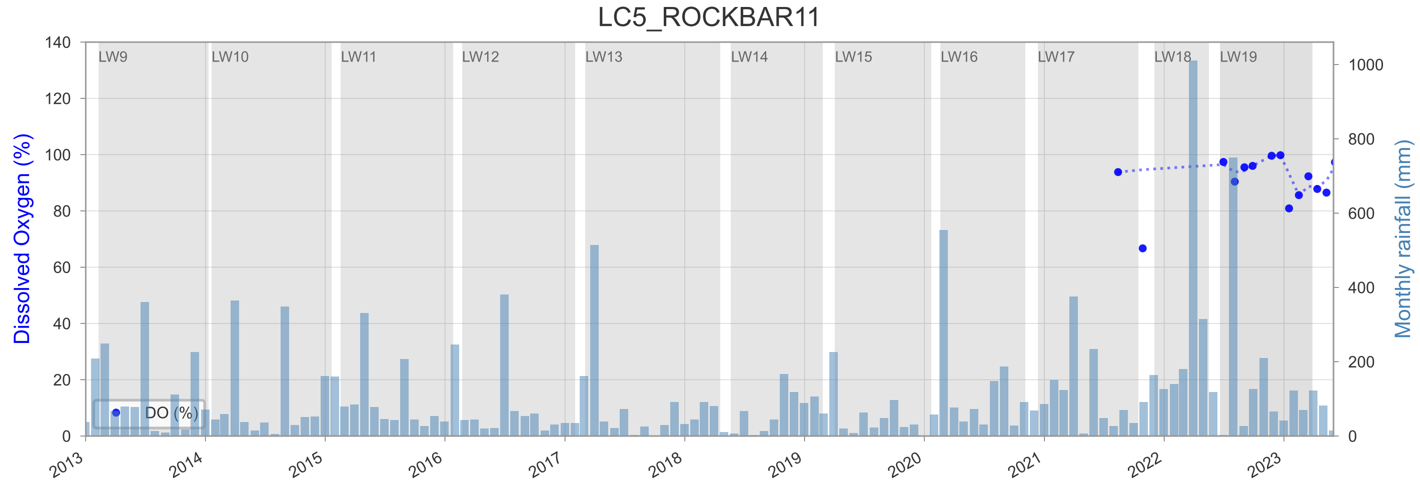


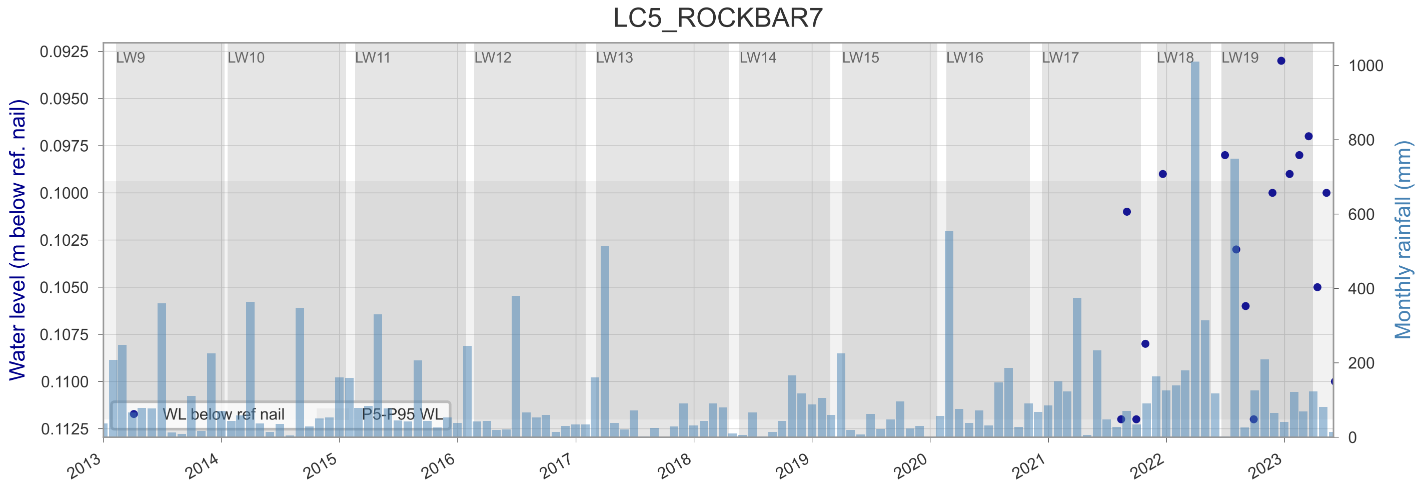
LC5_POOL26
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
LC5_POOL26
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
LC5_POOL26
pH units
Monthly rainfall (mm)
pH
LC5_POOL26
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

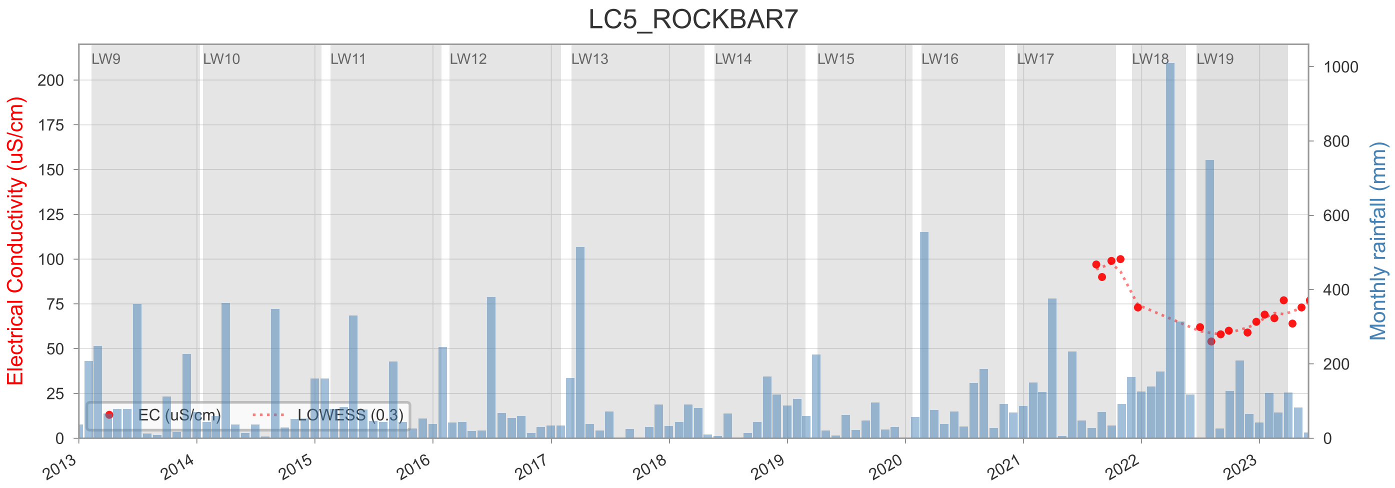

LC5_ROCKBAR11
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
P5-P95 WL
0.04
0.06
0.08
0.10
0.12
0.14
0
200
400
600
800
1000
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

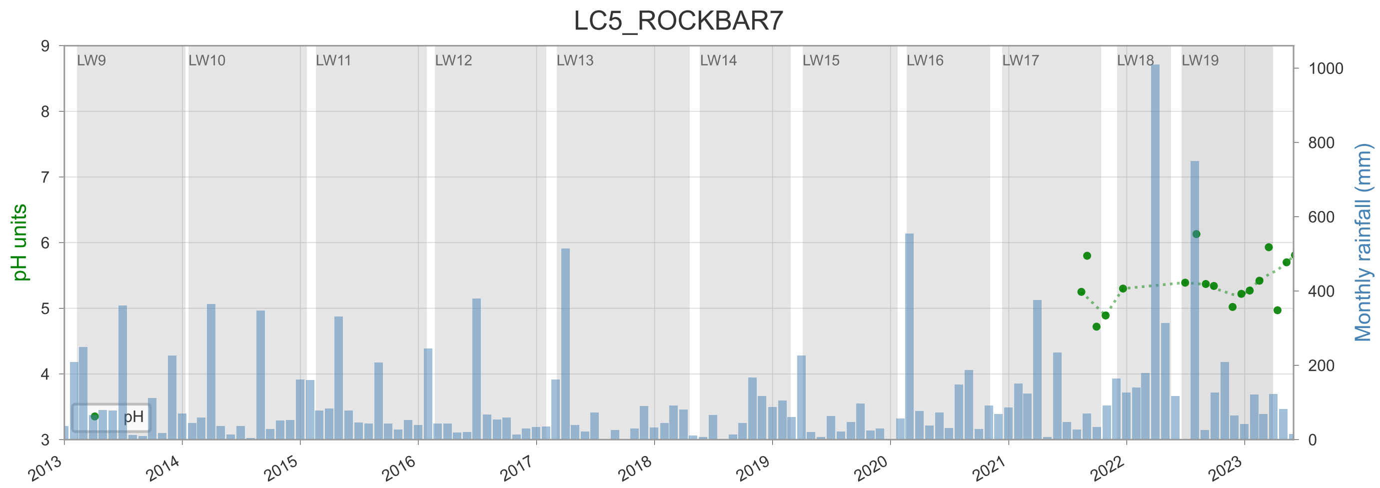

LC5_ROCKBAR11
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
0
25
50
75
100
125
150
175
200
0
200
400
600
800
1000
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

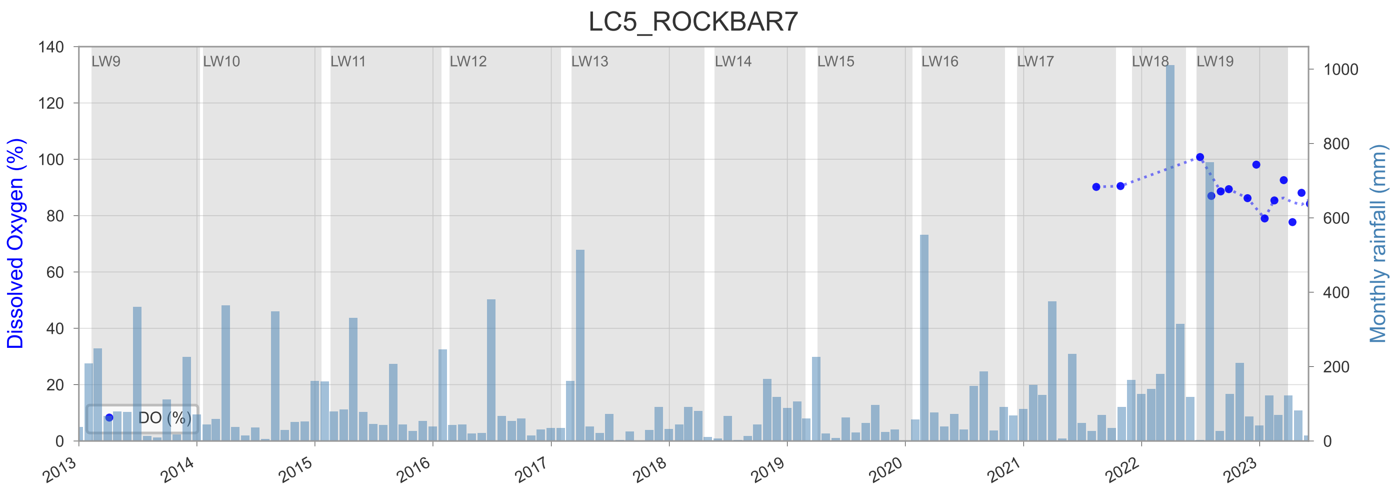

LC5_ROCKBAR11
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH units
Monthly rainfall (mm)
pH
3
4
5
6
7
8
9
0
200
400
600
800
1000
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023


LC5_ROCKBAR11
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
0
20
40
60
80
100
120
140
0
200
400
600
800
1000
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

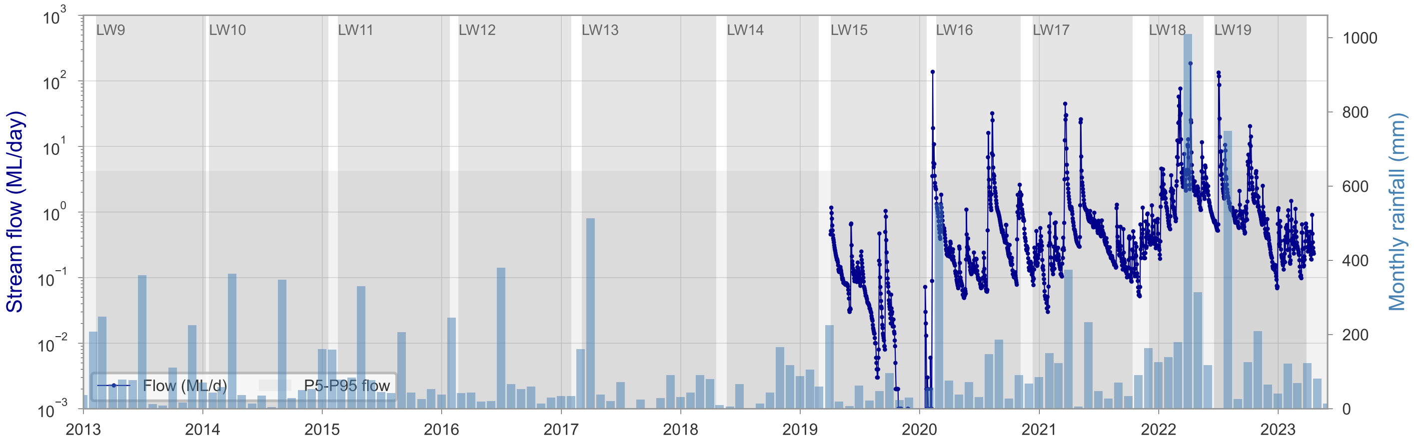

LC5_ROCKBAR7
Water level (m below ref. nail)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
P5-P95 WL


LC5_ROCKBAR7
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
EC (uS/cm)
LOWESS (0.3)

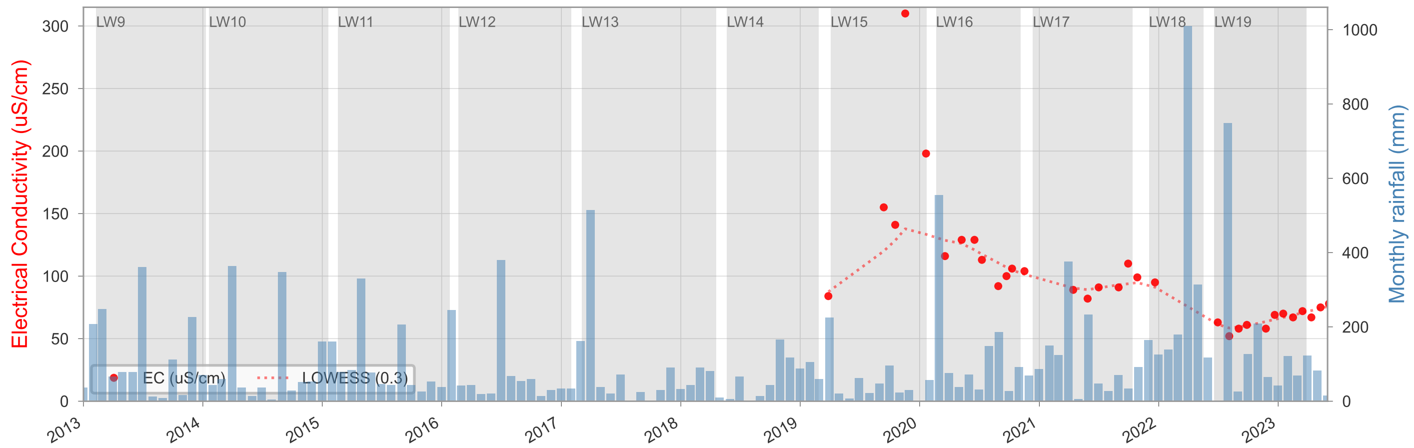

LC5_ROCKBAR7
pH units
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH


LC5_ROCKBAR7
Dissolved Oxygen (%)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
DO (%)

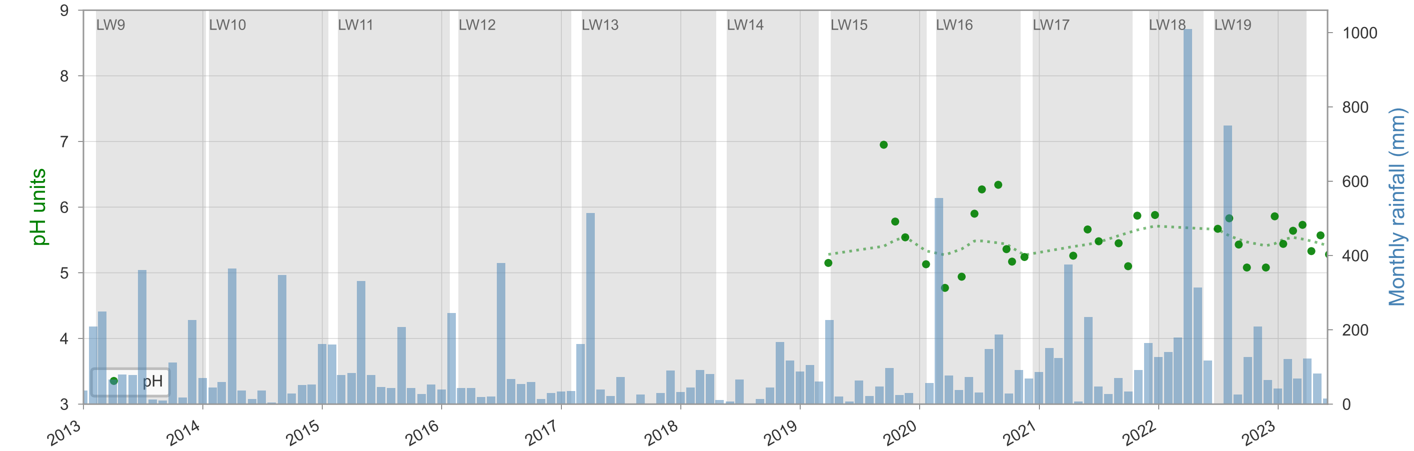
LC5S1



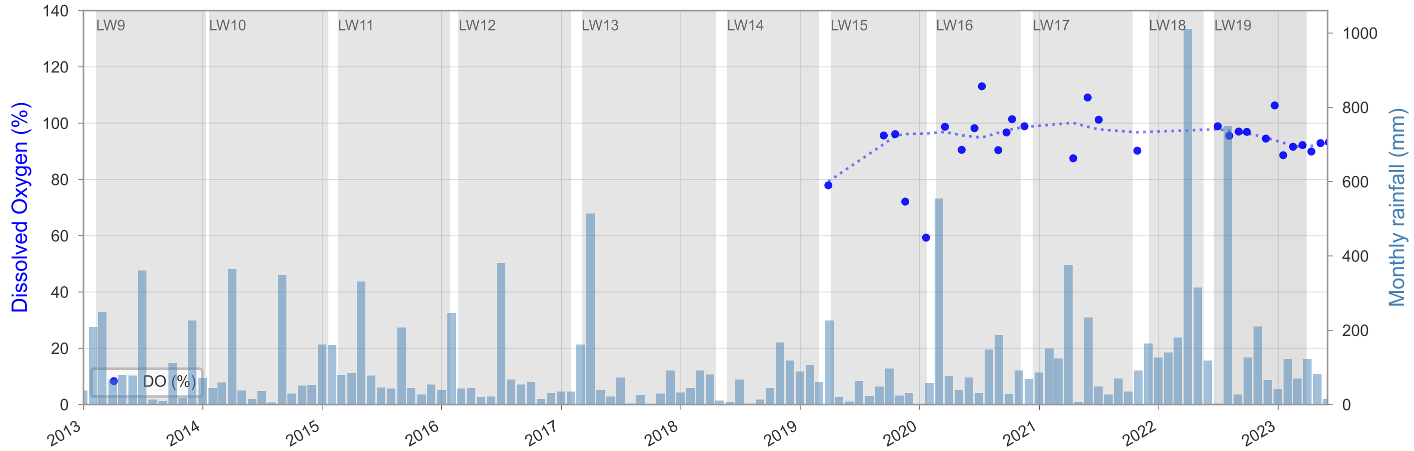
LC5_S1

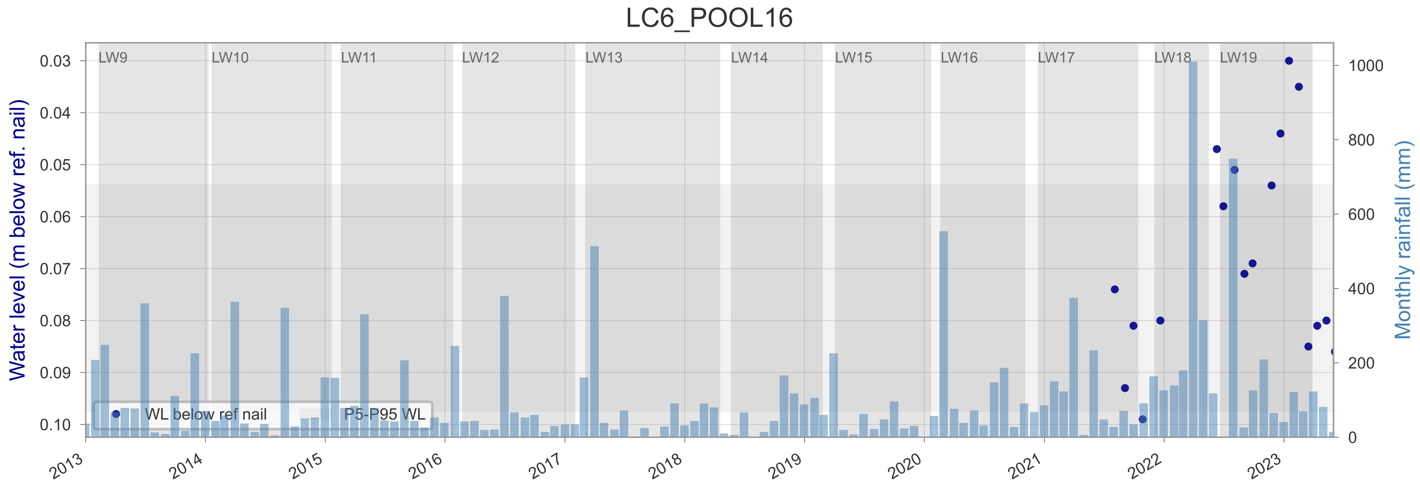


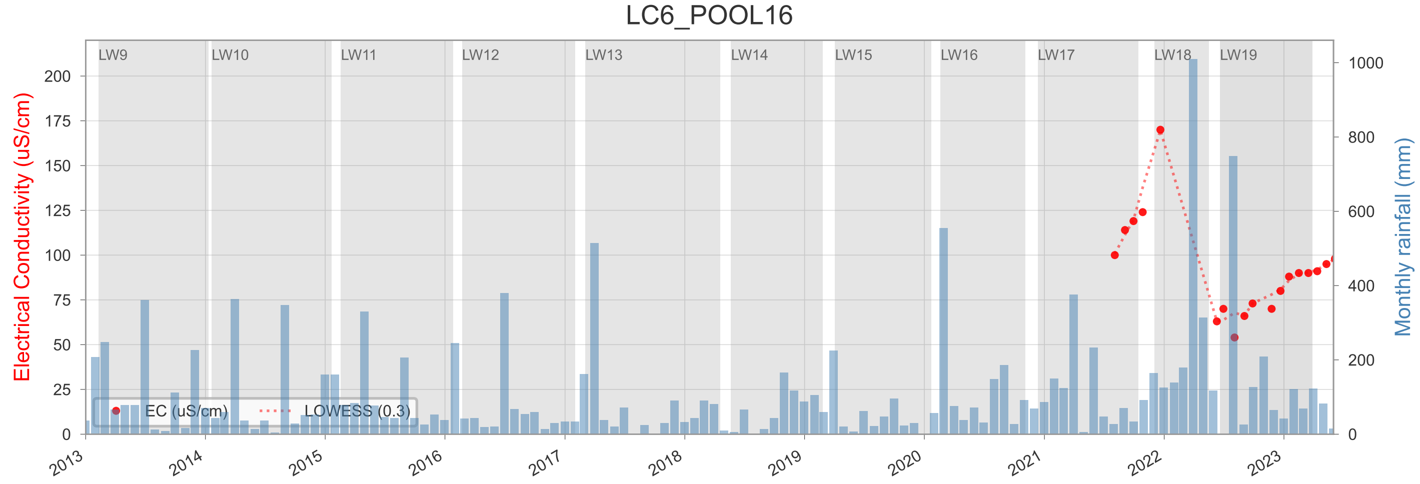
LC5_S1

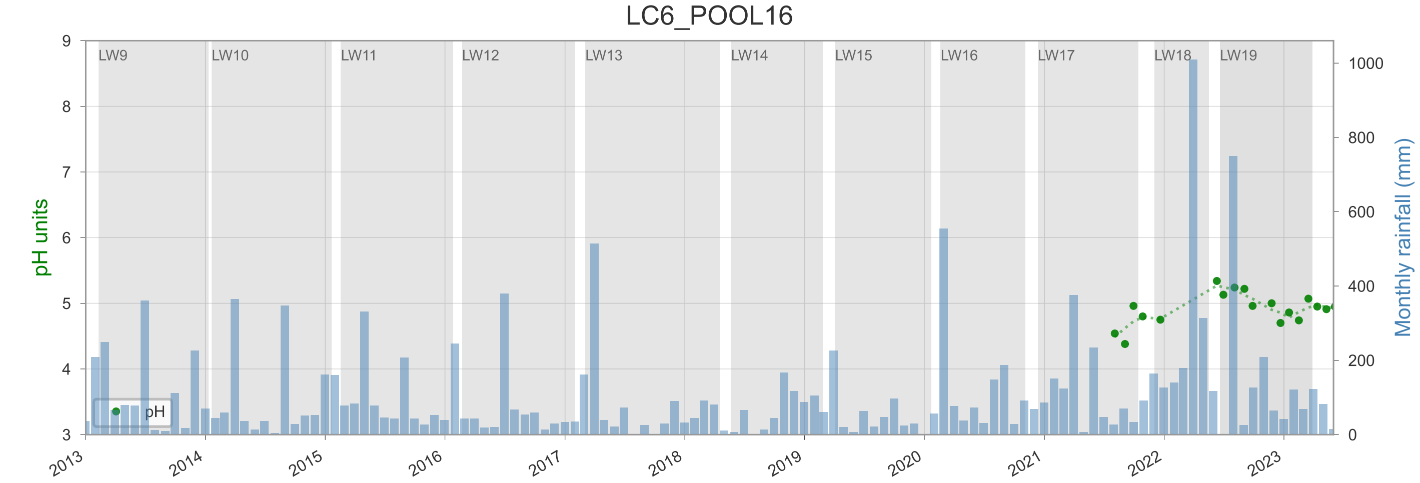


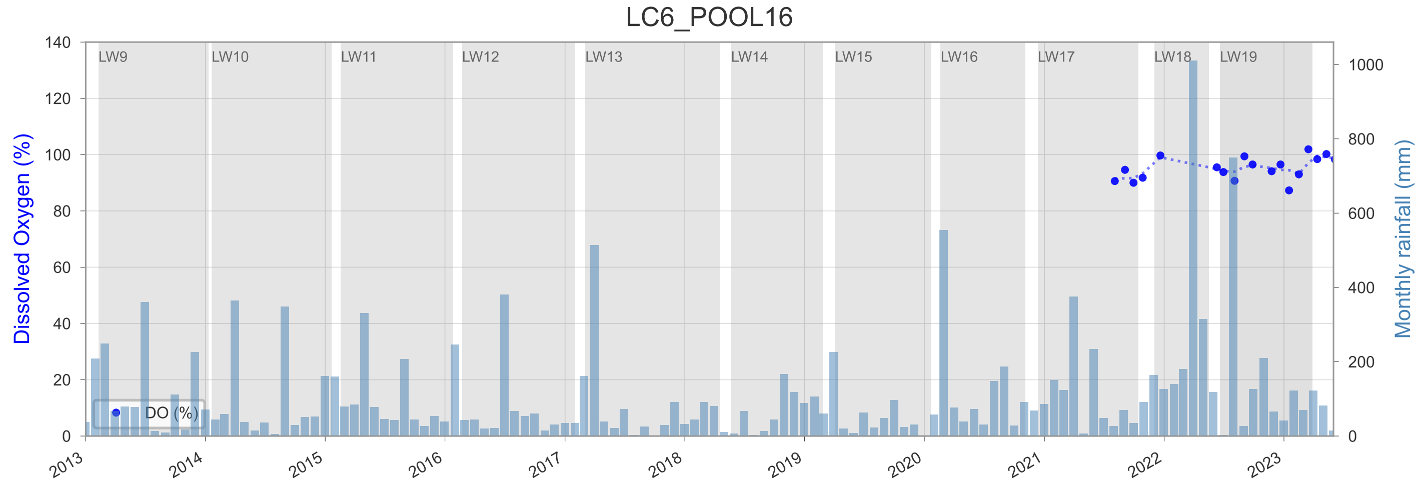
LC5_S1

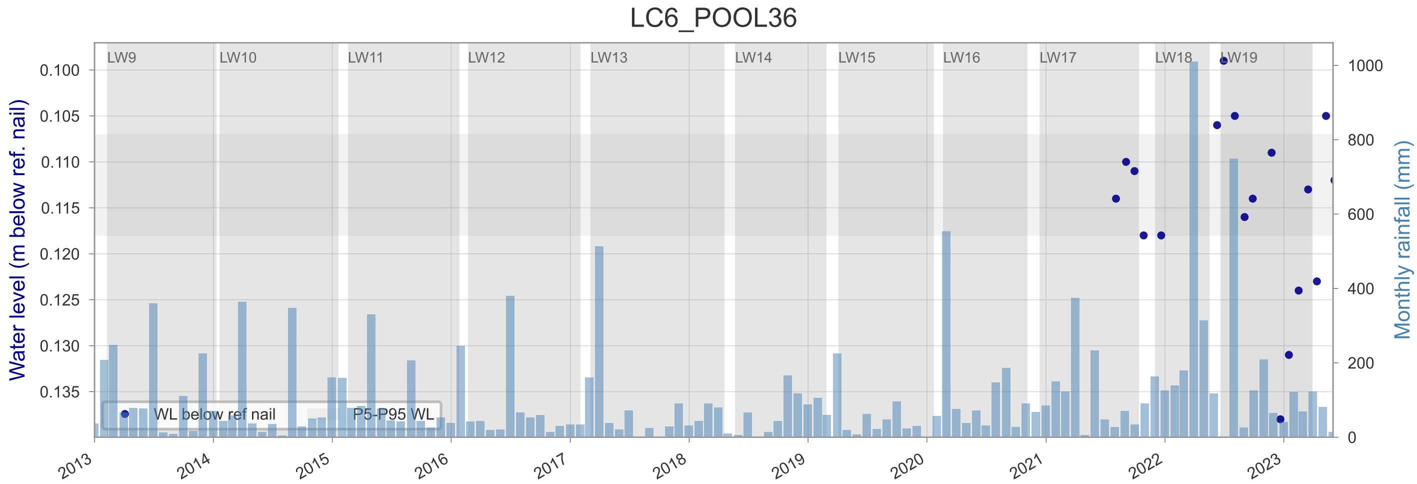


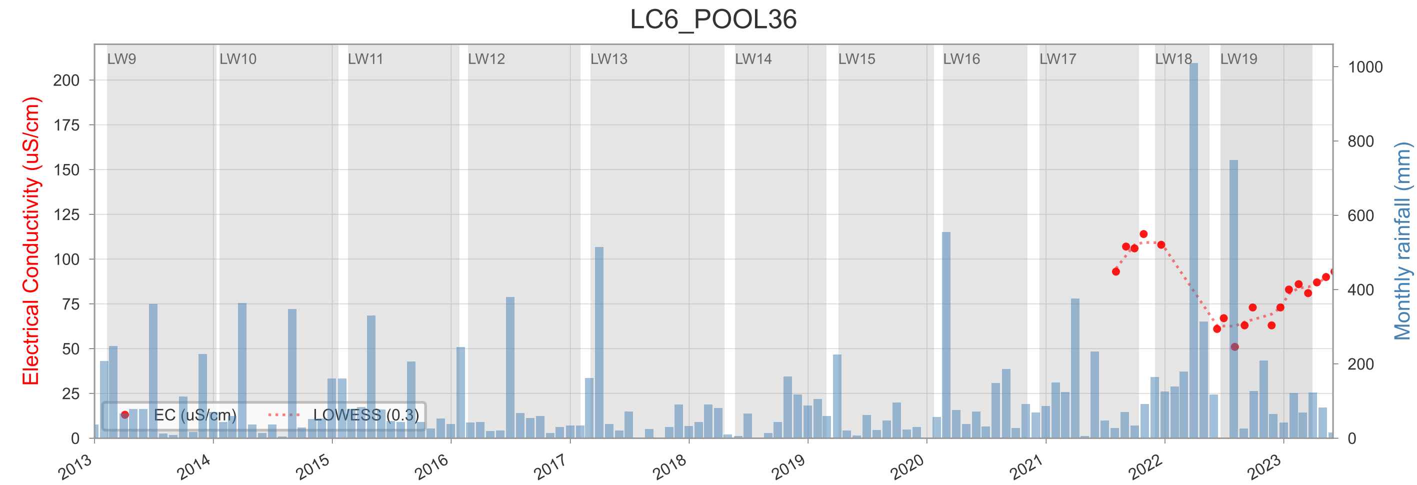

LC6_POOL16
Water level (m below ref. nail)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
P5-P95 WL

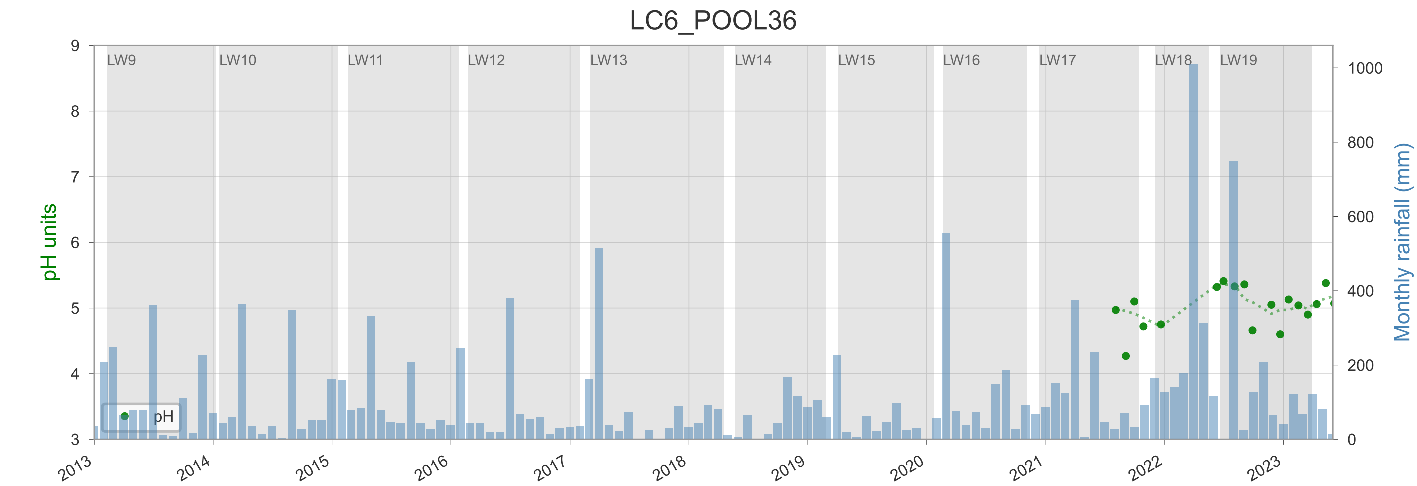

LC6_POOL16
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)

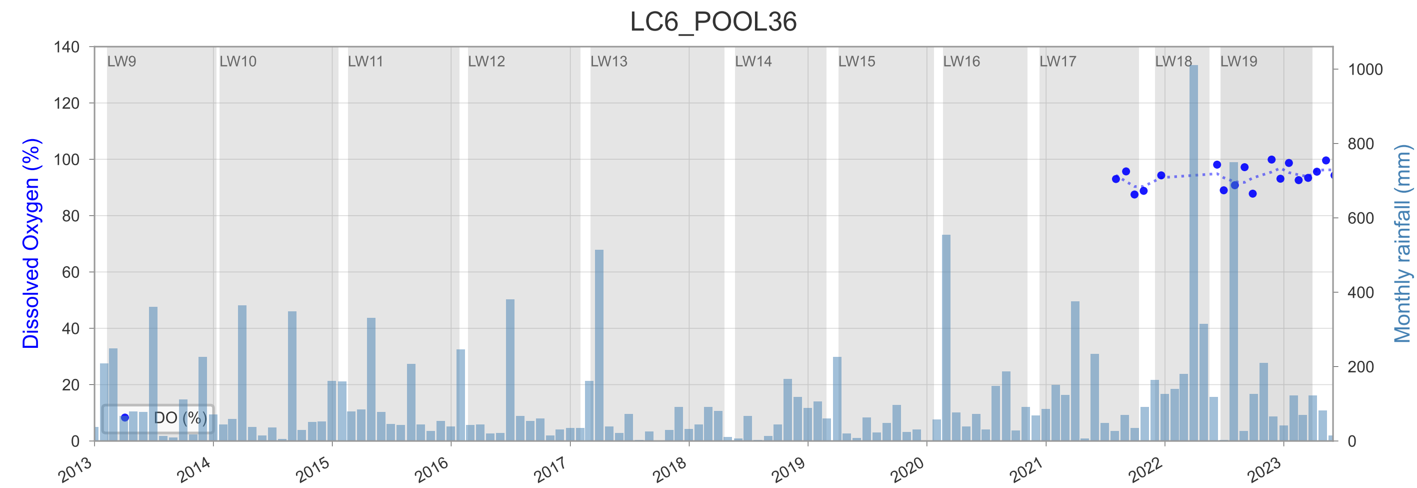

LC6_POOL16
pH units
Monthly rainfall (mm)
pH

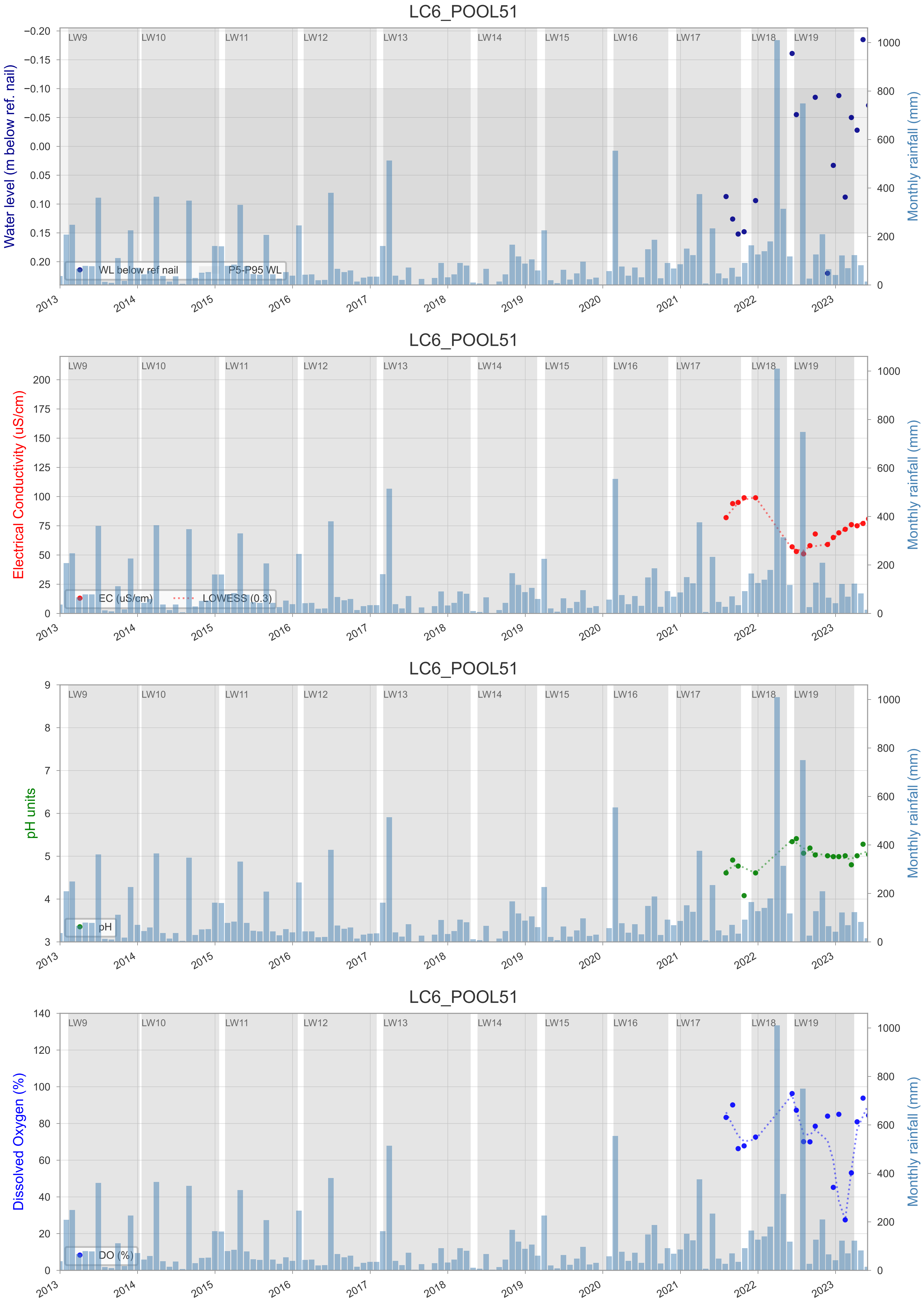

LC6_POOL16
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)

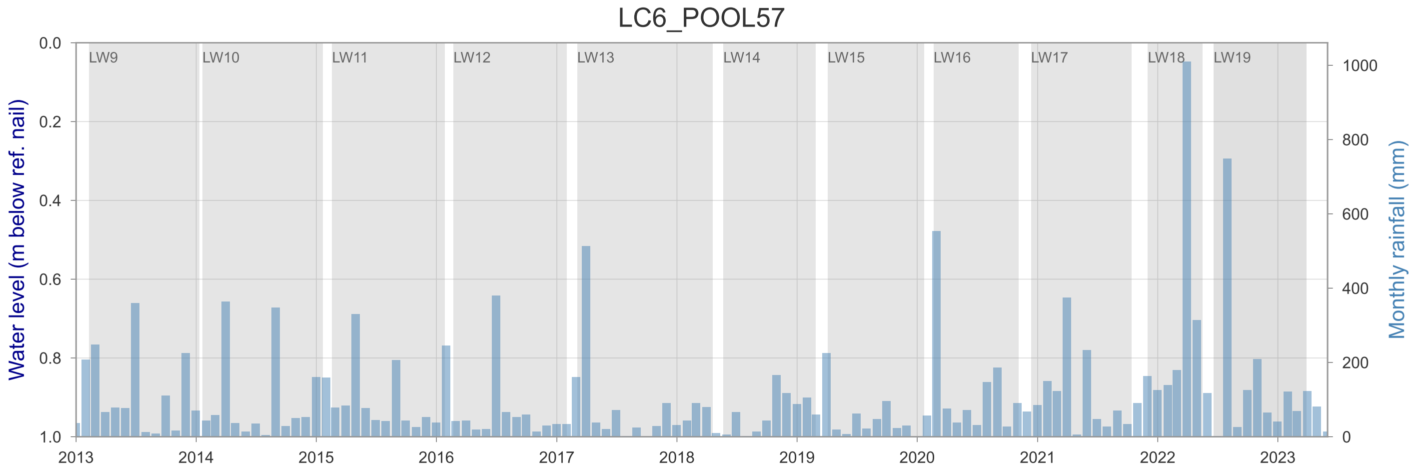

LC6_POOL36
Water level (m below ref. nail)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
P5-P95 WL
0.100
0.105
0.110
0.115
0.120
0.125
0.130
0.135
0
200
400
600
800
1000
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

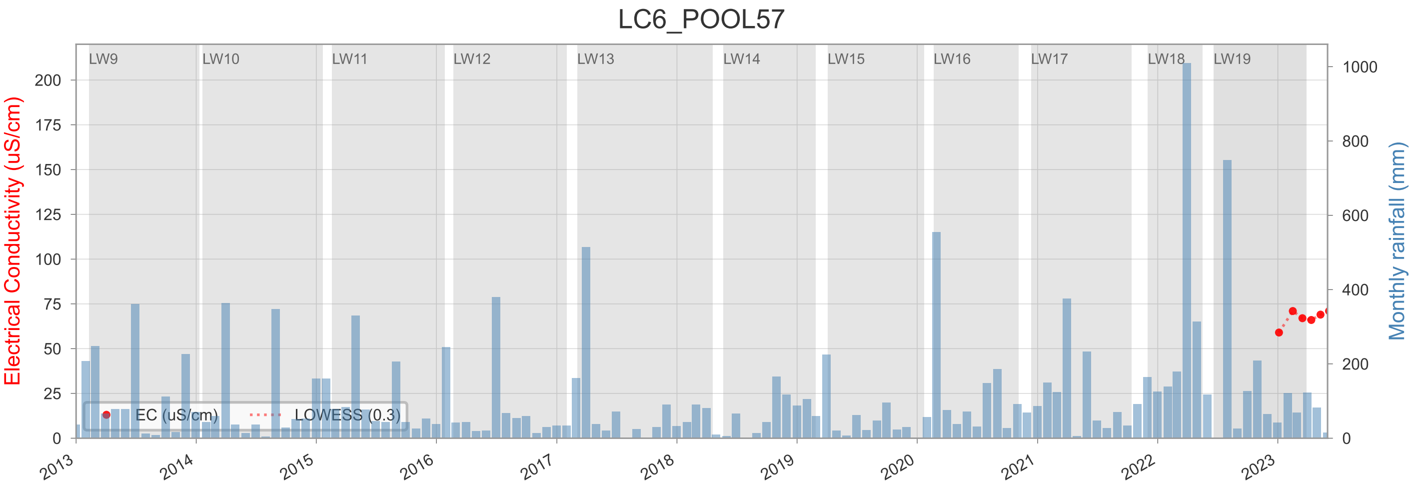

LC6_POOL36
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
EC (uS/cm)
LOWESS (0.3)
0
25
50
75
100
125
150
175
200
0
200
400
600
800
1000
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

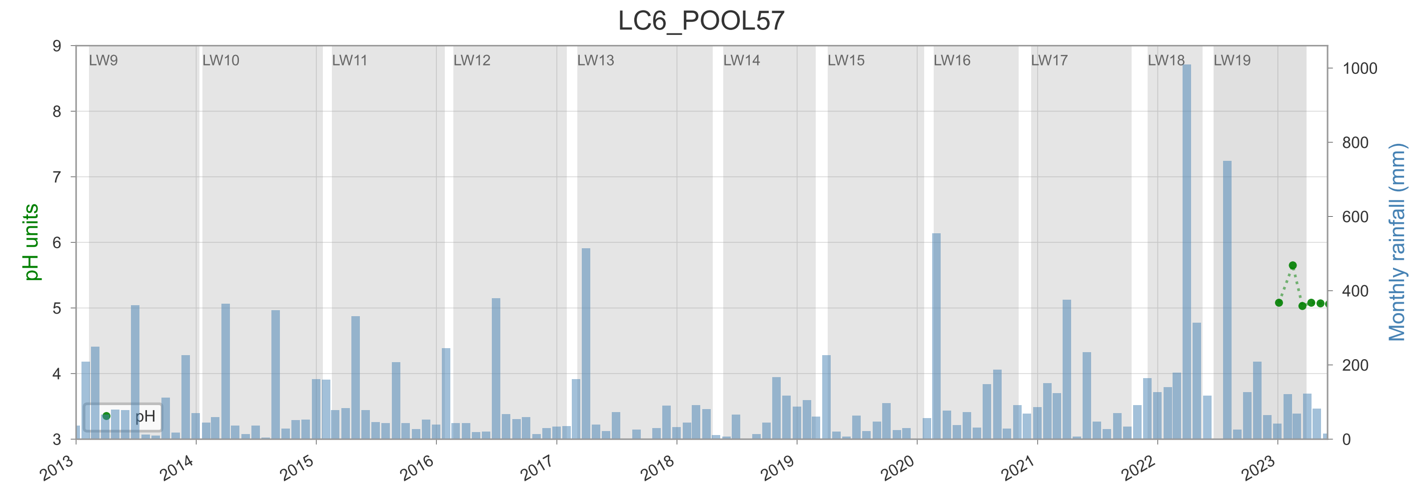

LC6_POOL36
pH units
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH
3
4
5
6
7
8
9
0
200
400
600
800
1000
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

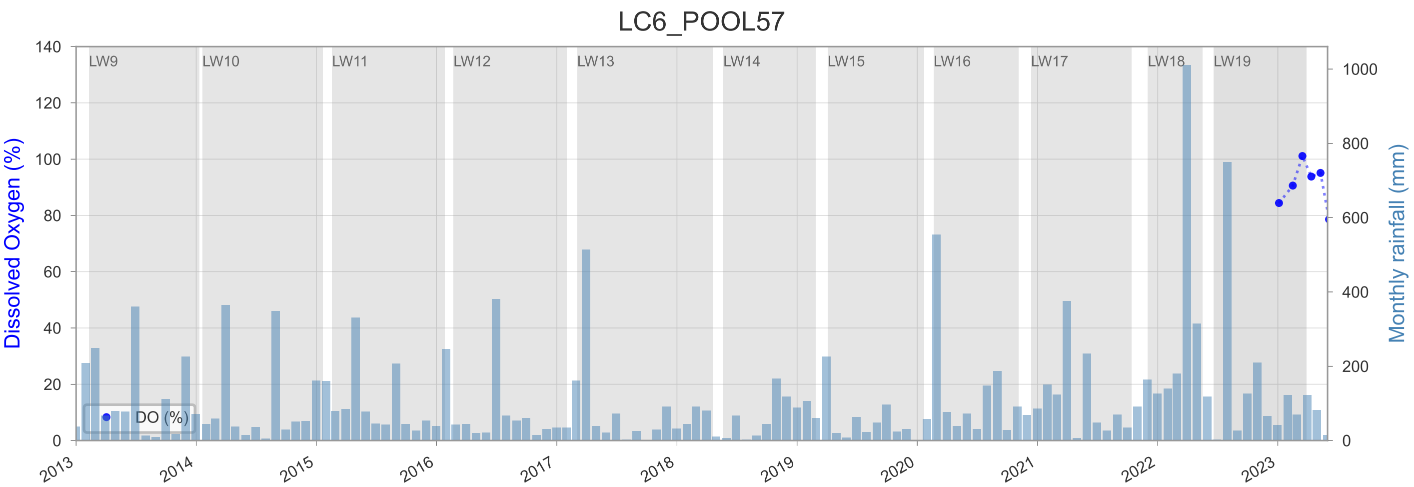

LC6_POOL36
Dissolved Oxygen (%)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
DO (%)
0
20
40
60
80
100
120
140
0
200
400
600
800
1000
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

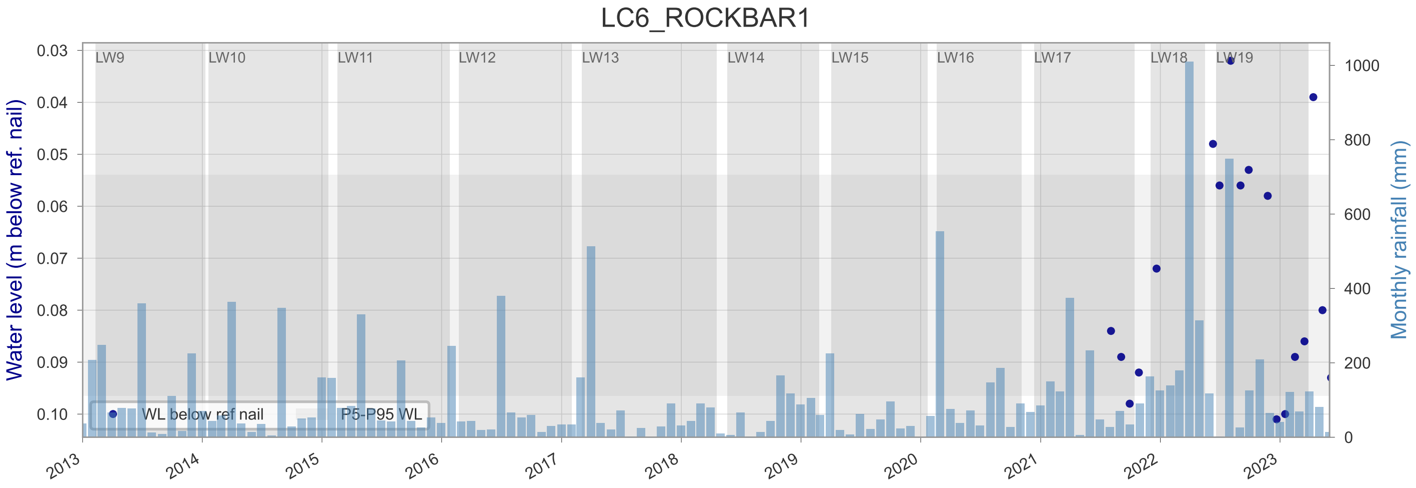

LC6_POOL51
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
P5-P95 WL
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LC6_POOL51
Electrical Conductivity (uS/cm)
EC (uS/cm)
LOWESS (0.3)
LC6_POOL51
pH units
pH
LC6_POOL51
Dissolved Oxygen (%)
DO (%)

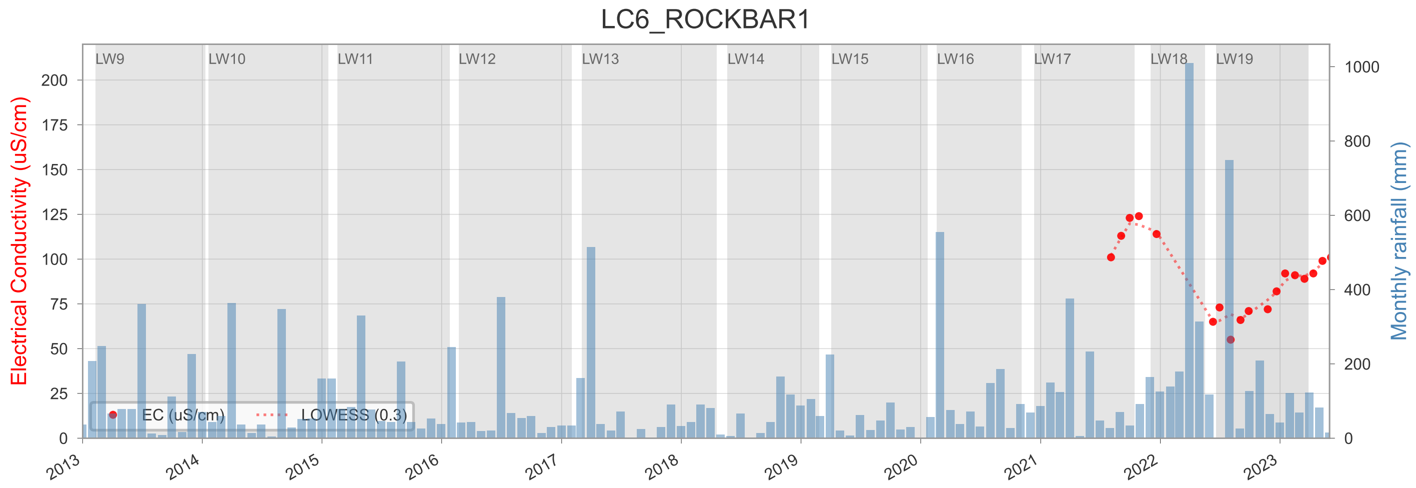

LC6_POOL57
Water level (m below ref. nail)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

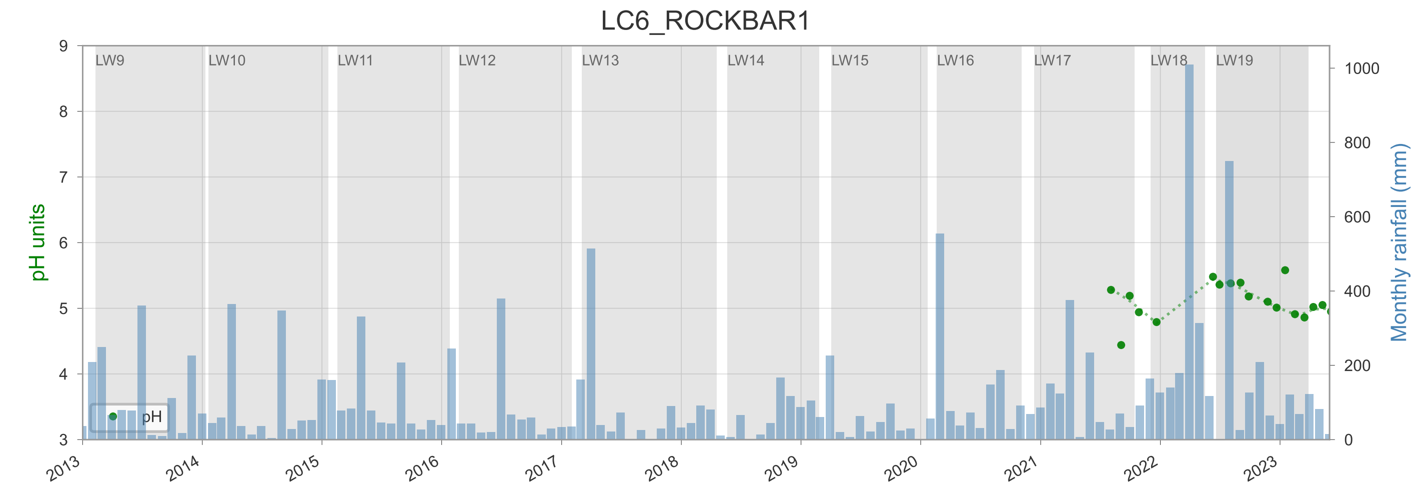

LC6_POOL57
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)

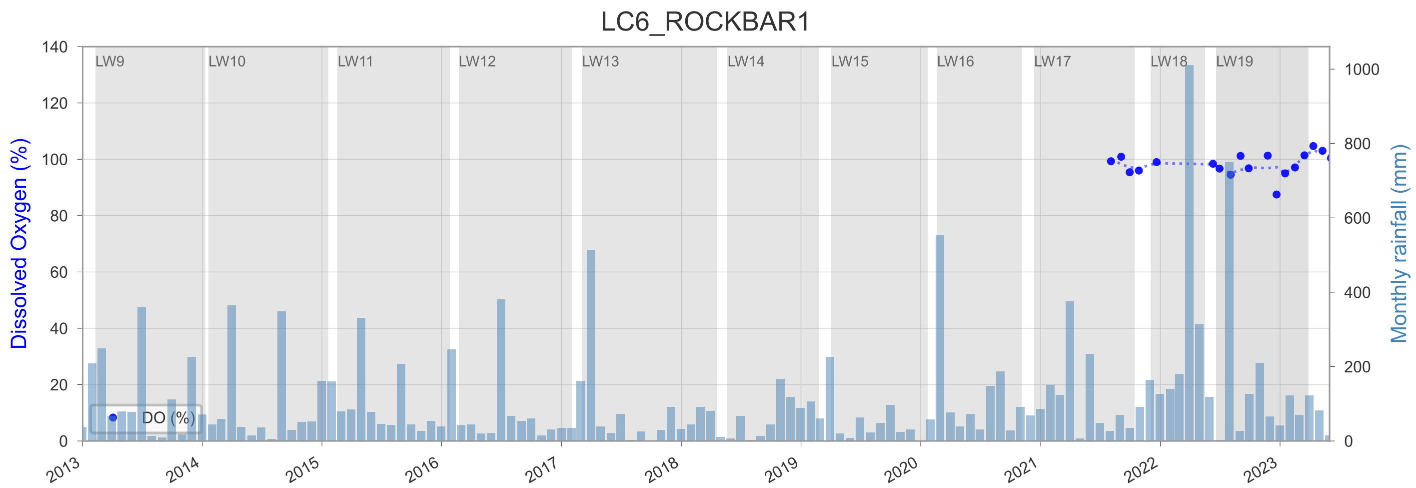

LC6_POOL57
pH units
Monthly rainfall (mm)
pH

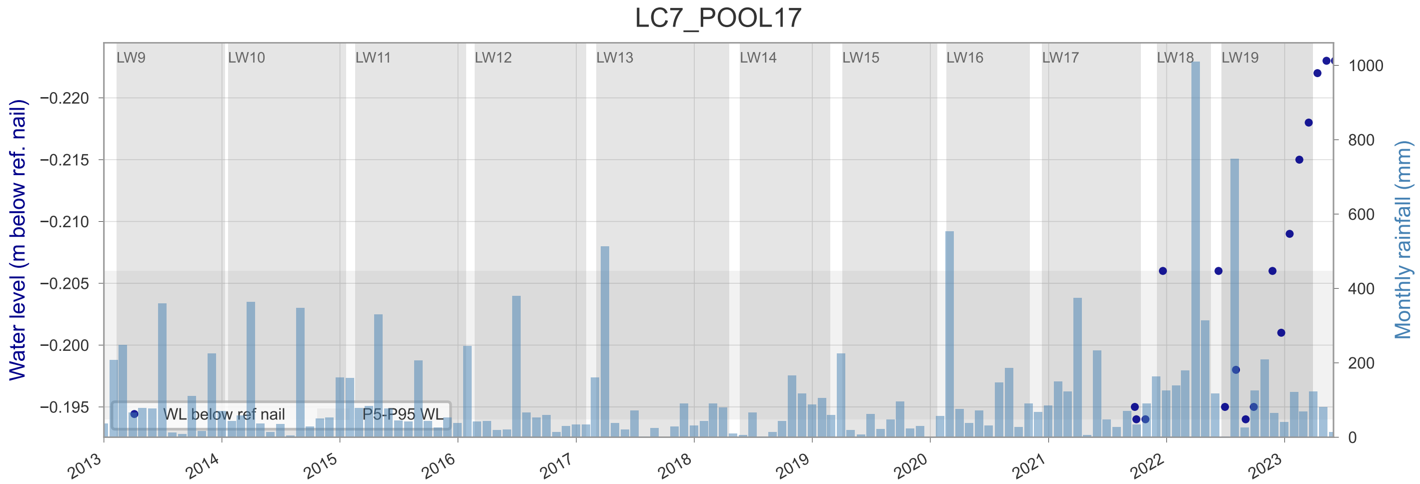

LC6_POOL57
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)

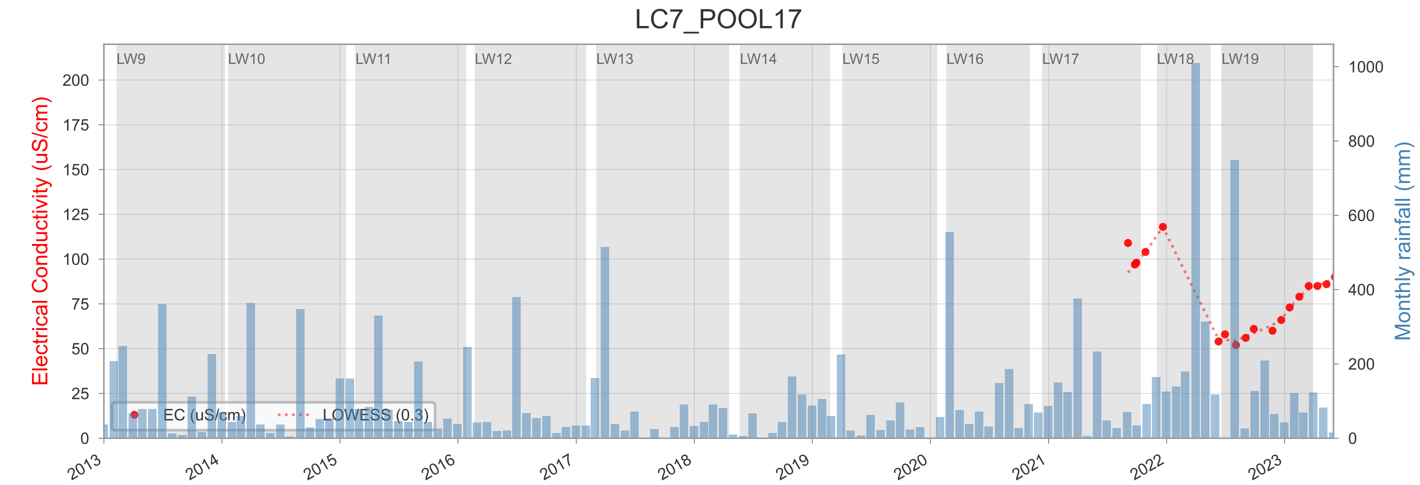

LC6_ROCKBAR1
Water level (m below ref. nail)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
P5-P95 WL
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
0
200
400
600
800
1000
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

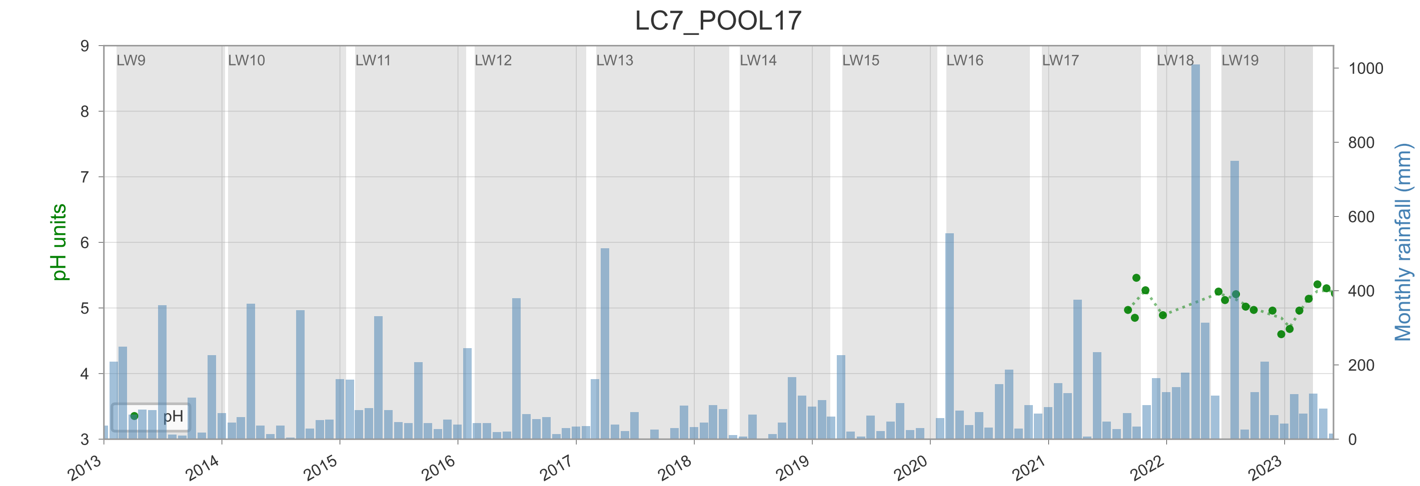

LC6_ROCKBAR1
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
EC (uS/cm)
LOWESS (0.3)
0
25
50
75
100
125
150
175
200
0
200
400
600
800
1000
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

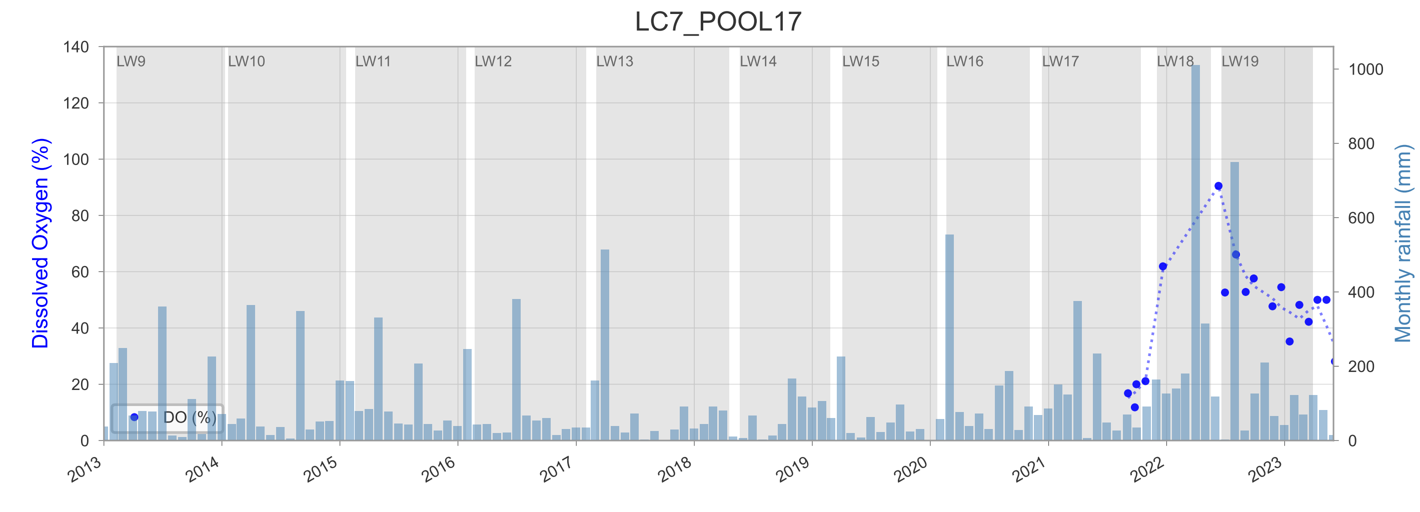

LC6_ROCKBAR1
pH units
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH
3
4
5
6
7
8
9
0
200
400
600
800
1000
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

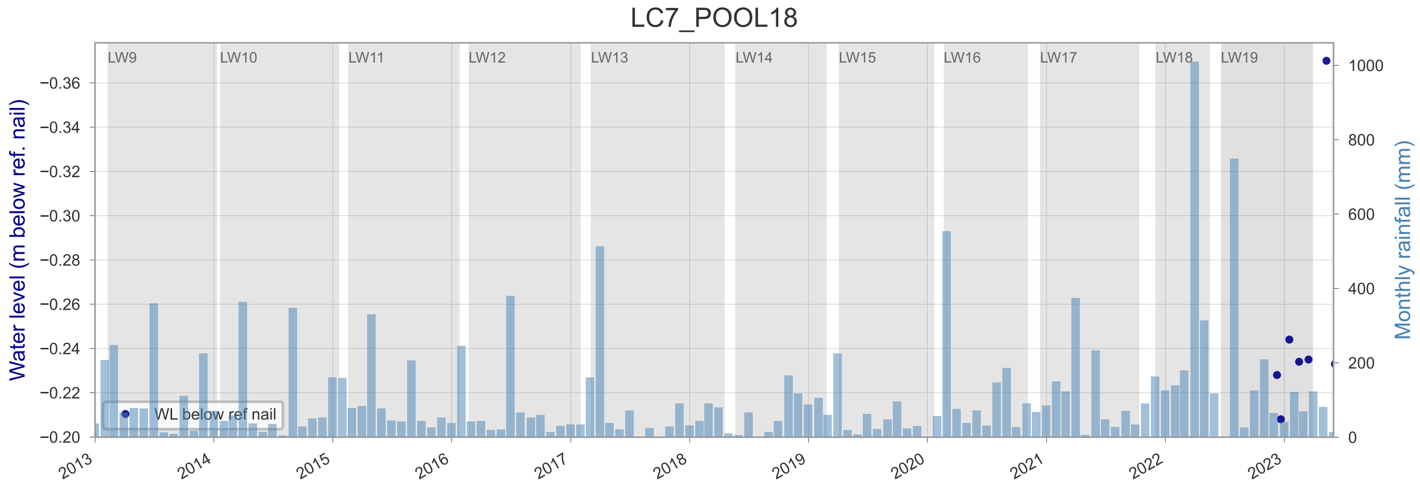

LC6_ROCKBAR1
Dissolved Oxygen (%)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
DO (%)
0
20
40
60
80
100
120
140
0
200
400
600
800
1000
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

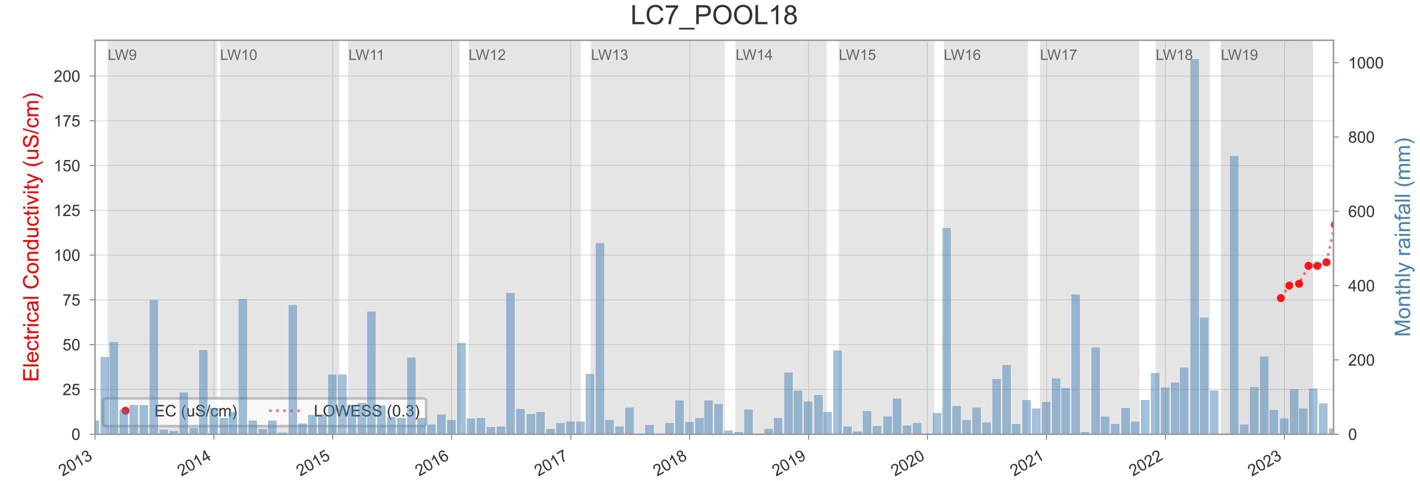

LC7_POOL17
Water level (m below ref. nail)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
P5-P95 WL

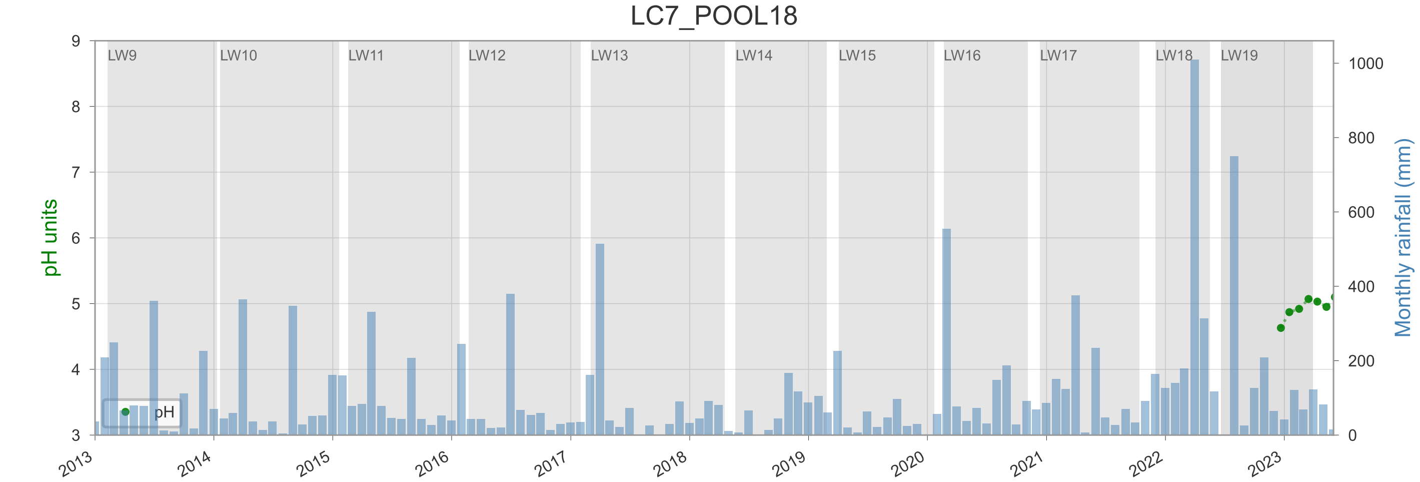

LC7_POOL17
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
EC (uS/cm)
LOWESS (0.3)

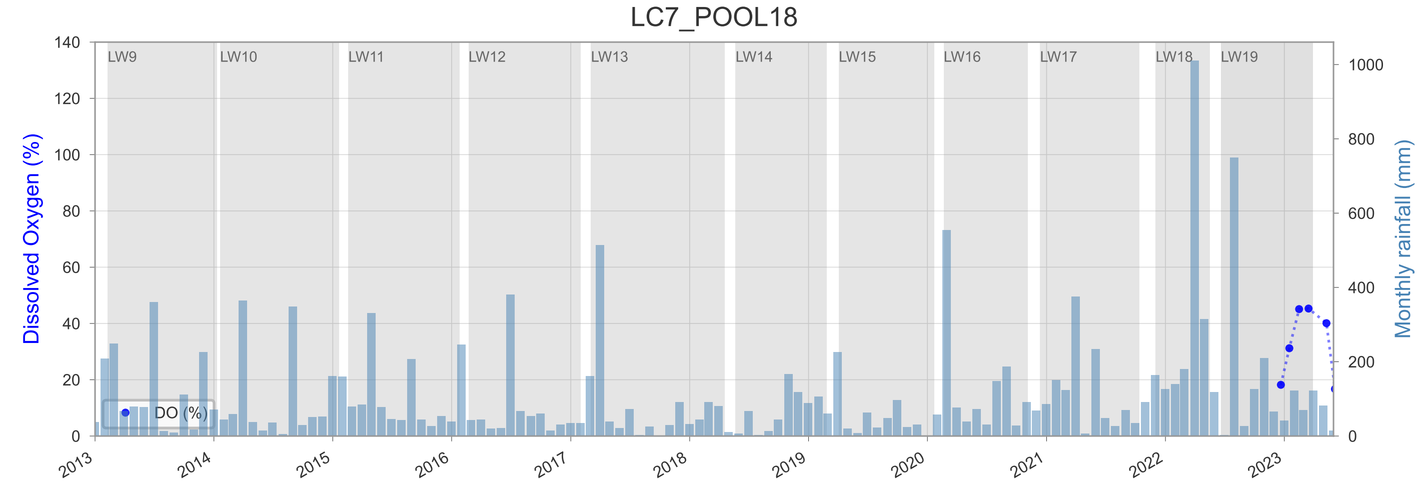

LC7_POOL17
pH units
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH

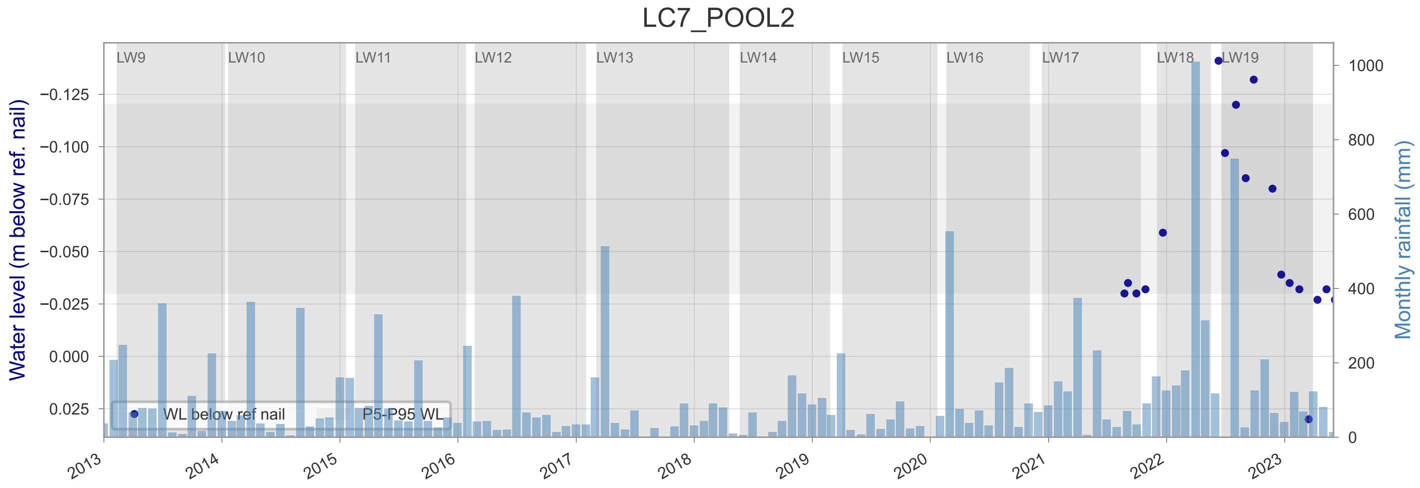

LC7_POOL17
Dissolved Oxygen (%)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
DO (%)

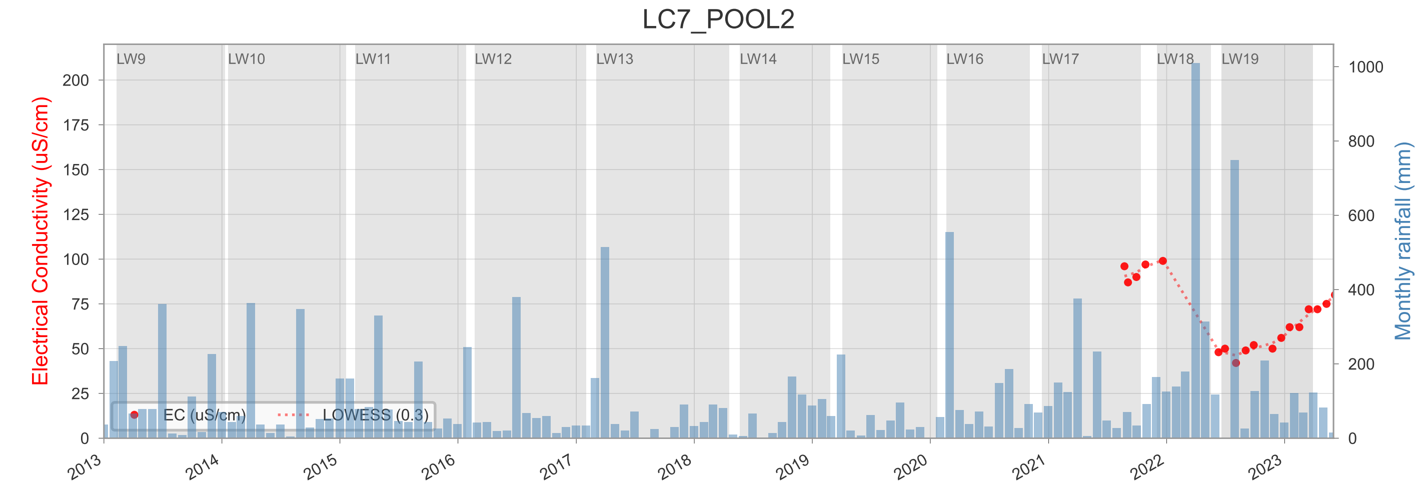

LC7_POOL18
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail

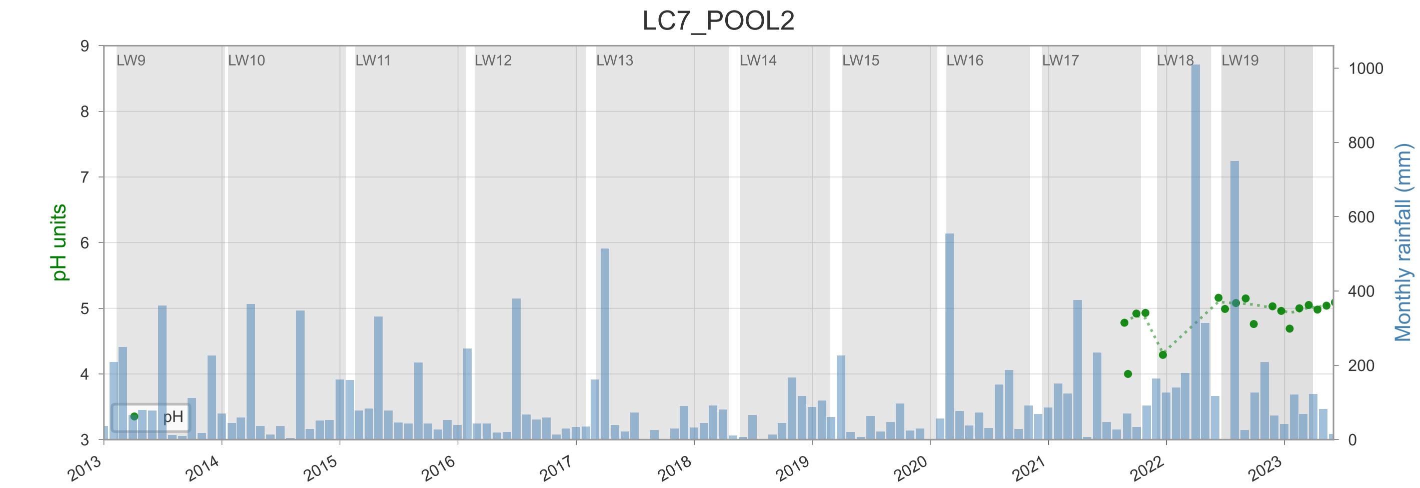

LC7_POOL18
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)

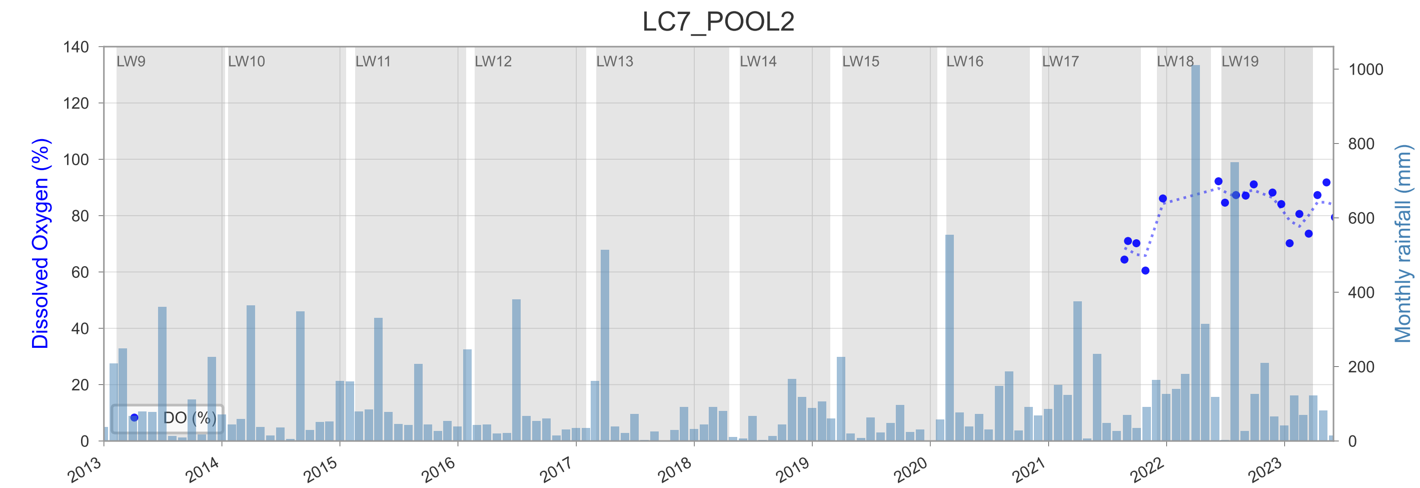

LC7_POOL18
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH units
Monthly rainfall (mm)
pH

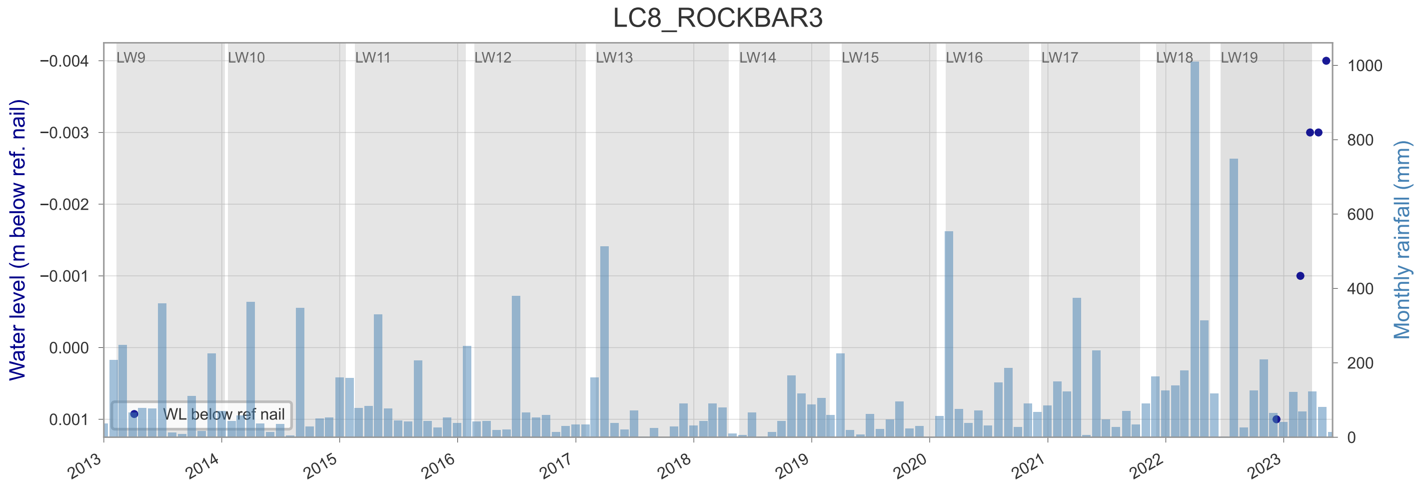

LC7_POOL18
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)


LC7_POOL2
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
P5-P95 WL
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

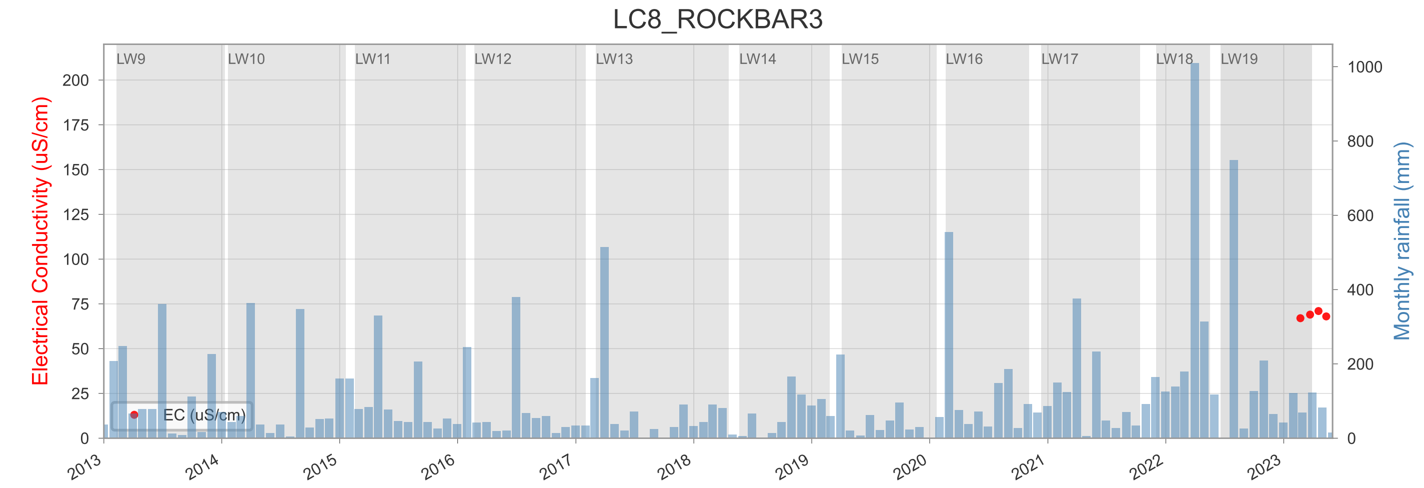

LC7_POOL2
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)


LC7_POOL2
pH units
Monthly rainfall (mm)
pH

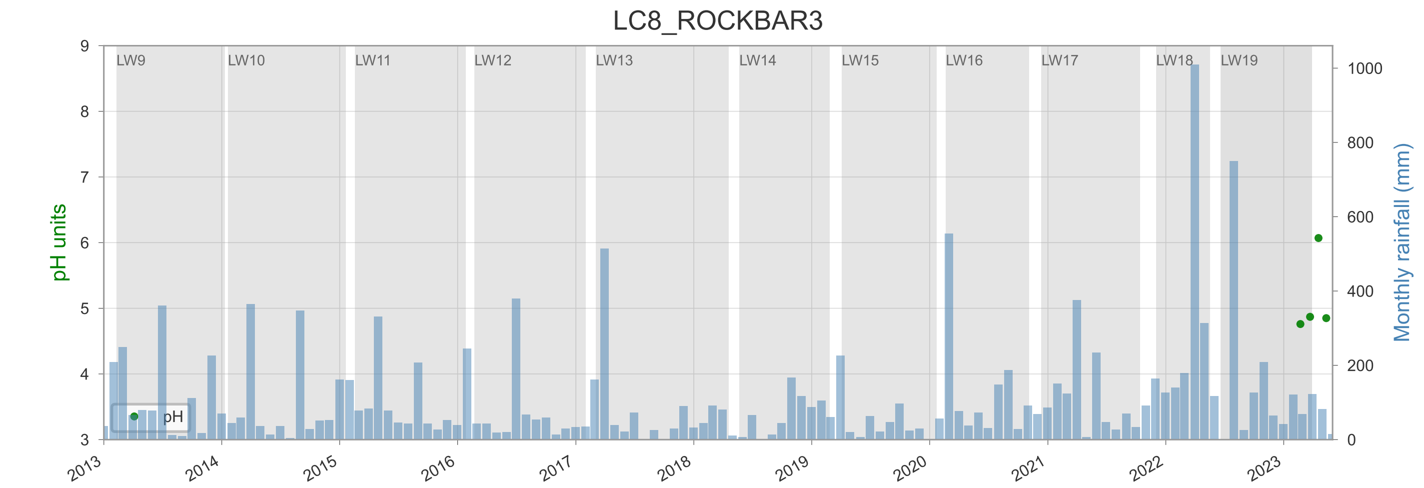

LC7_POOL2
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)



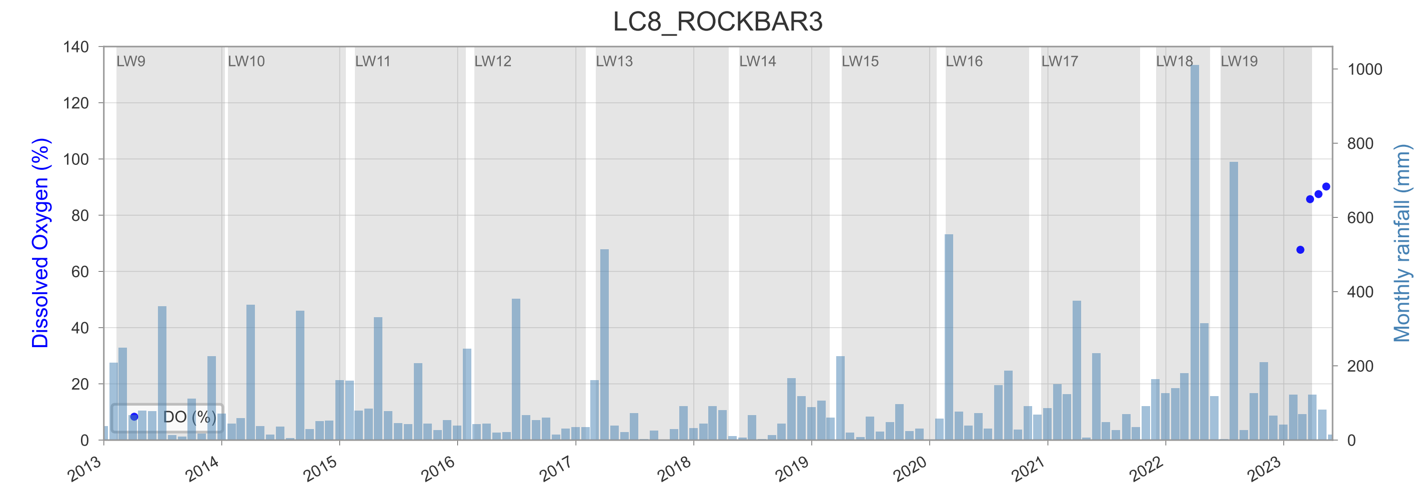
LC8_ROCKBAR3
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19



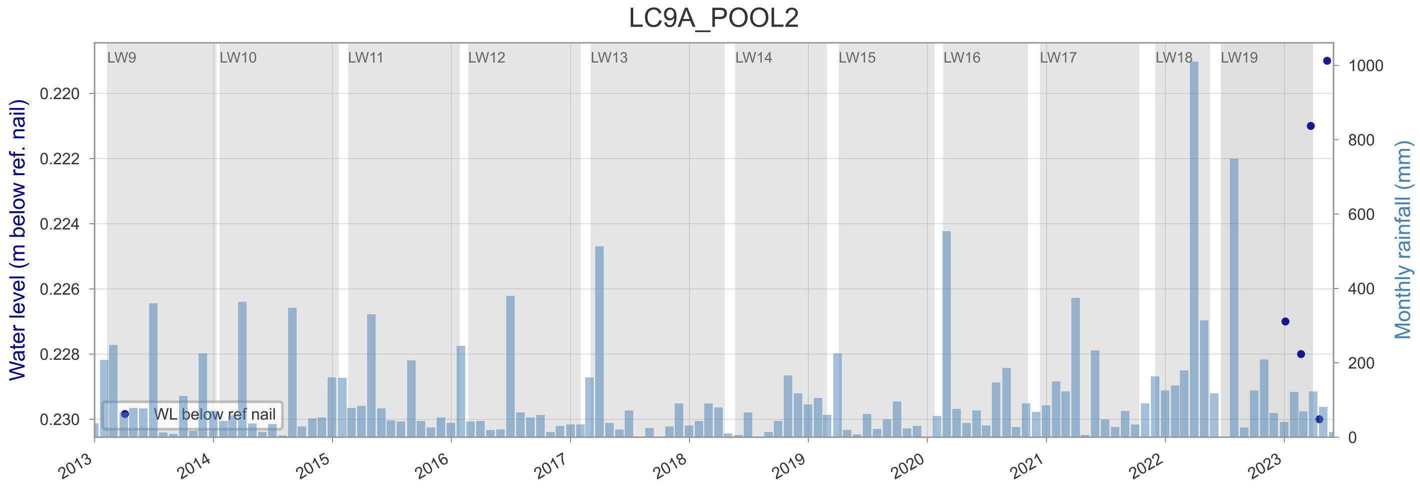
LC8_ROCKBAR3
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19



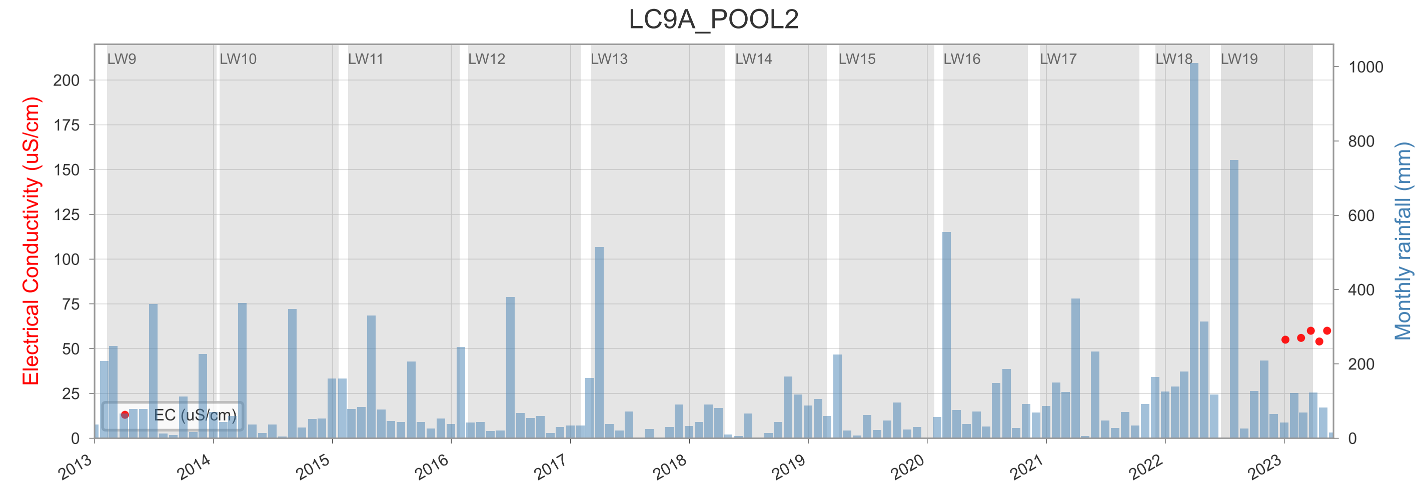
LC8_ROCKBAR3
pH units
Monthly rainfall (mm)
pH
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19



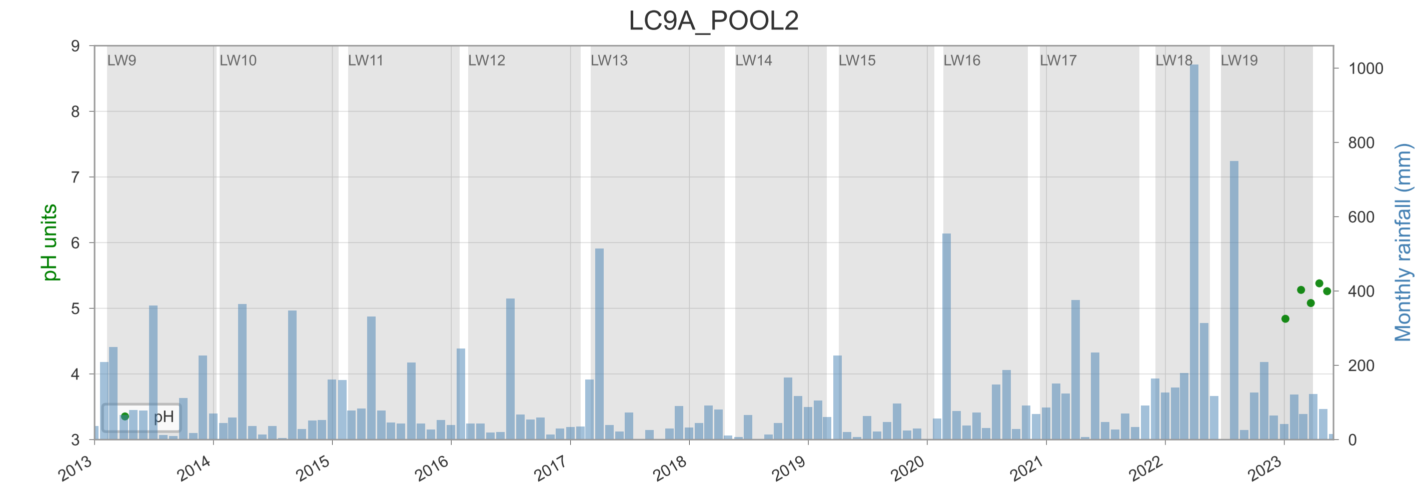
LC8_ROCKBAR3
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19



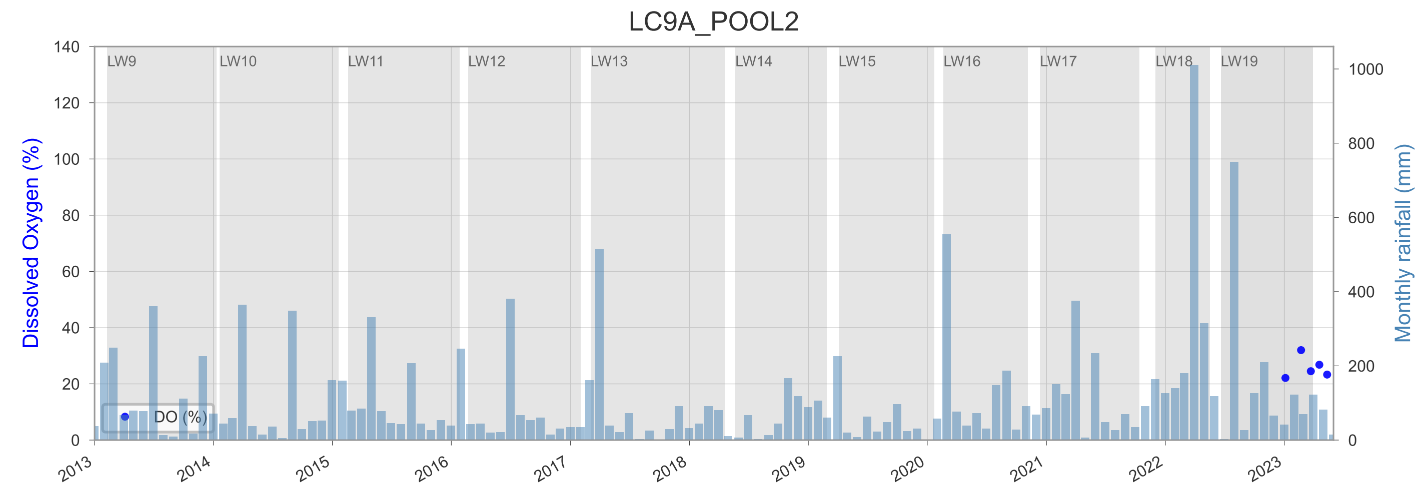
LC9A_POOL2
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19



LC9A_POOL2
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

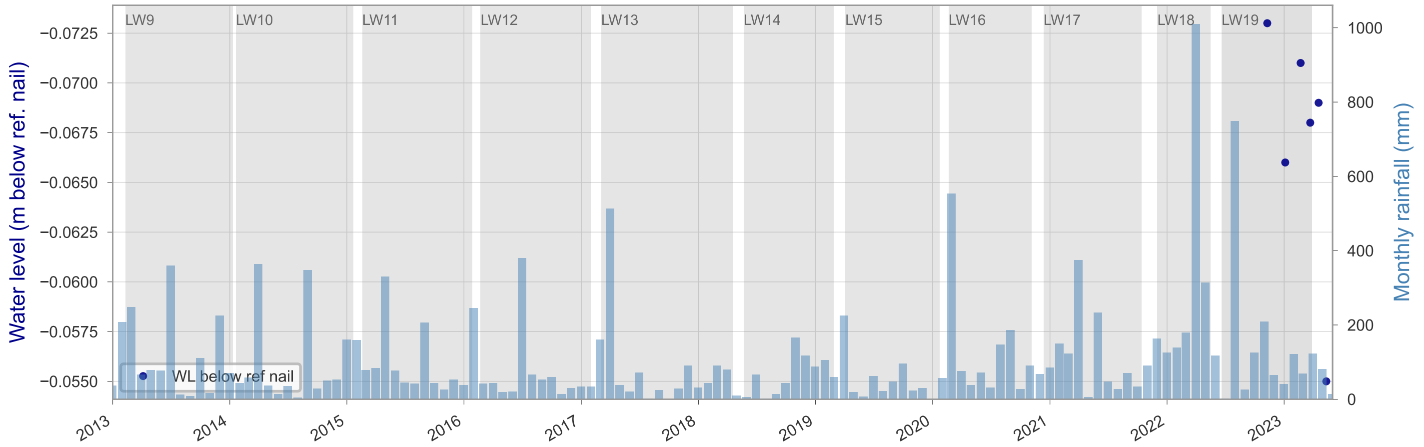


LC9A_POOL2
pH units
Monthly rainfall (mm)
pH
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

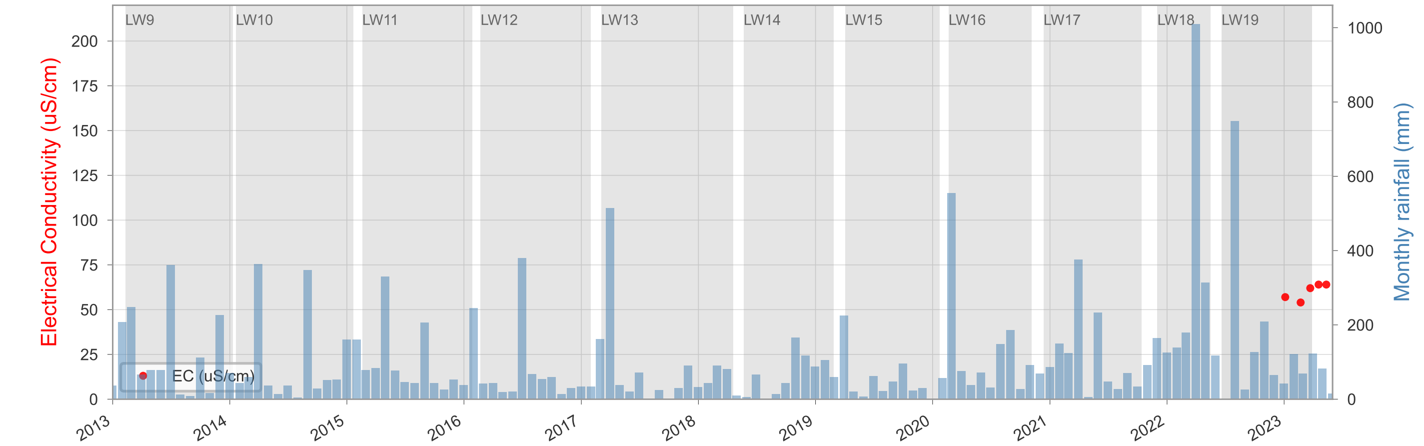


LC9A_POOL2
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

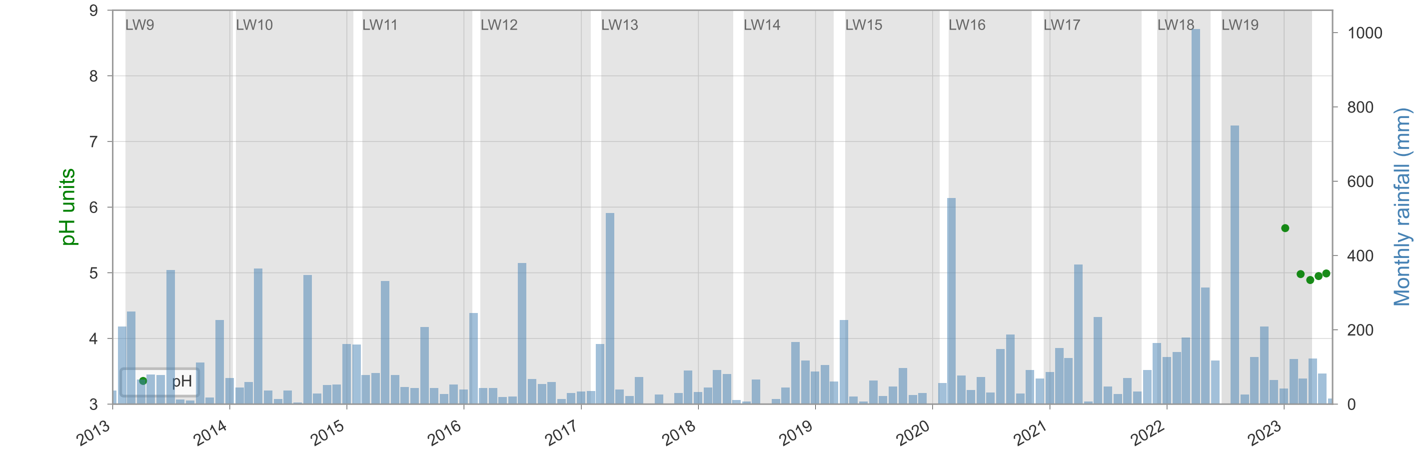
LC9_POOL15



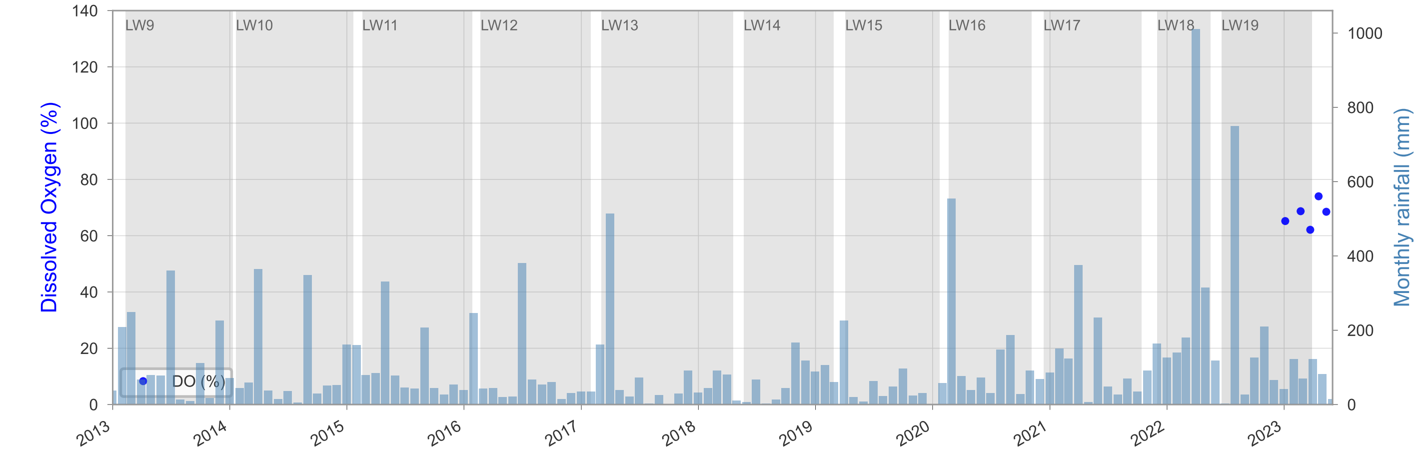
LC9_POOL15

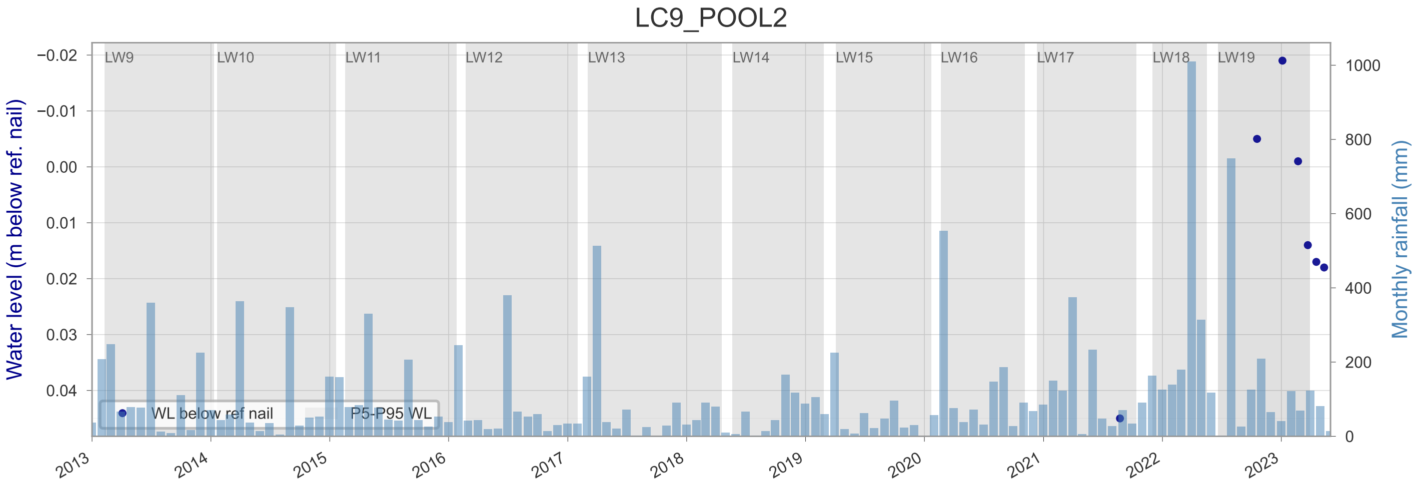


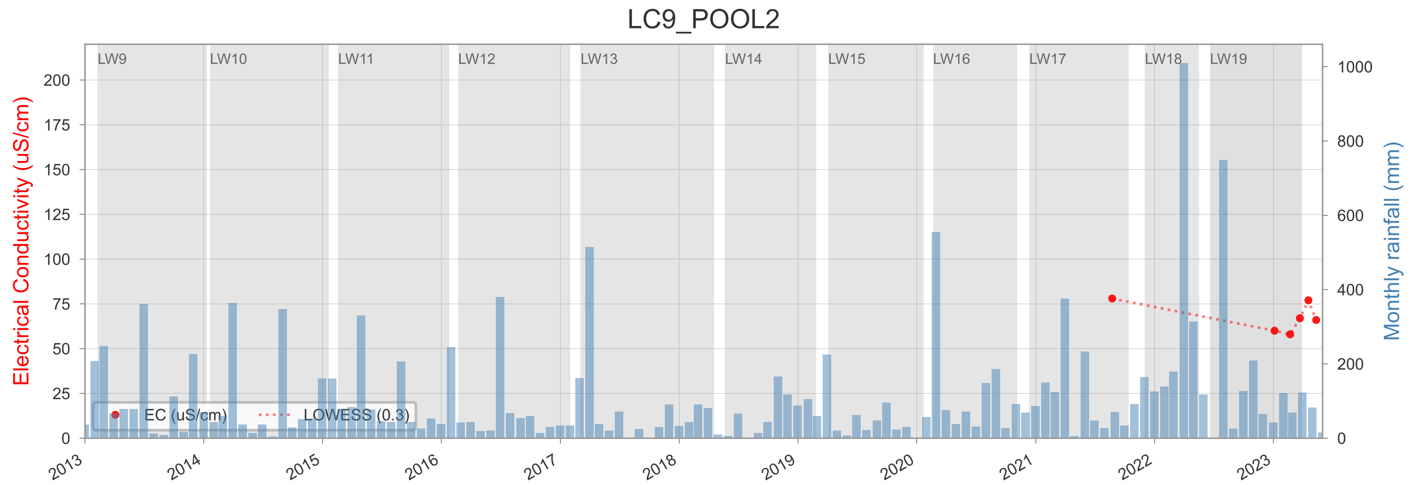
LC9_POOL15

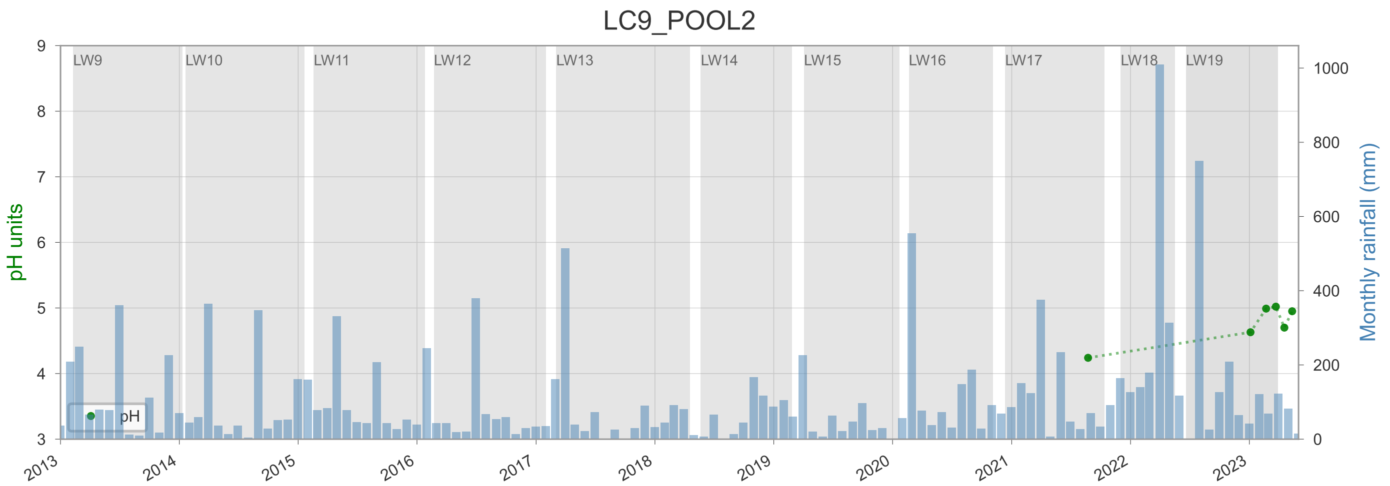


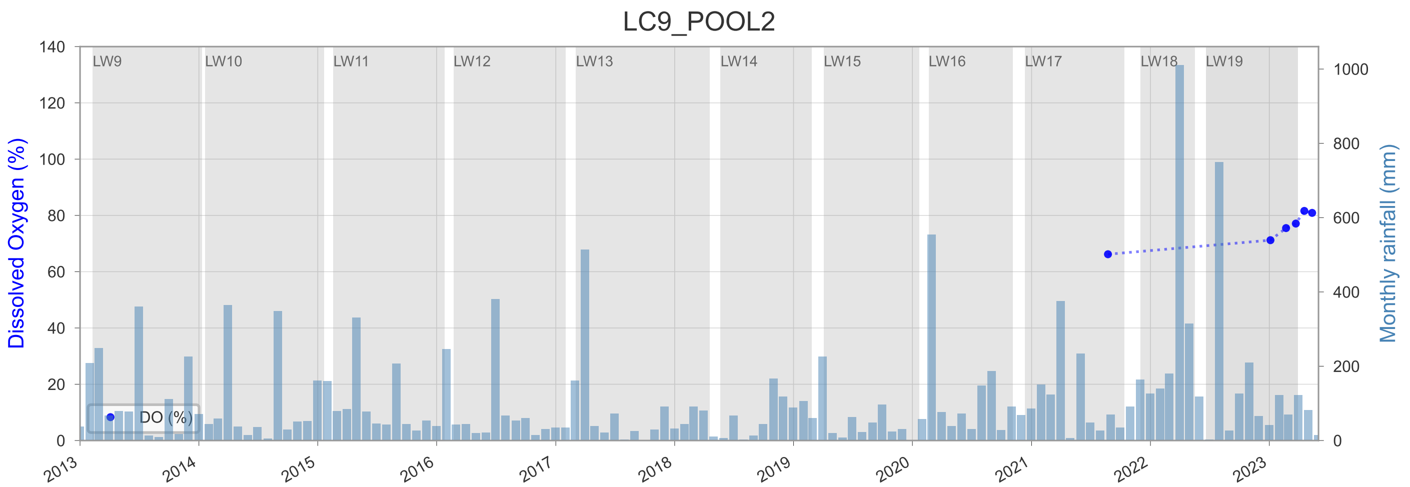
LC9_POOL15

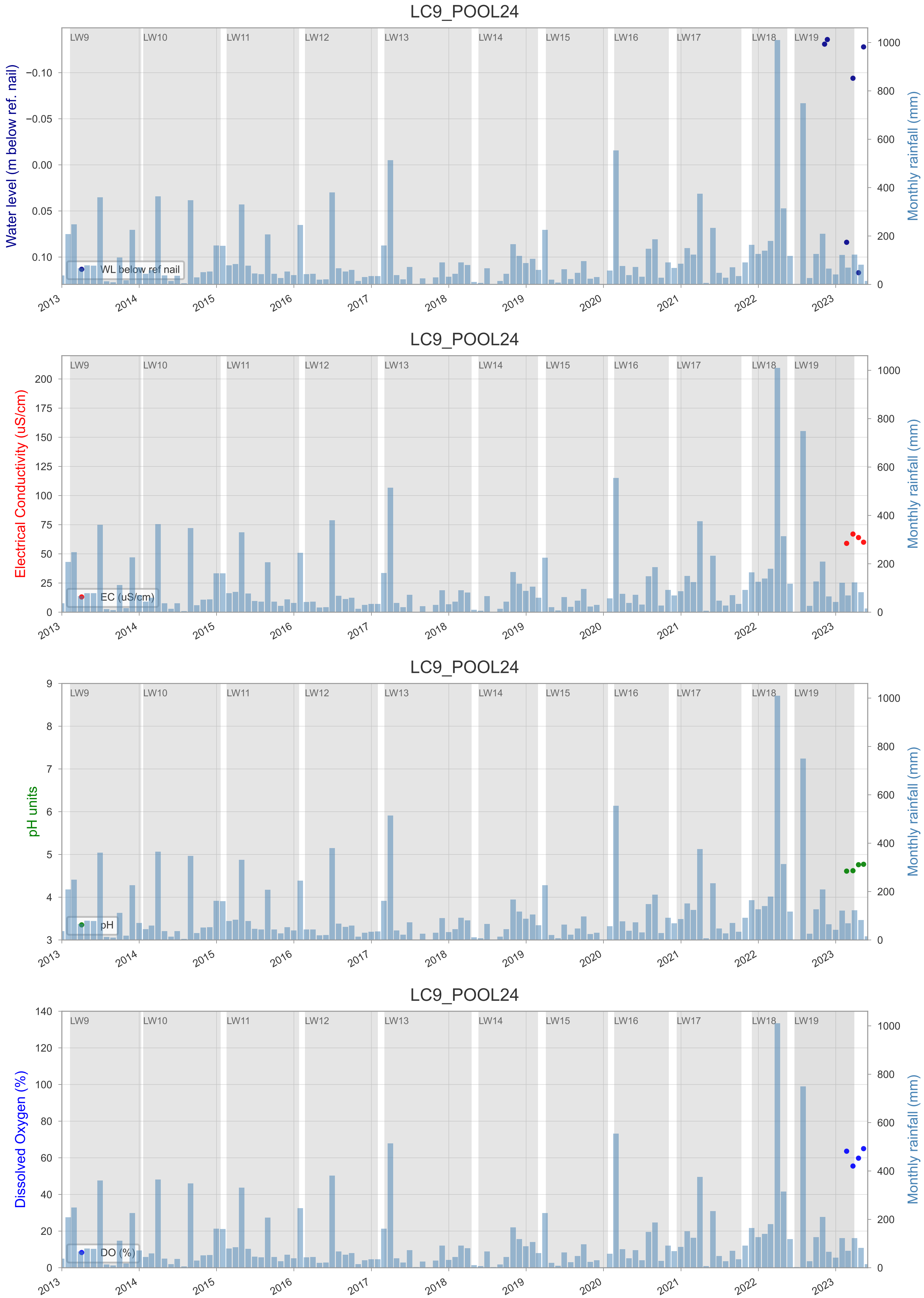


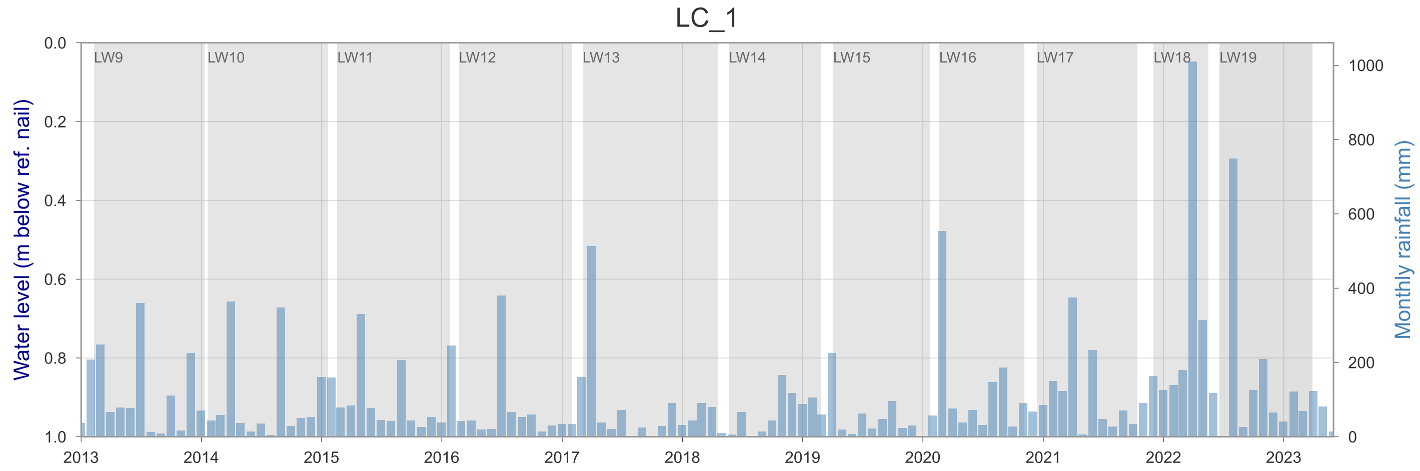

LC9_POOL2
Water level (m below ref. nail)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
P5-P95 WL

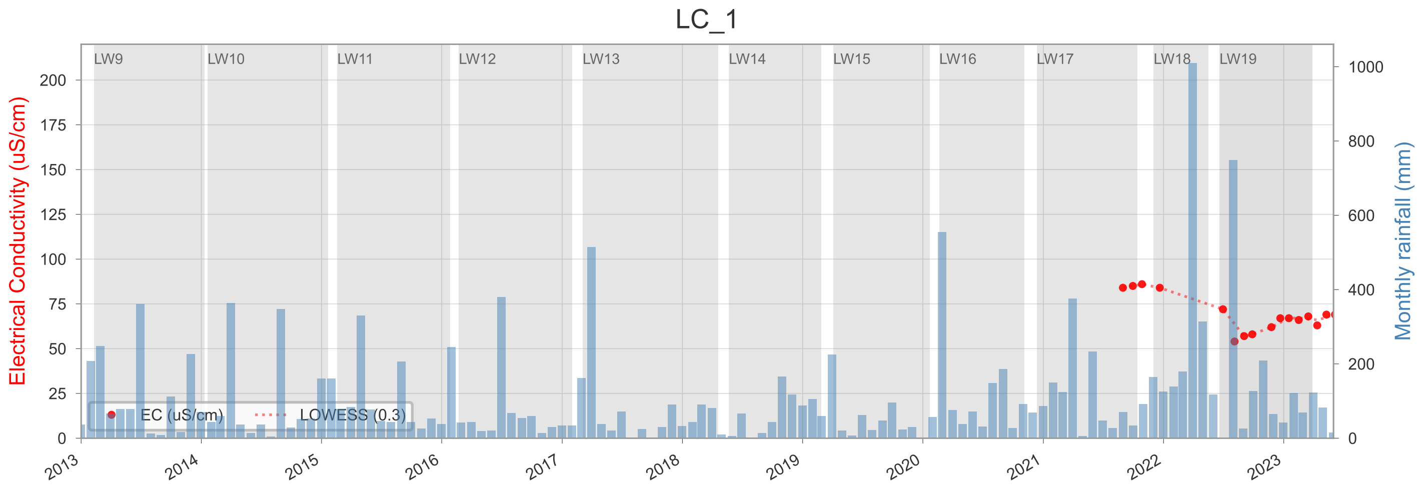

LC9_POOL2
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
EC (uS/cm)
LOWESS (0.3)

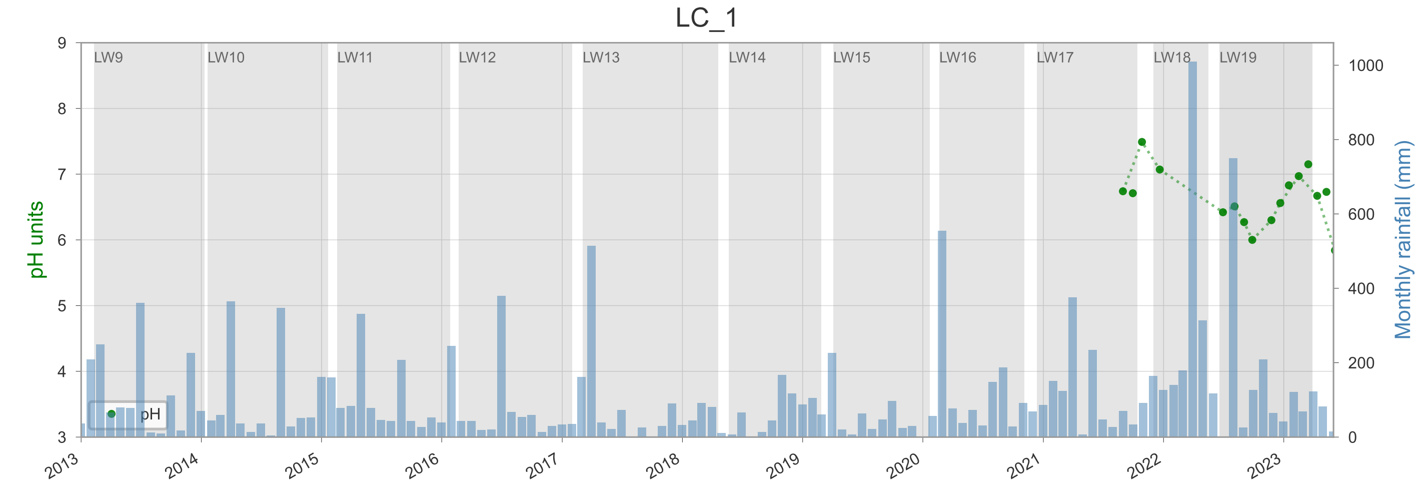

LC9_POOL2
pH units
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH

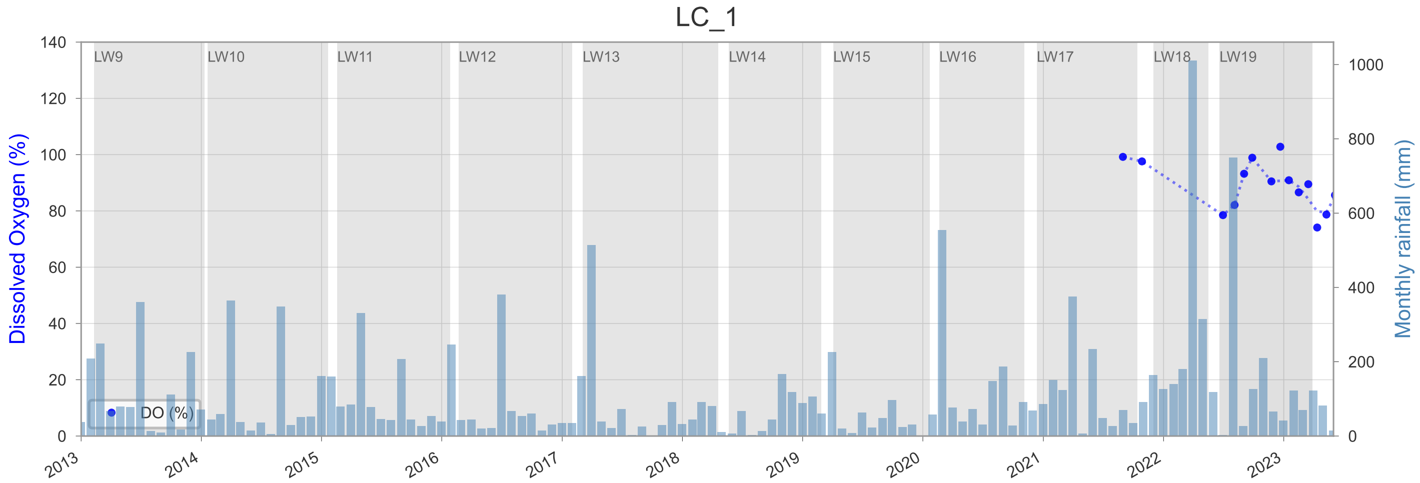

LC9_POOL2
Dissolved Oxygen (%)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
DO (%)

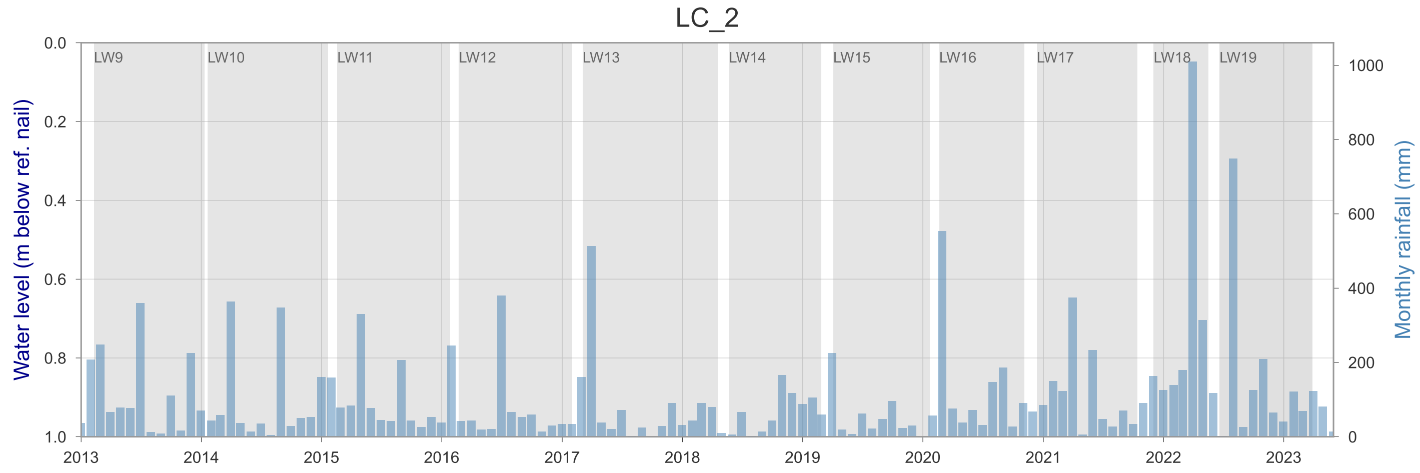

LC9_POOL24
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
LC9_POOL24
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LC9_POOL24
pH units
Monthly rainfall (mm)
pH
LC9_POOL24
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

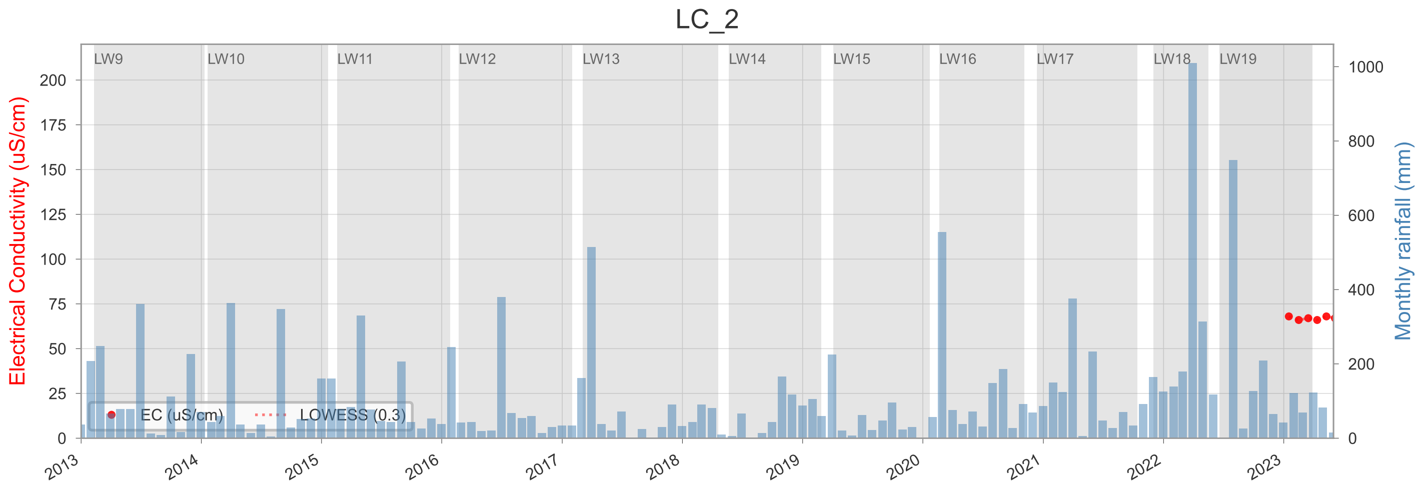

LC_1
Water level (m below ref. nail)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

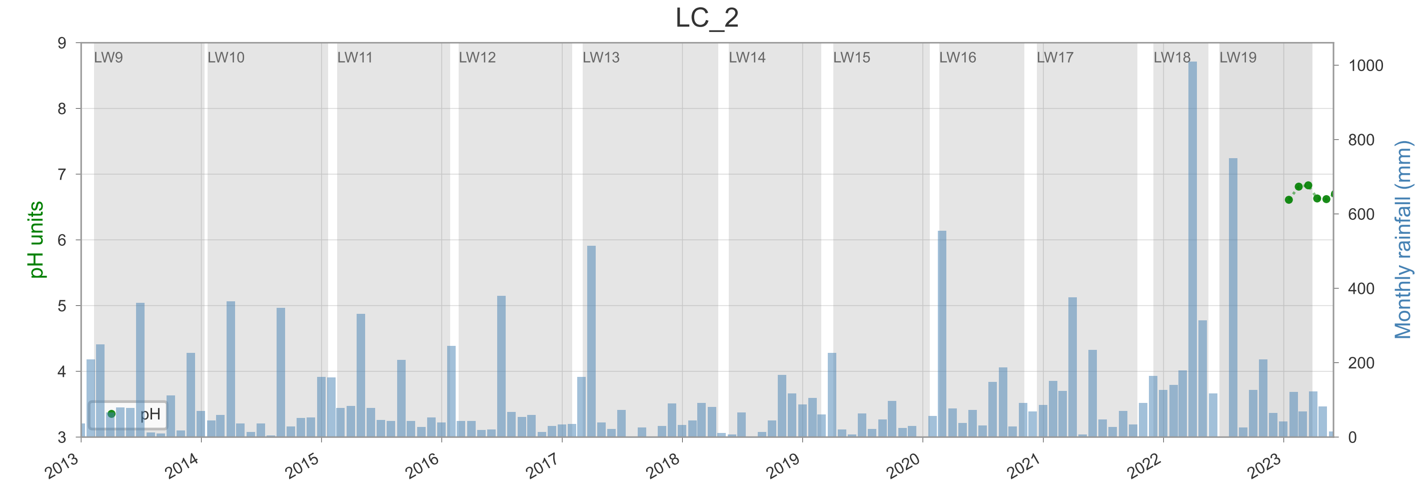

LC_1
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

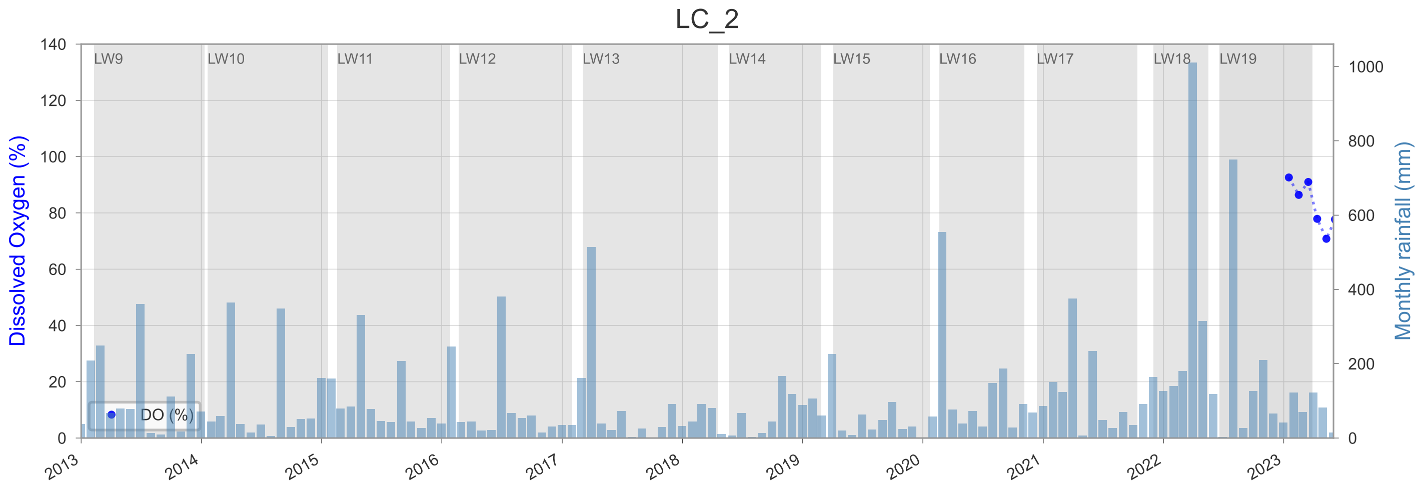

LC_1
pH units
Monthly rainfall (mm)
pH
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

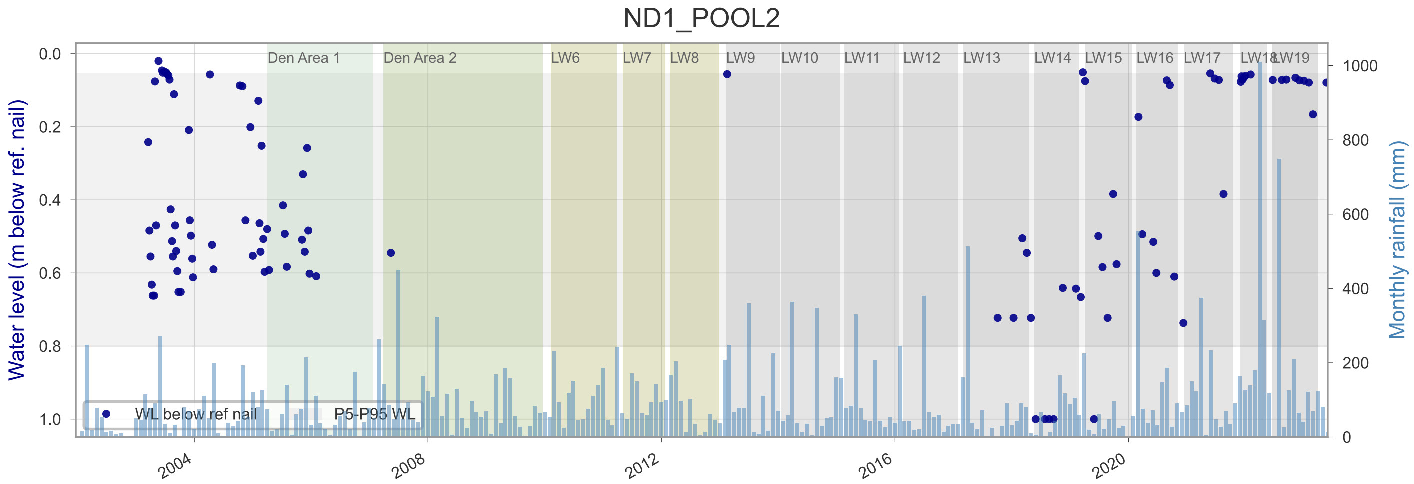

LC_1
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

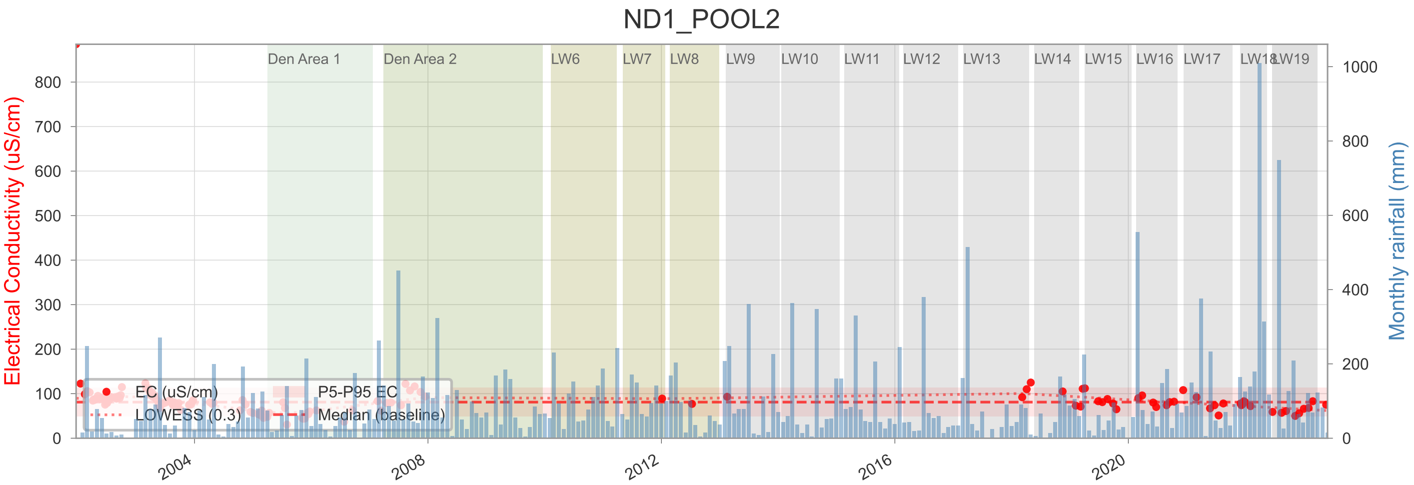

LC_2
Water level (m below ref. nail)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

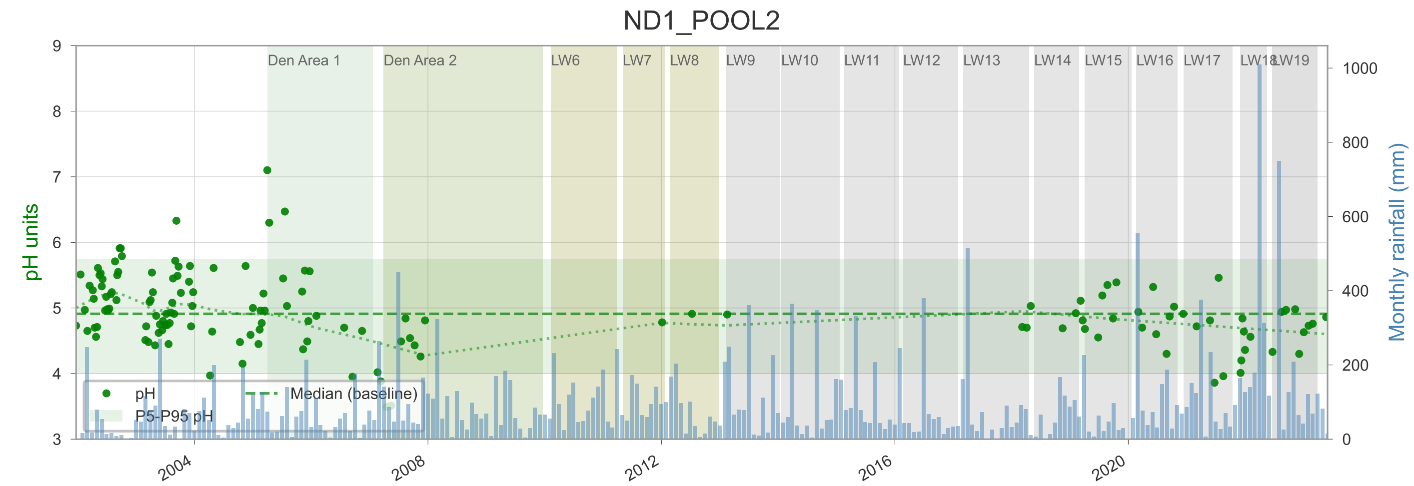

LC_2
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

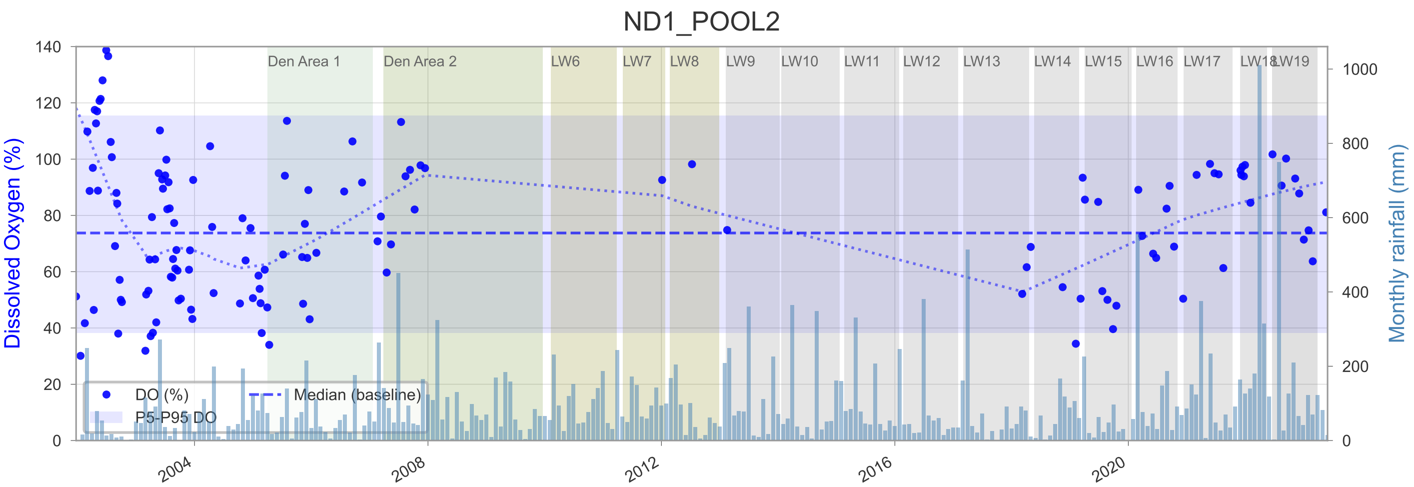

LC_2
pH units
Monthly rainfall (mm)
pH
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

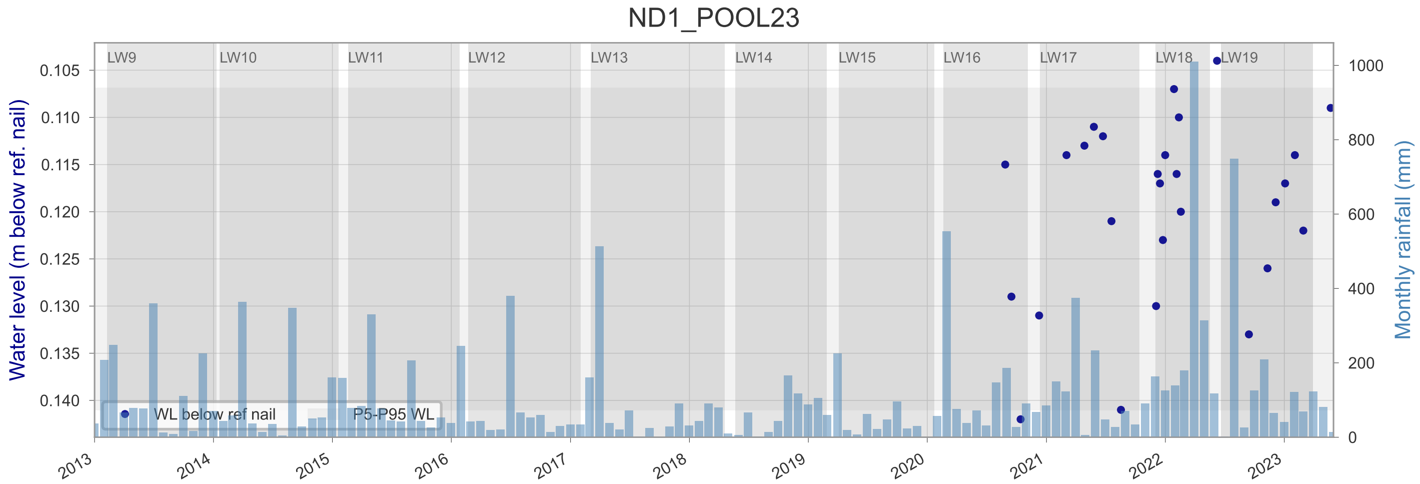

LC_2
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

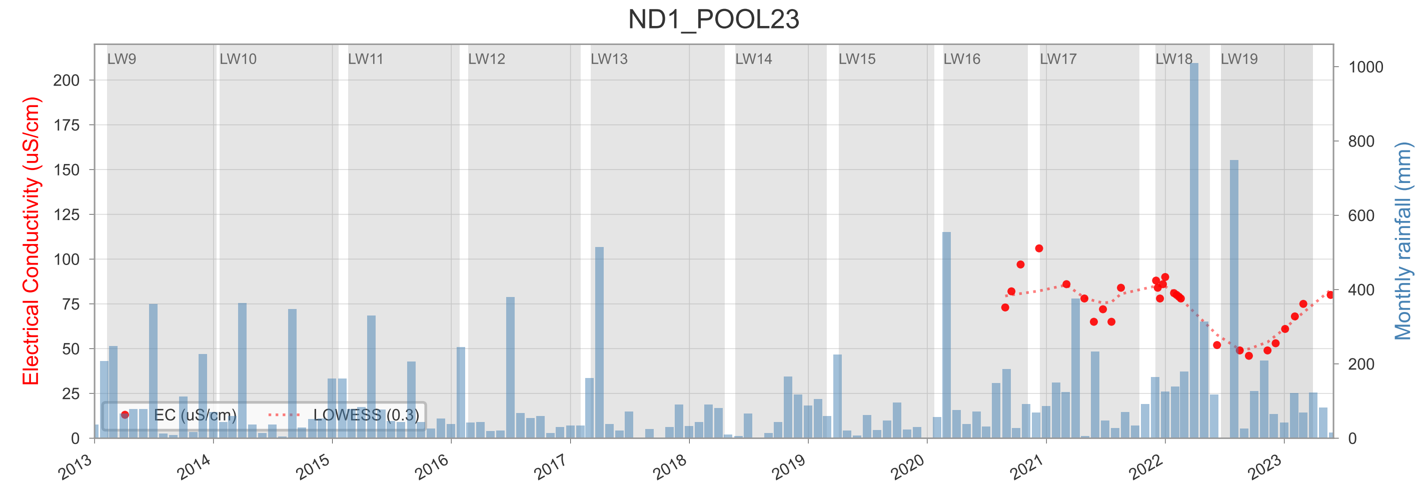

ND1_POOL2
Water level (m below ref. nail)
Monthly rainfall (mm)
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
P5-P95 WL

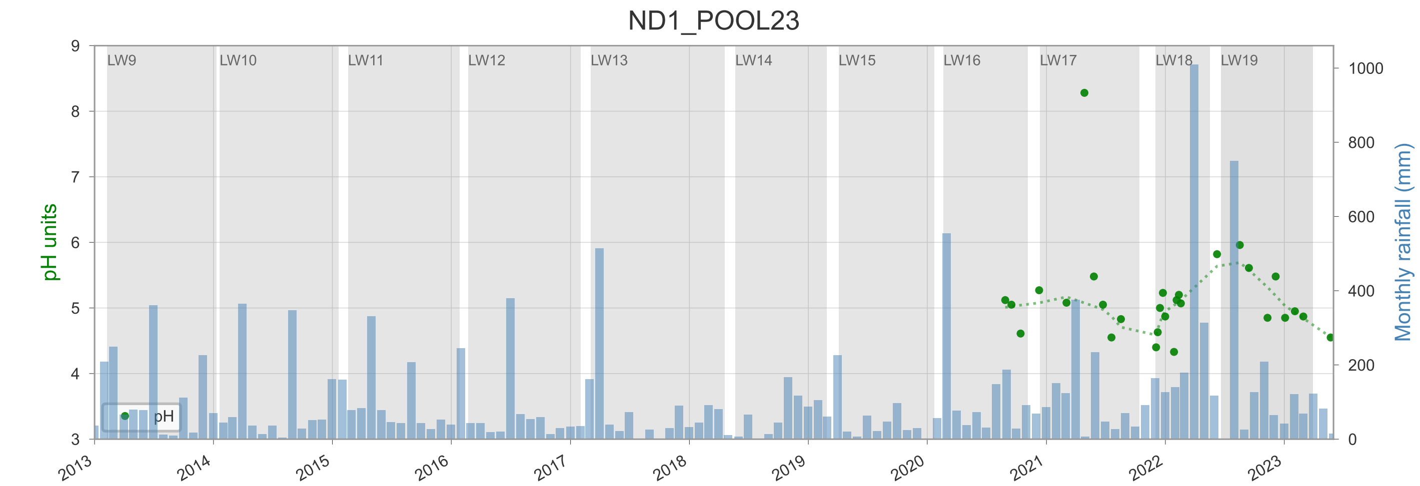

ND1_POOL2
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

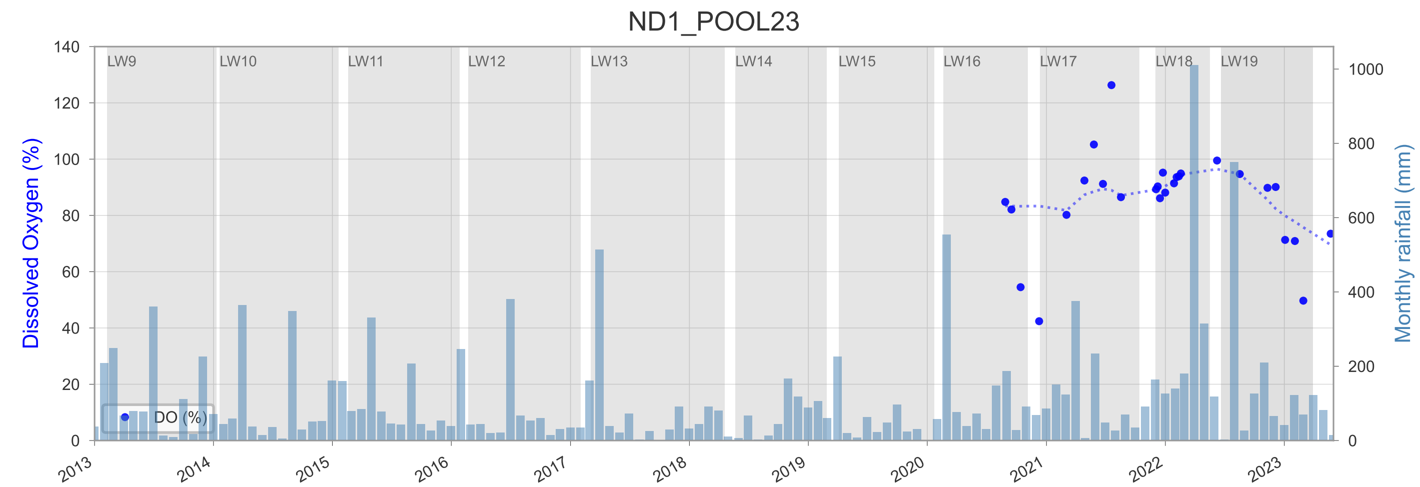

ND1_POOL2
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)

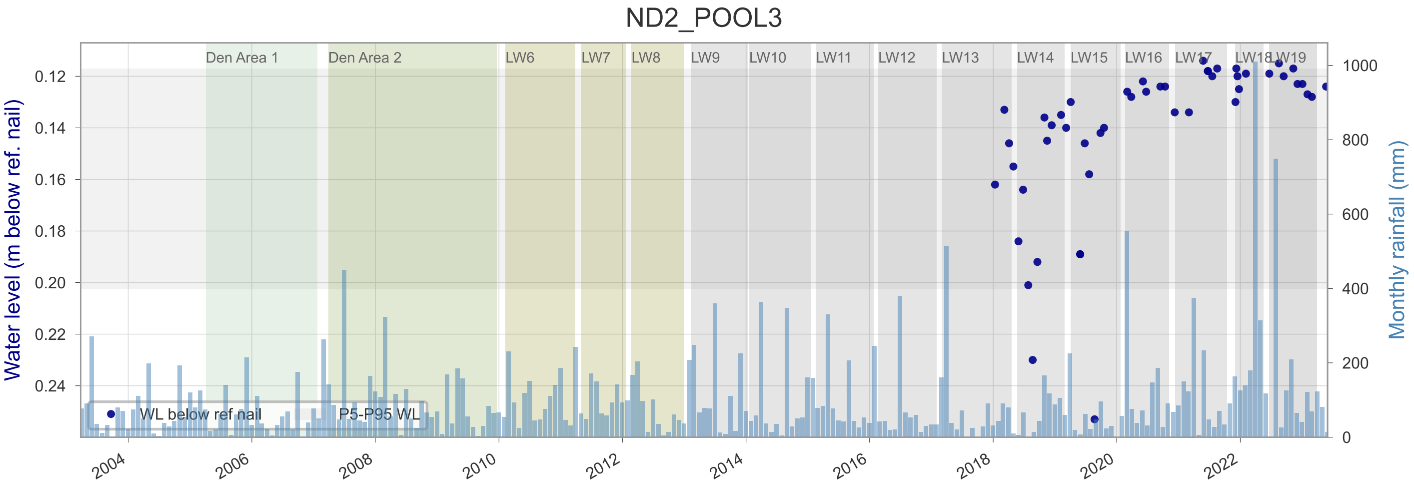

ND1_POOL2
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)

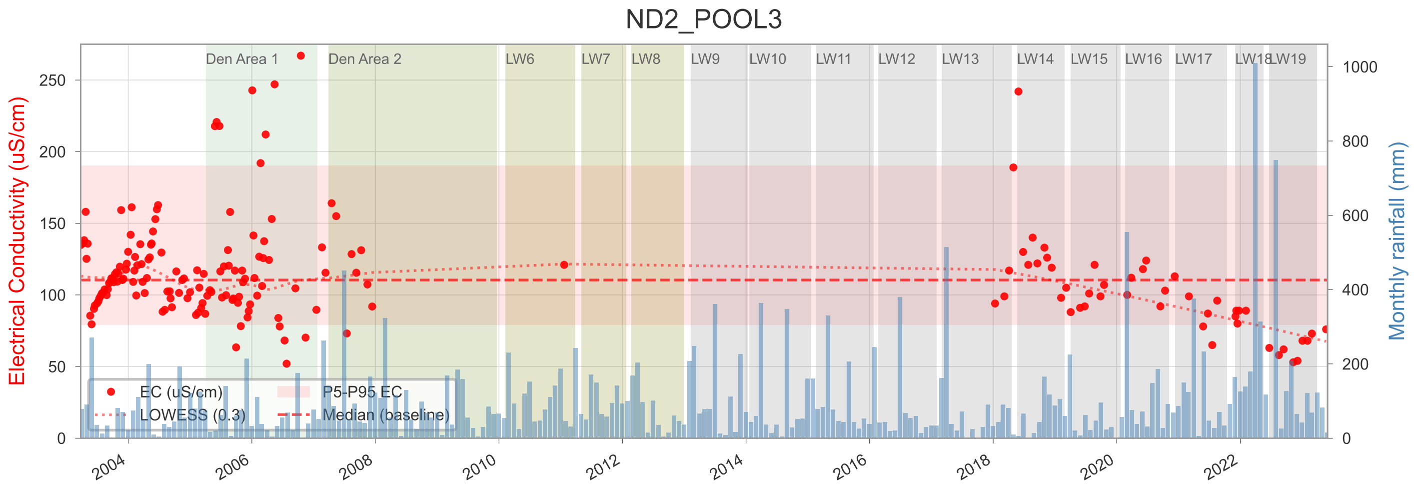

ND1_POOL23
Water level (m below ref. nail)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
P5-P95 WL

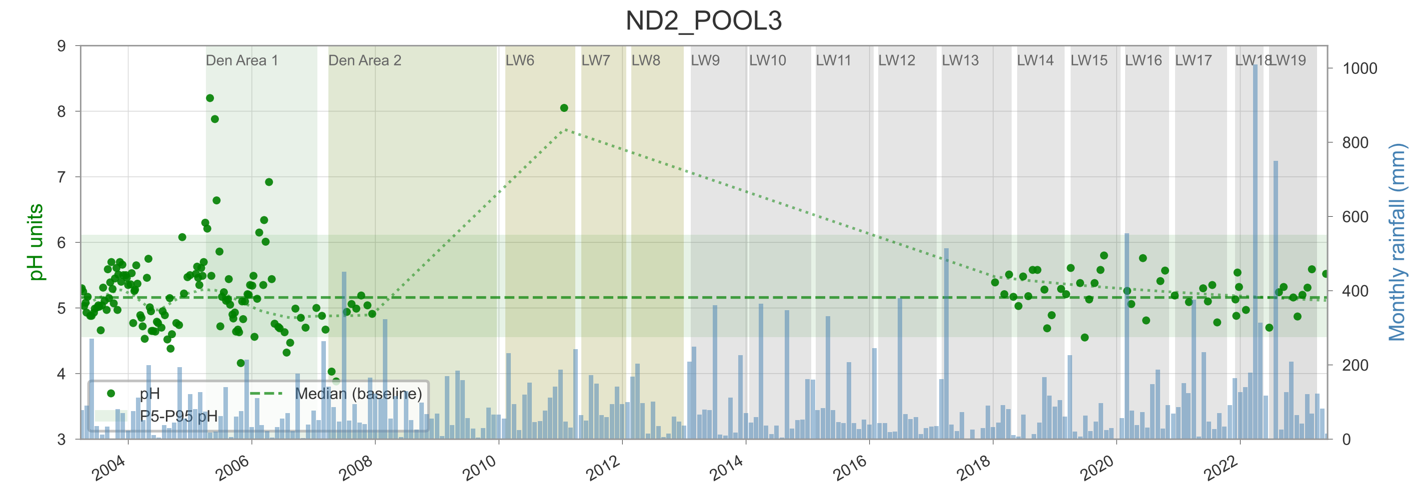

ND1_POOL23
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
EC (uS/cm)
LOWESS (0.3)

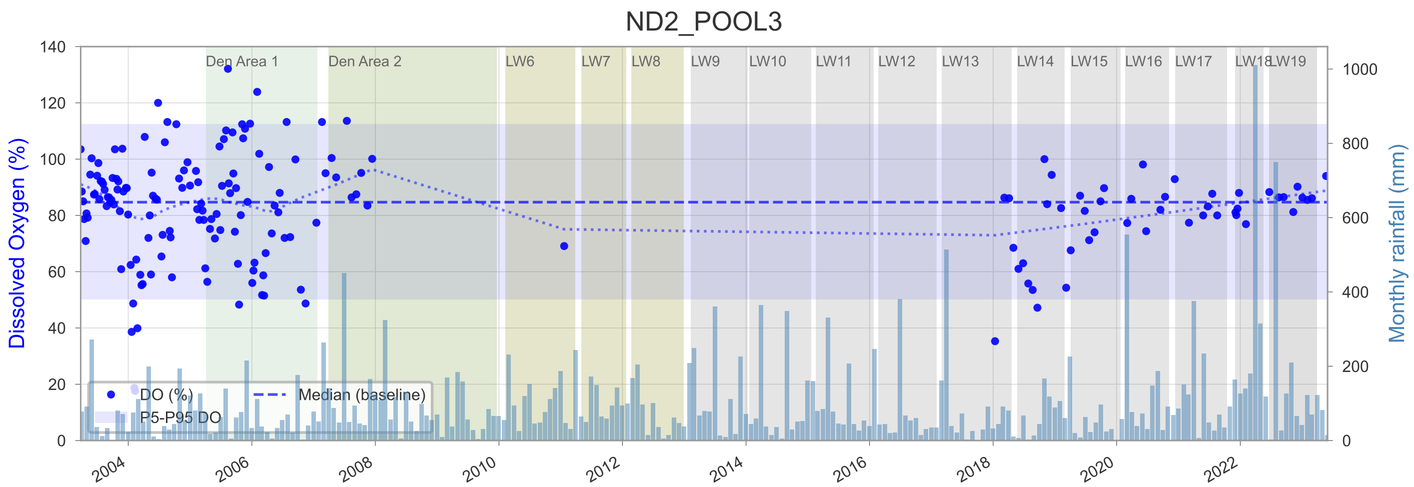

ND1_POOL23
pH units
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH

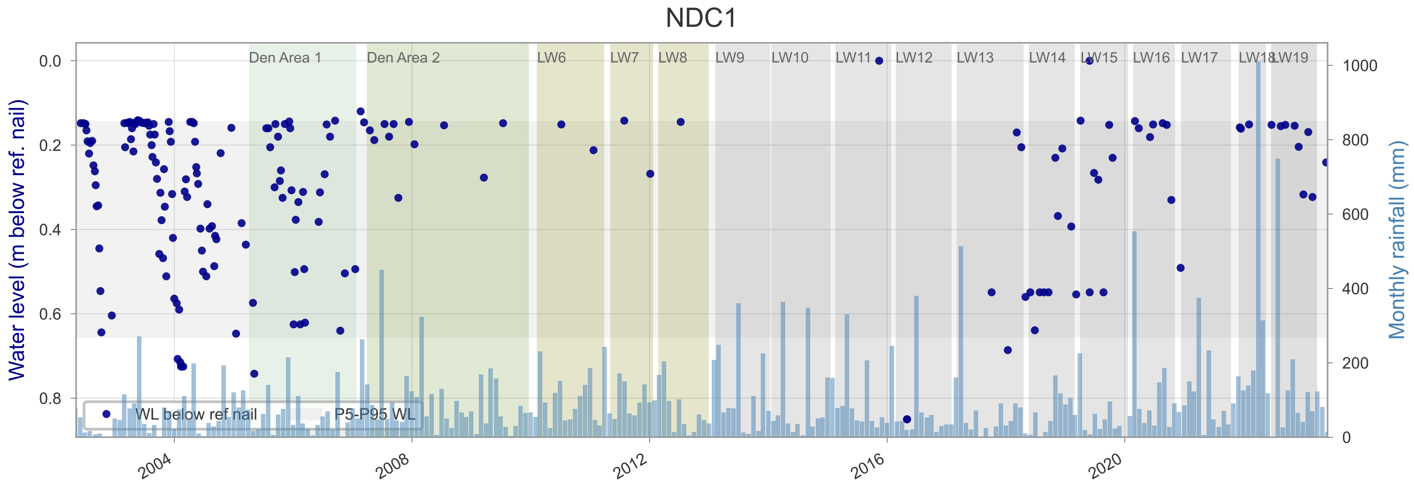

ND1_POOL23
Dissolved Oxygen (%)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
DO (%)

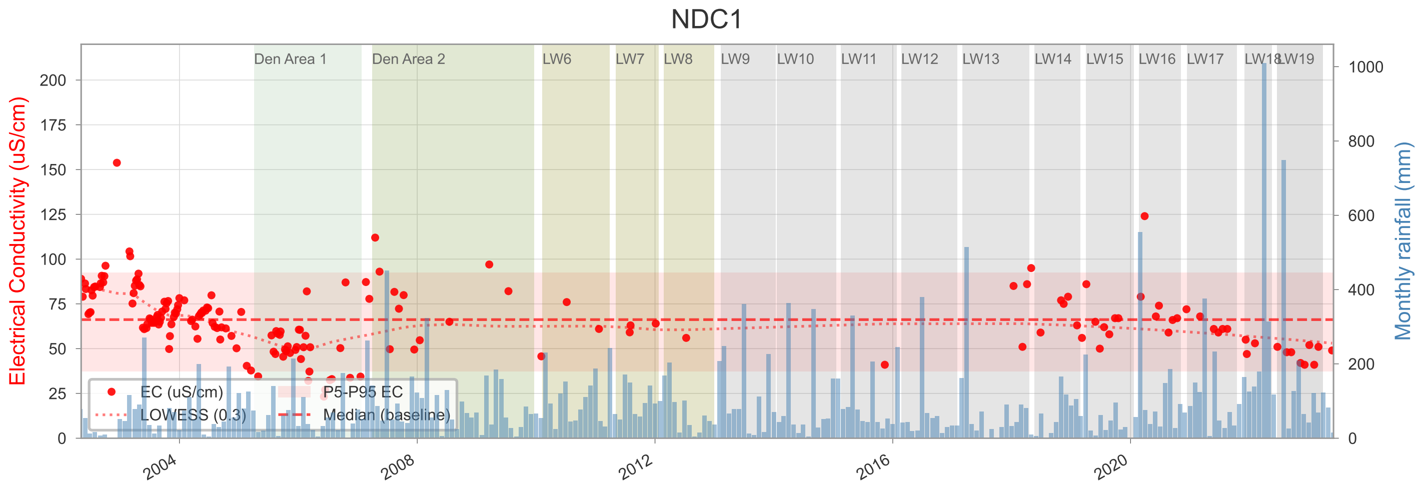

ND2_POOL3
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
P5-P95 WL

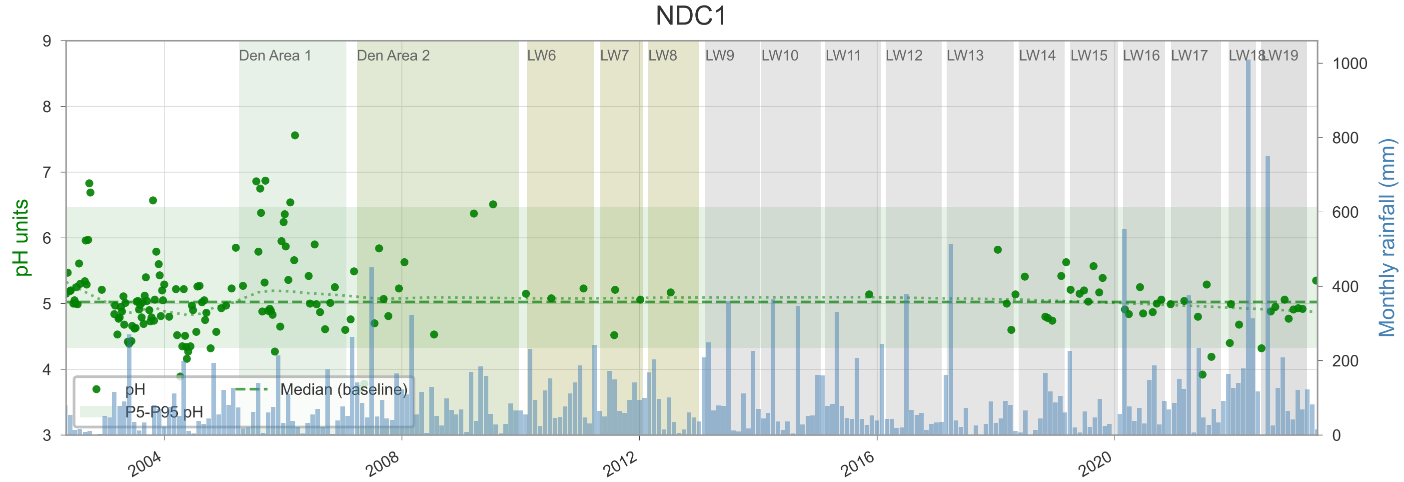

ND2_POOL3
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

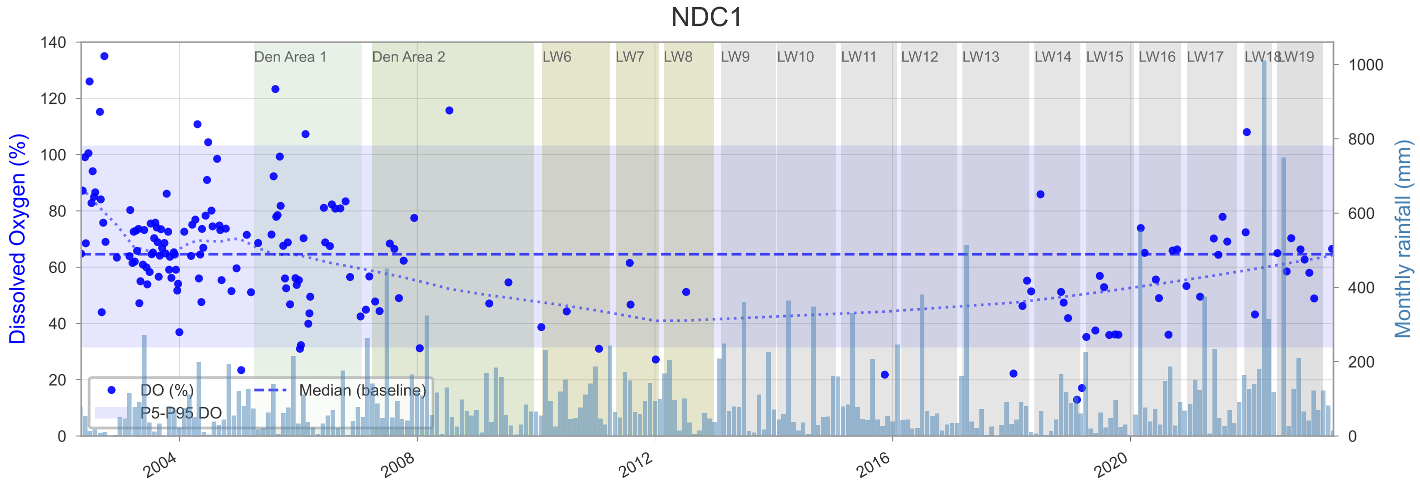

ND2_POOL3
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)

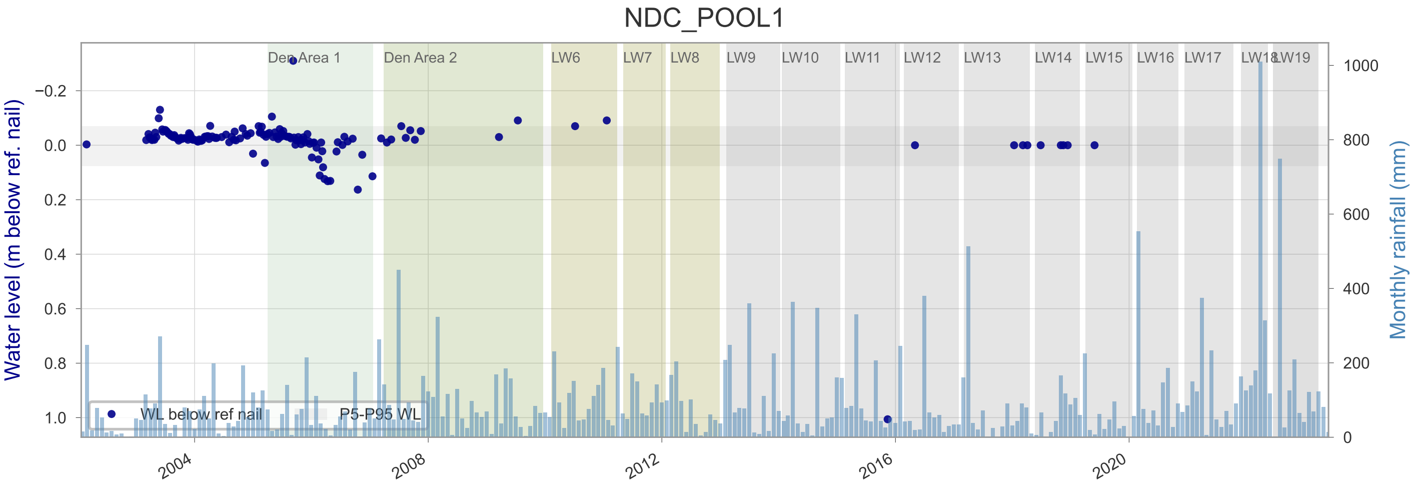

ND2_POOL3
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)

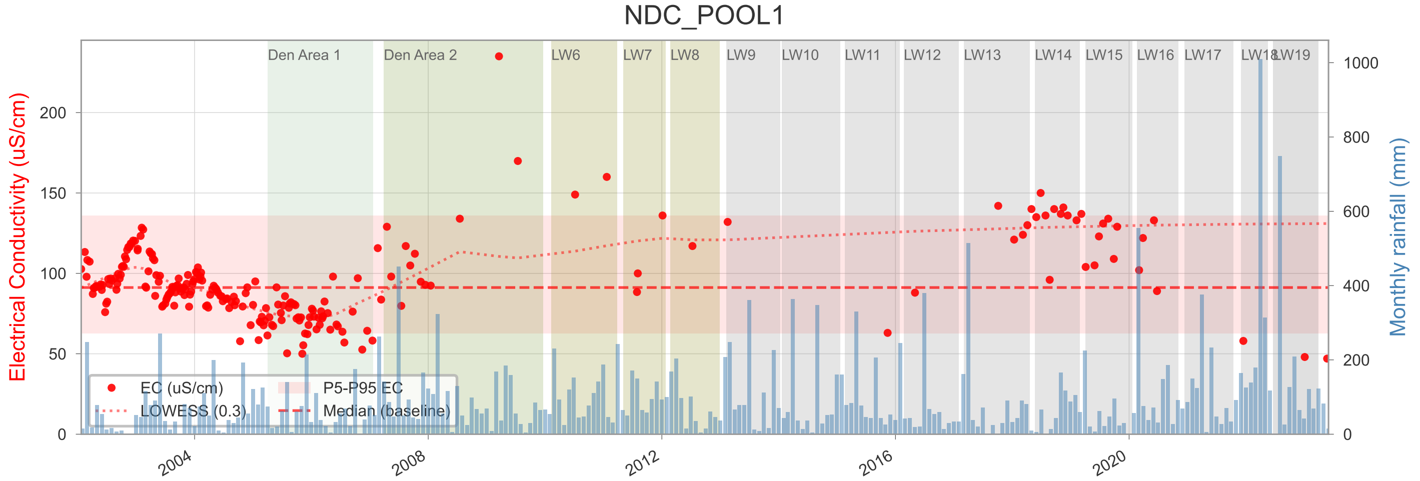

NDC1
Water level (m below ref. nail)
Monthly rainfall (mm)
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref.nail
P5-P95 WL
0.0
0.2
0.4
0.6
0.8
0
200
400
600
800
1000
2004
2008
2012
2016
2020

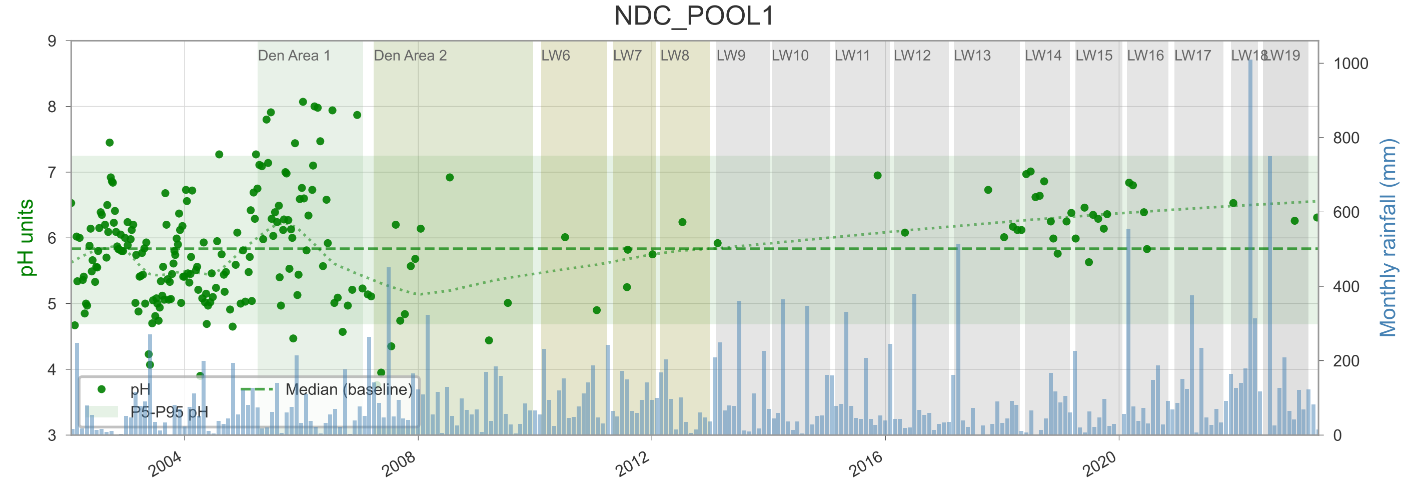

NDC1
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)
0
25
50
75
100
125
150
175
200
0
200
400
600
800
1000
2004
2008
2012
2016
2020

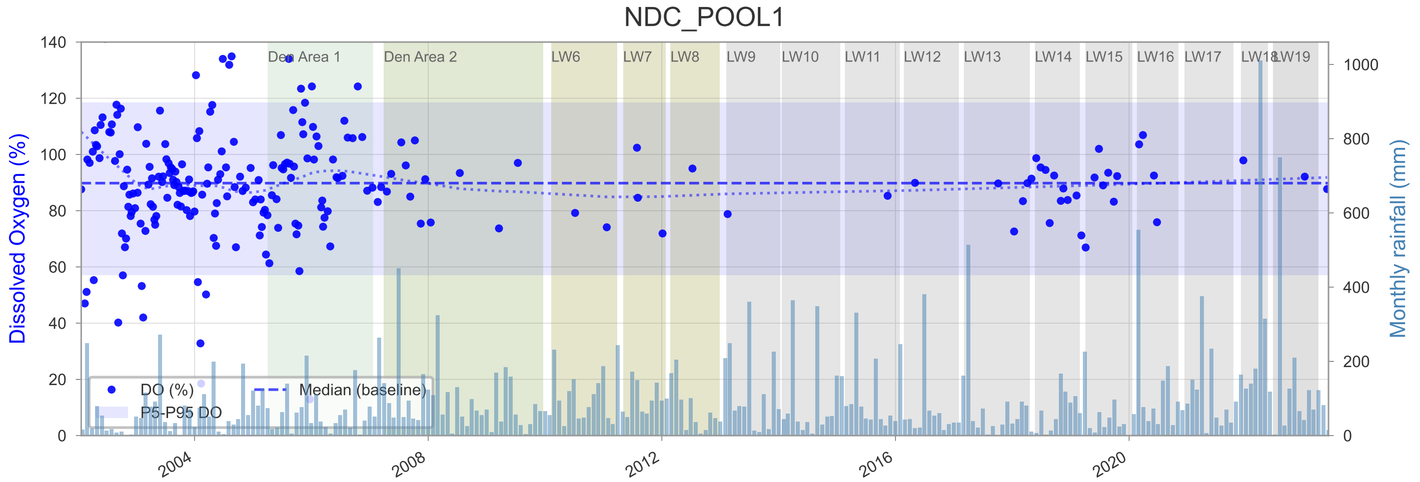

NDC1
pH units
Monthly rainfall (mm)
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH
P5-P95 pH
Median (baseline)
3
4
5
6
7
8
9
0
200
400
600
800
1000
2004
2008
2012
2016
2020

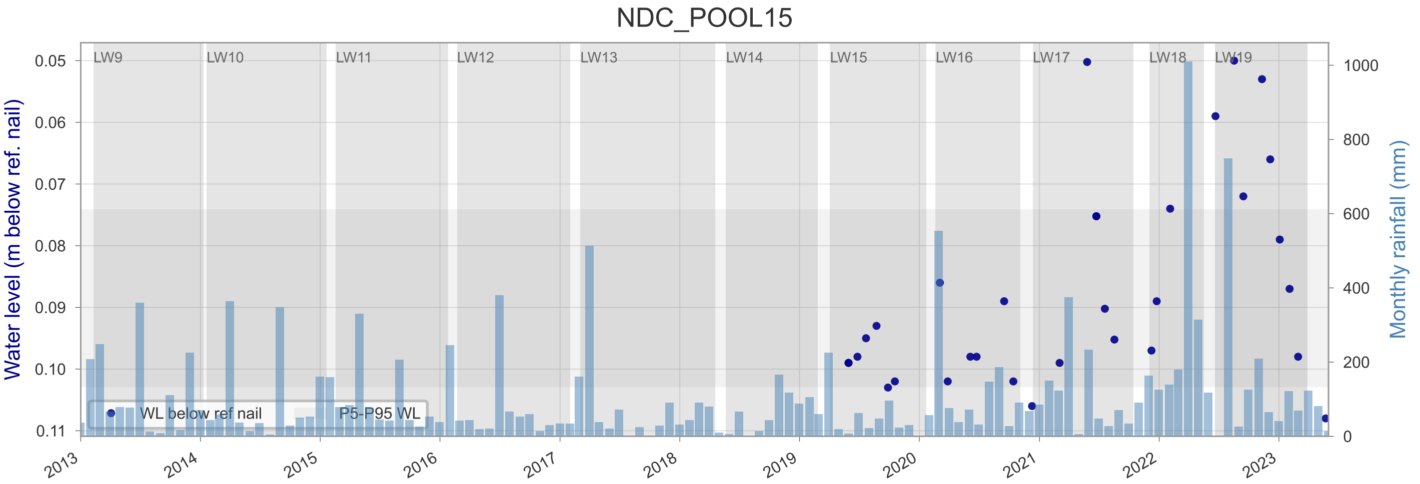

NDC1
Dissolved Oxygen (%)
Monthly rainfall (mm)
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
DO (%)
P5-P95 DO
Median (baseline)
0
20
40
60
80
100
120
140
0
200
400
600
800
1000
2004
2008
2012
2016
2020

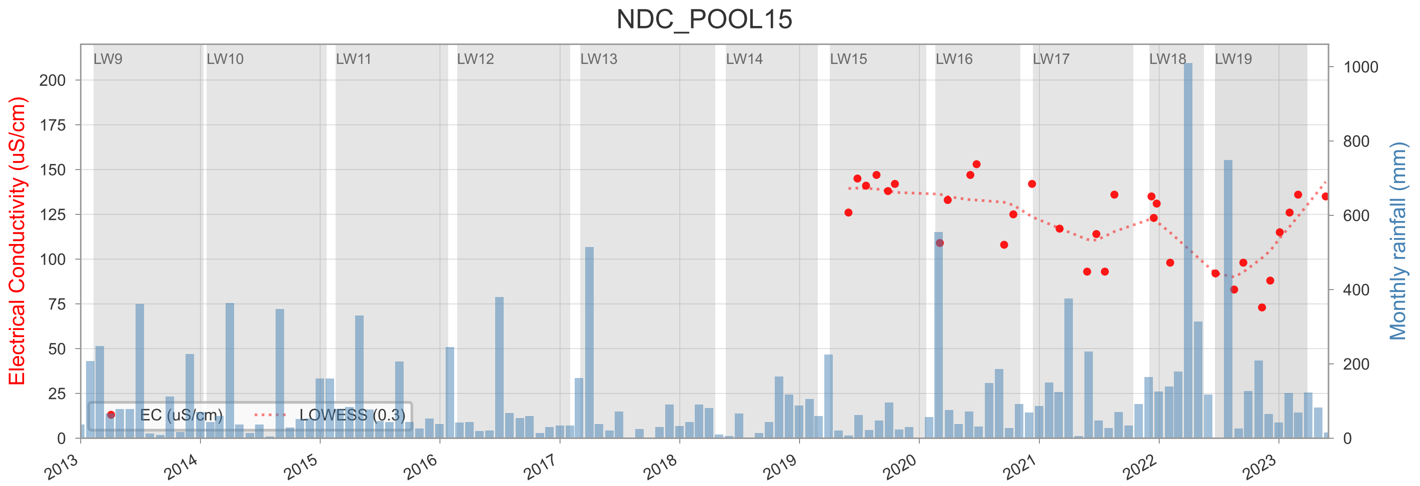

NDC_POOL1
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
P5-P95 WL
2004
2008
2012
2016
2020

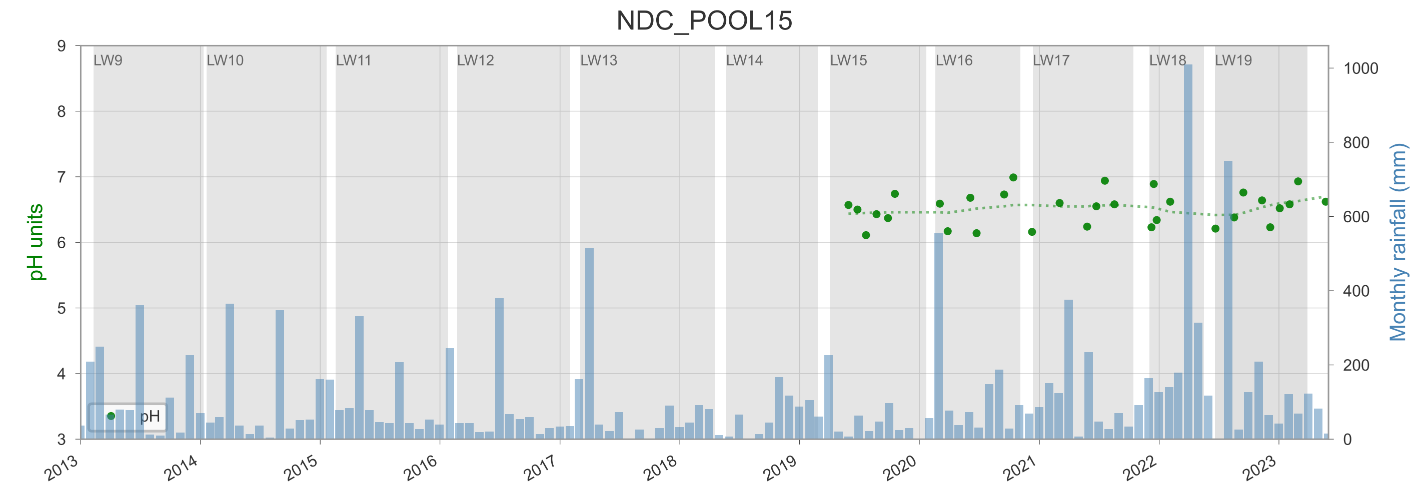

NDC_POOL1
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)
2004
2008
2012
2016
2020

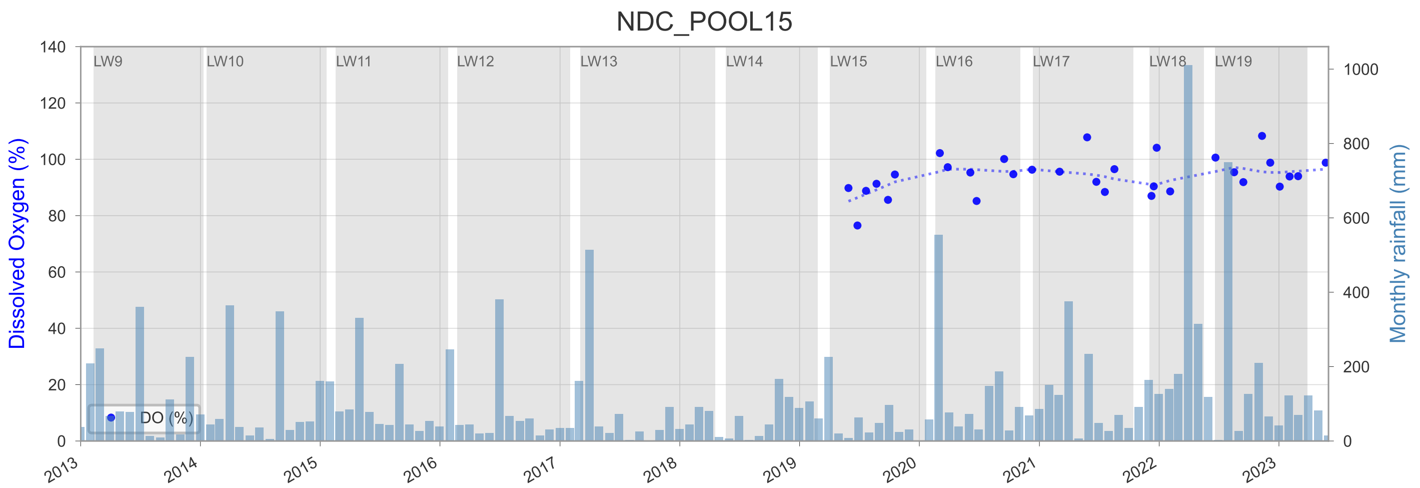

NDC_POOL1
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)
2004
2008
2012
2016
2020

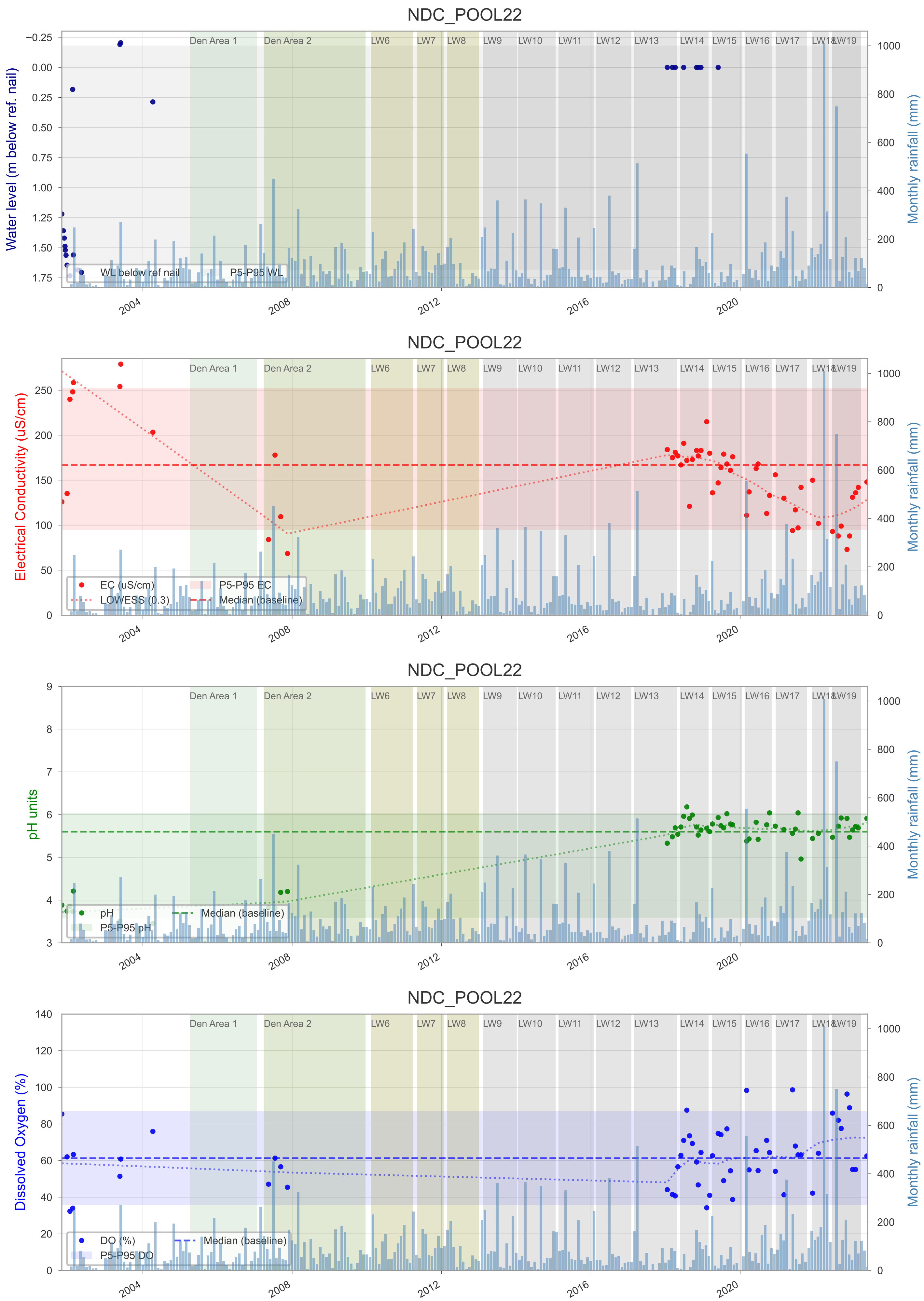

NDC_POOL1
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)
2004
2008
2012
2016
2020

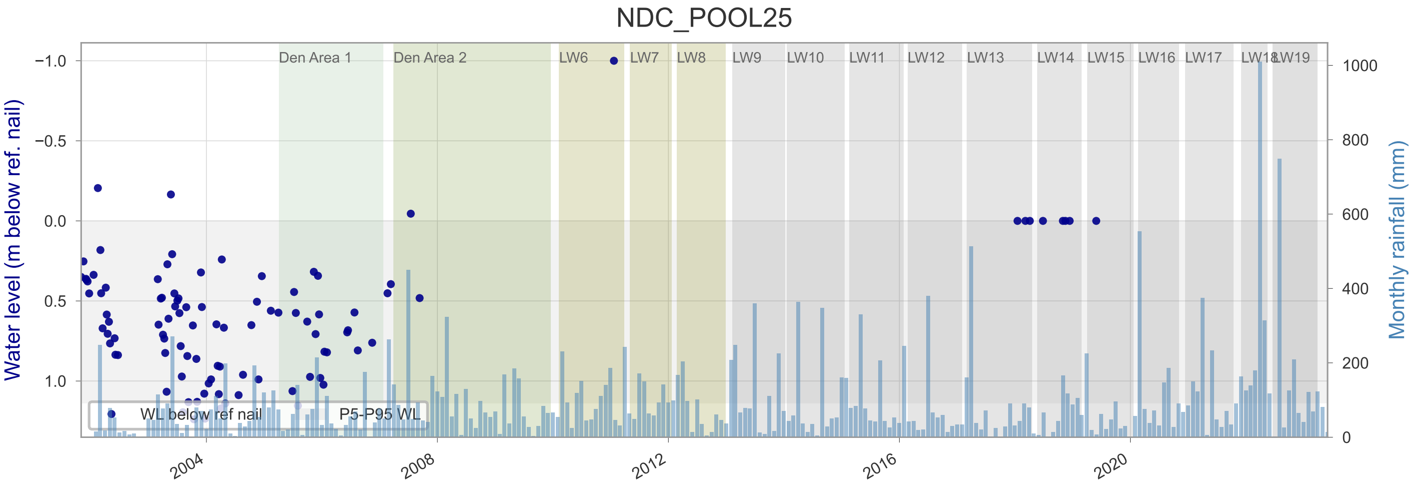

NDC_POOL15
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
P5-P95 WL
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

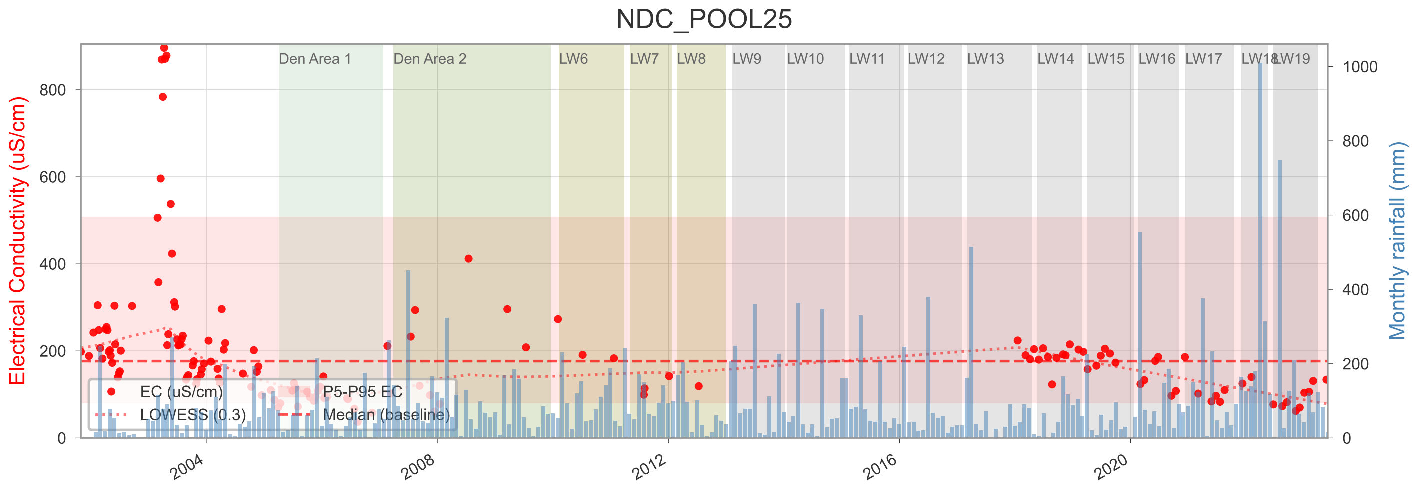

NDC_POOL15
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

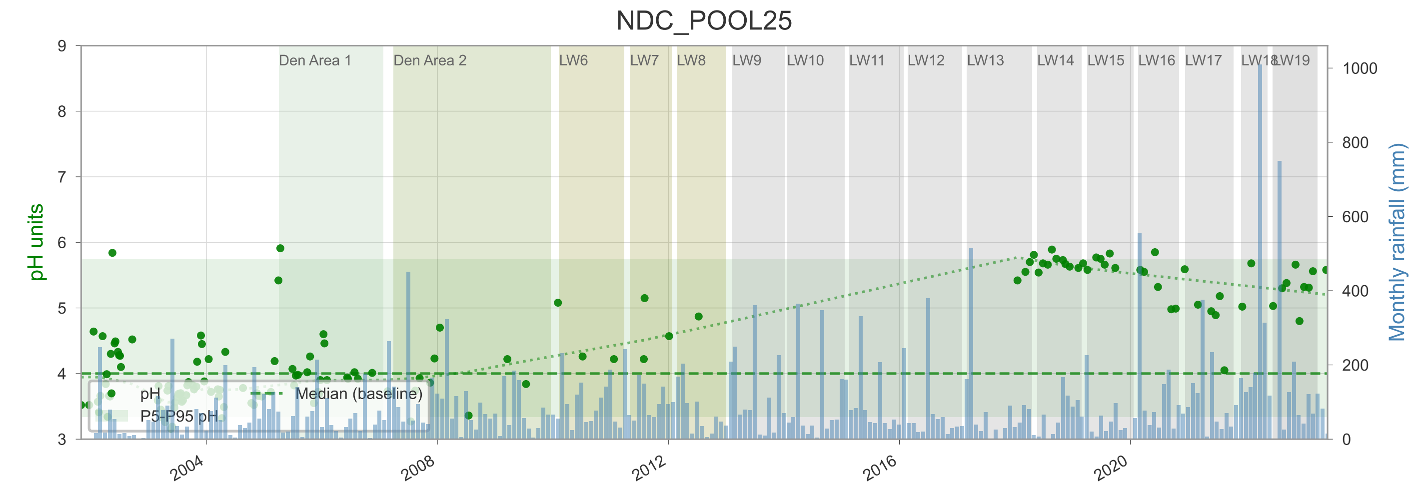

NDC_POOL15
pH units
Monthly rainfall (mm)
pH
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

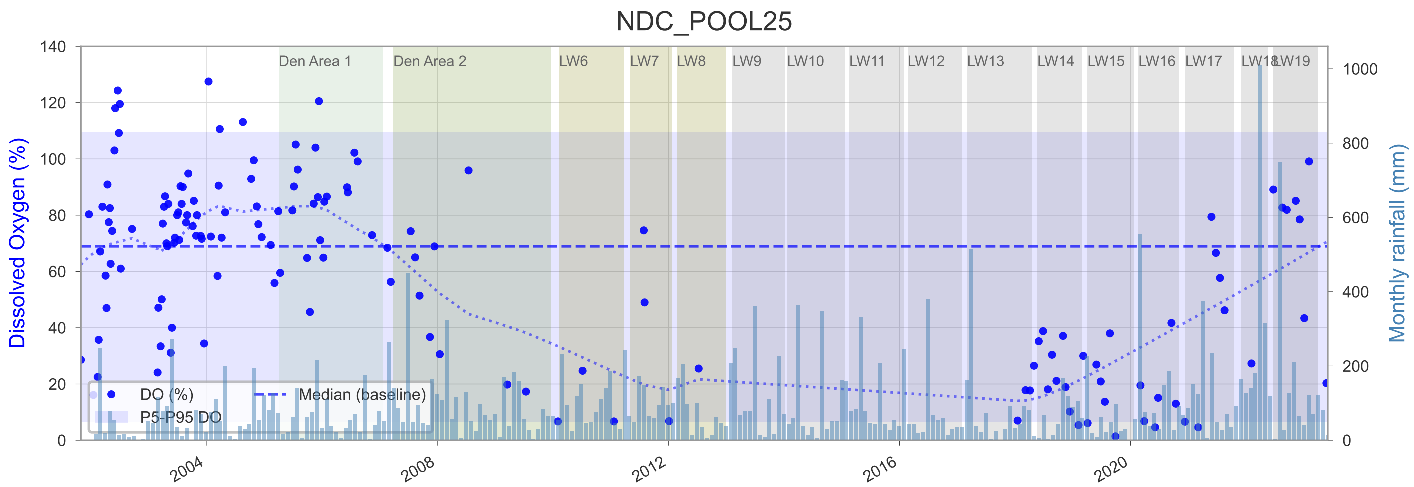

NDC_POOL15
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

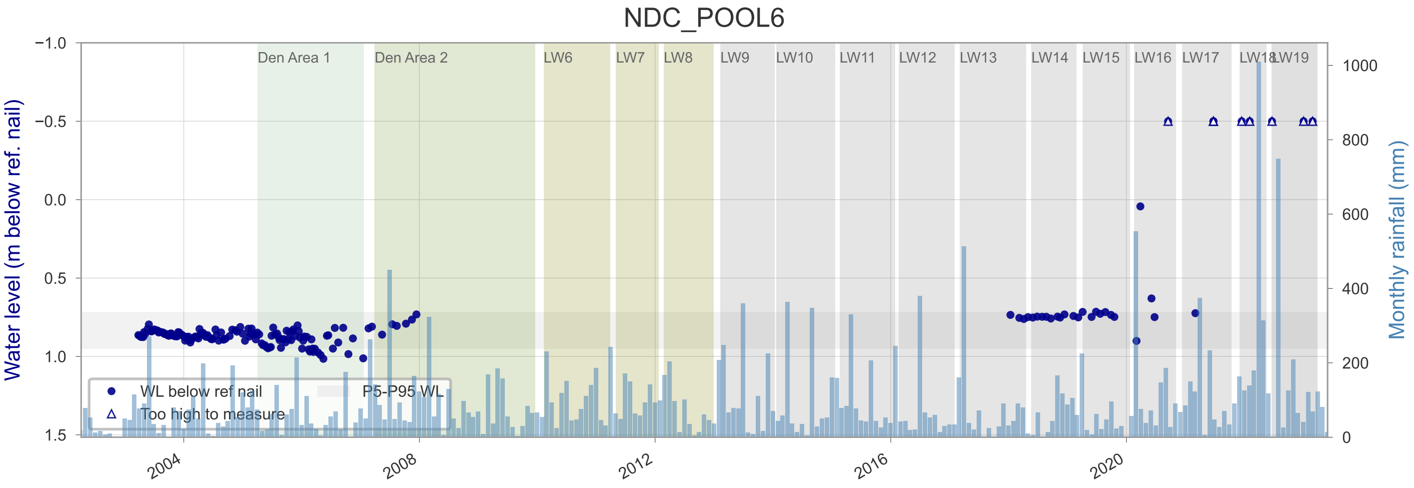

NDC_POOL22
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
P5-P95 WL
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
2004
2008
2012
2016
2020
NDC_POOL22
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)
NDC_POOL22
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)
NDC_POOL22
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)

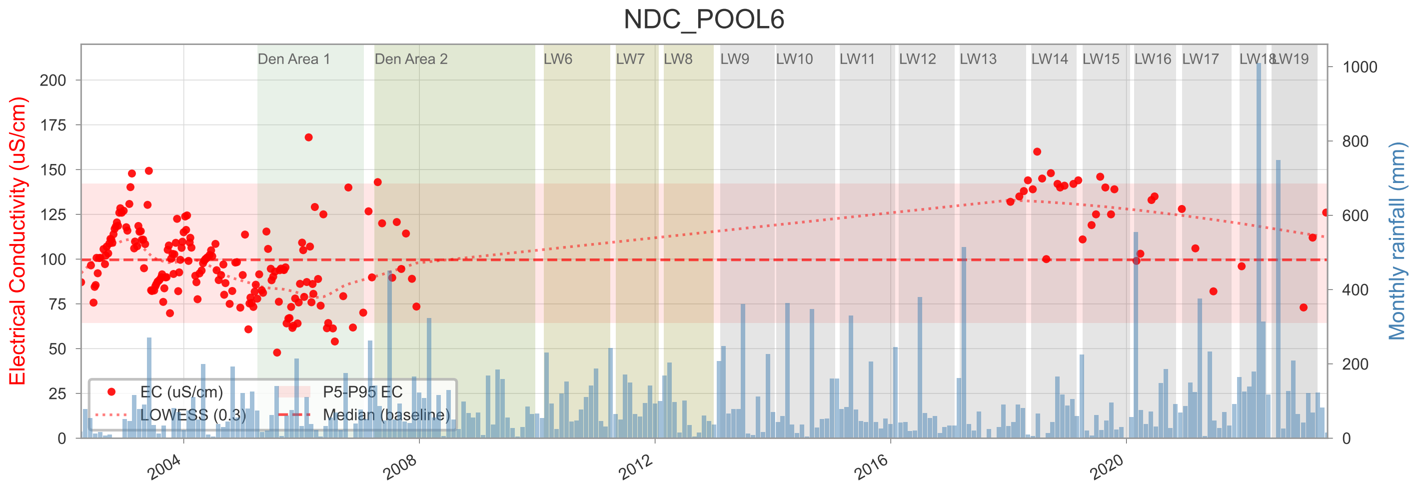

NDC_POOL25
Water level (m below ref. nail)
Monthly rainfall (mm)
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
P5-P95 WL

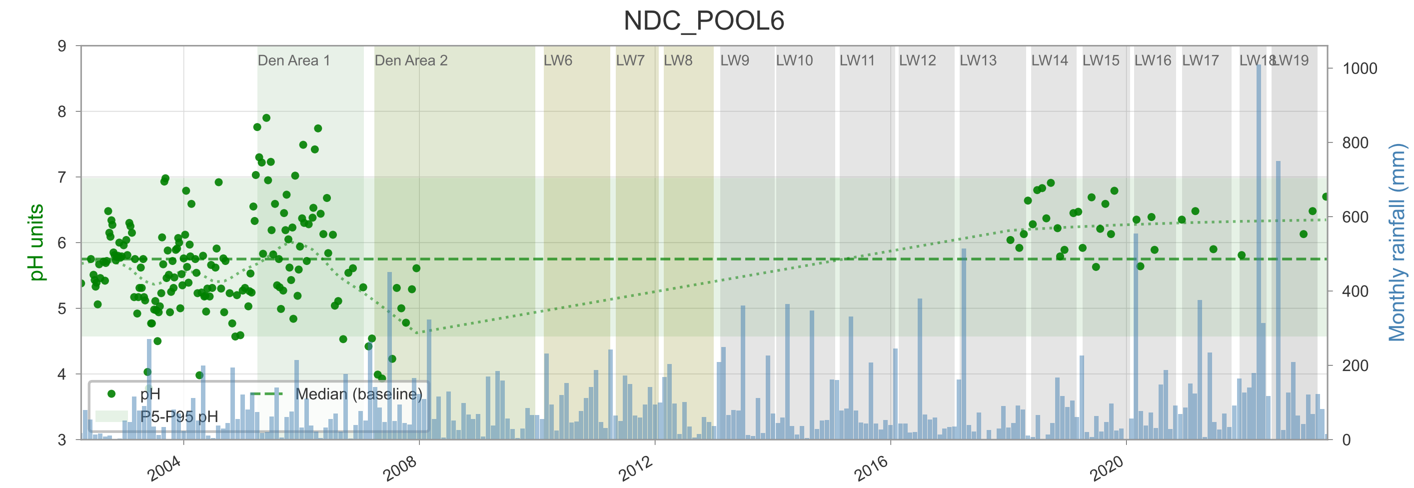

NDC_POOL25
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

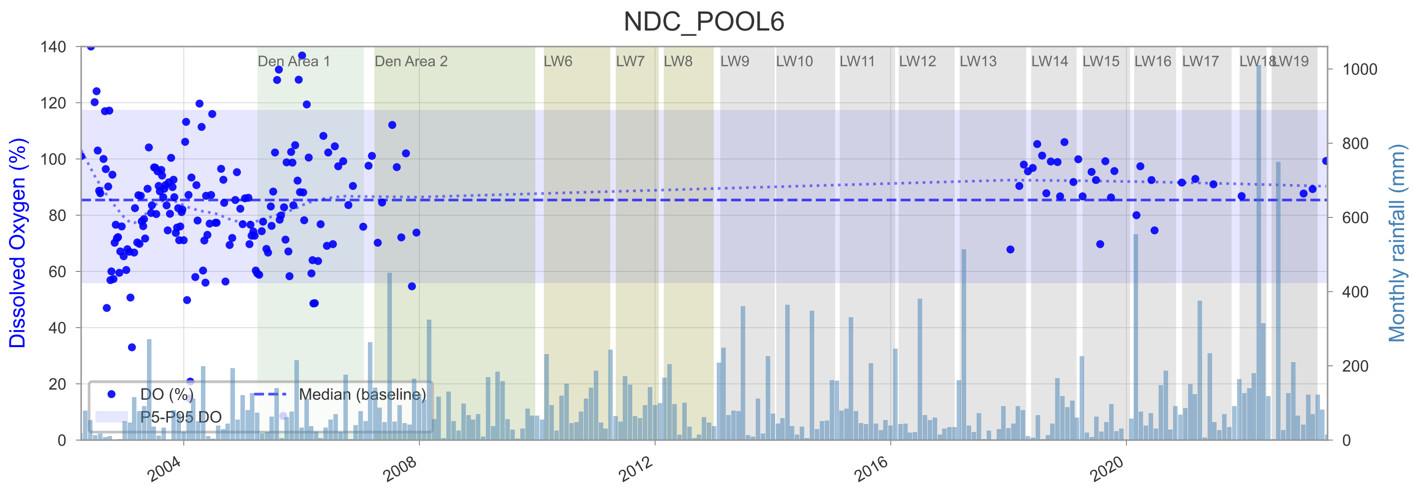

NDC_POOL25
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)

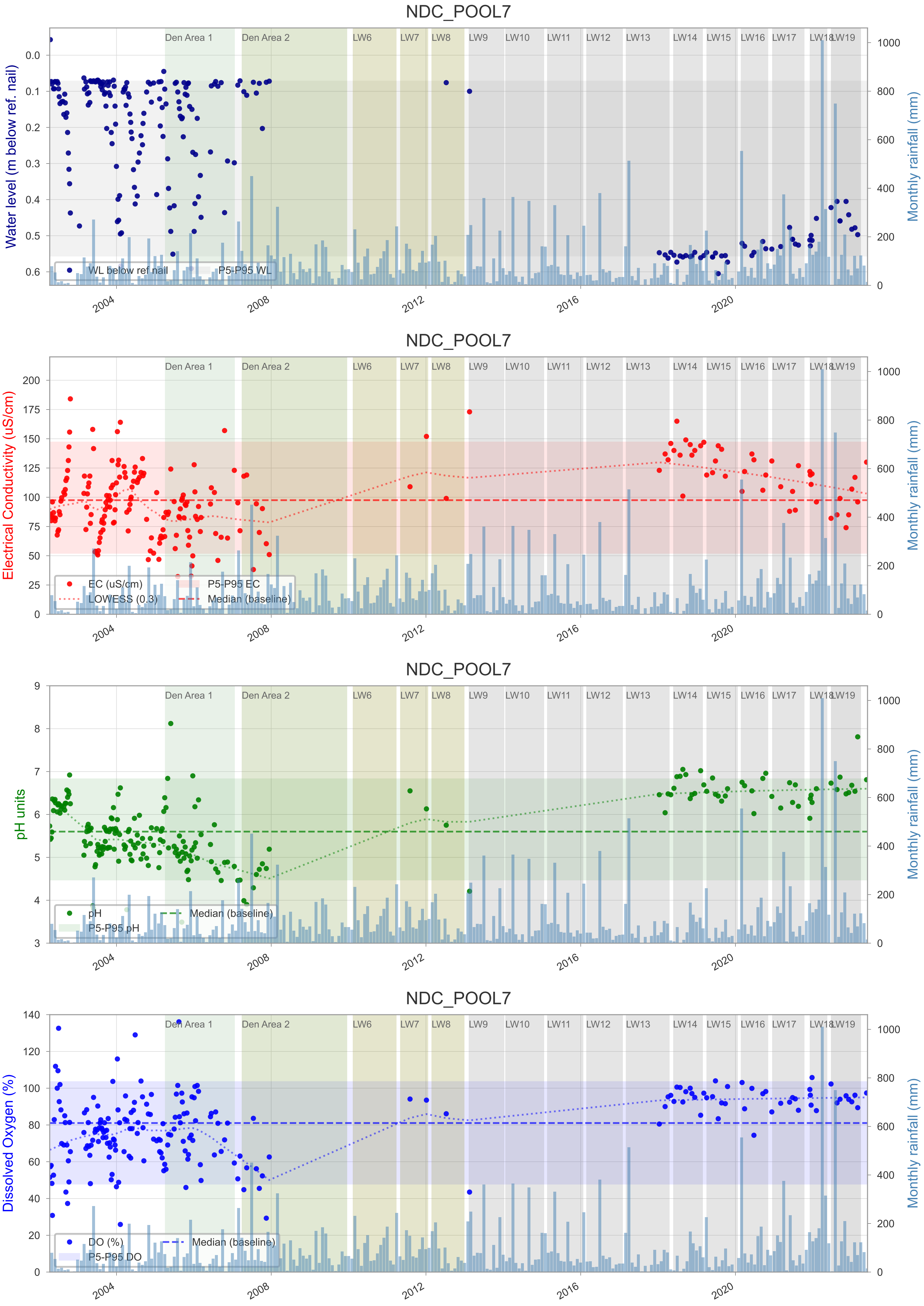

NDC_POOL25
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)


NDC_POOL6
Water level (m below ref. nail)
Monthly rainfall (mm)
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
Too high to measure
P5-P95 WL
2004
2008
2012
2016
2020

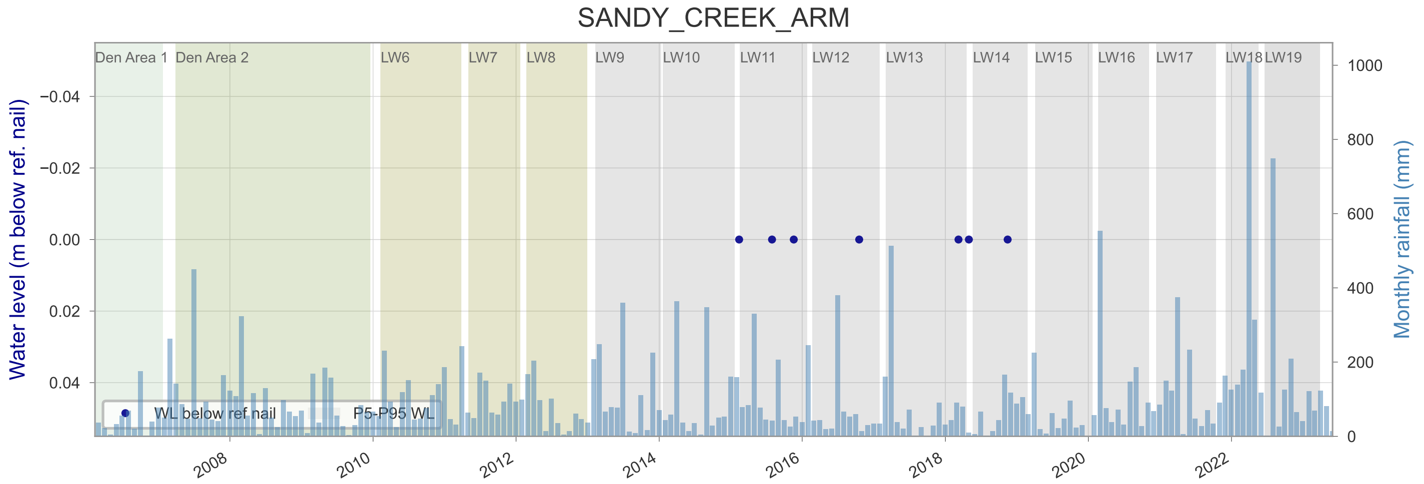

NDC_POOL6
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)
2004
2008
2012
2016
2020

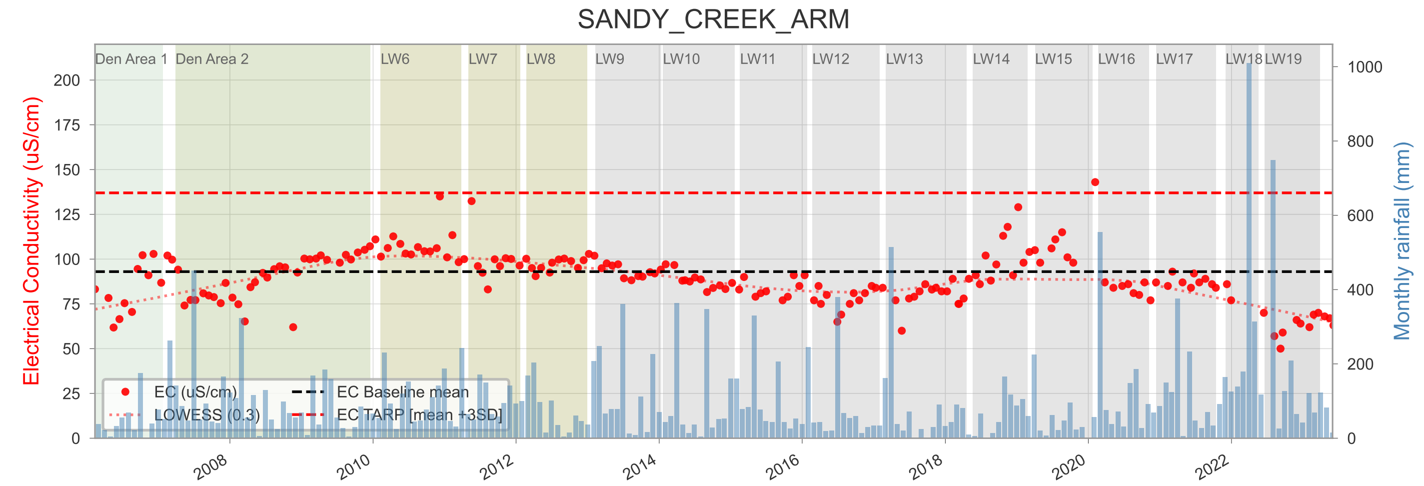

NDC_POOL6
pH units
Monthly rainfall (mm)
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH
P5-P95 pH
Median (baseline)
2004
2008
2012
2016
2020

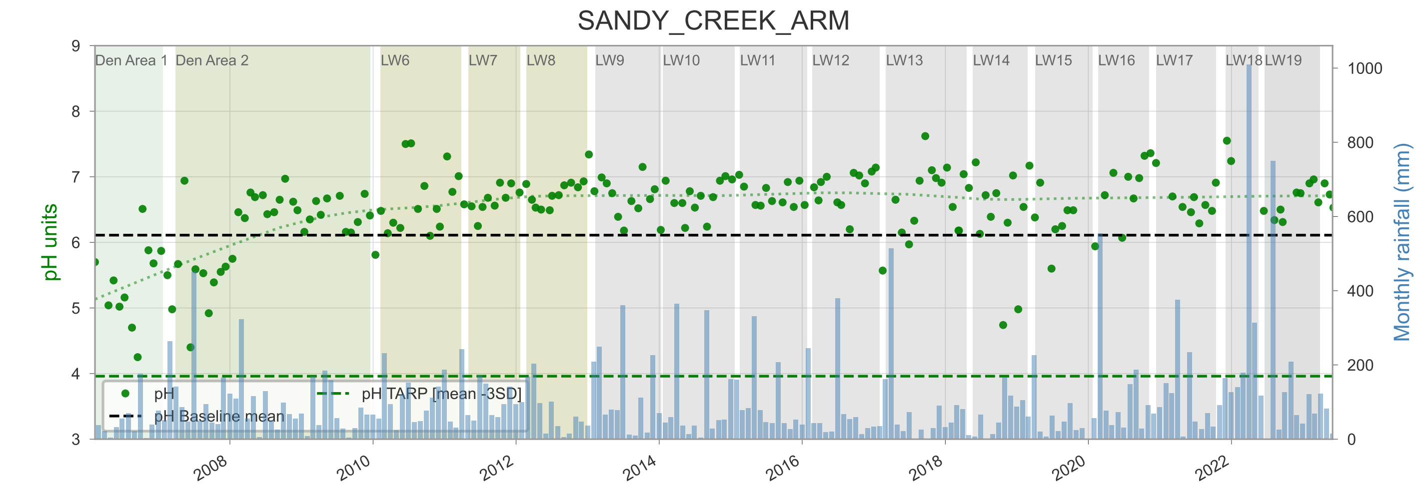

NDC_POOL6
Dissolved Oxygen (%)
Monthly rainfall (mm)
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
DO (%)
P5-P95 DO
Median (baseline)
2004
2008
2012
2016
2020

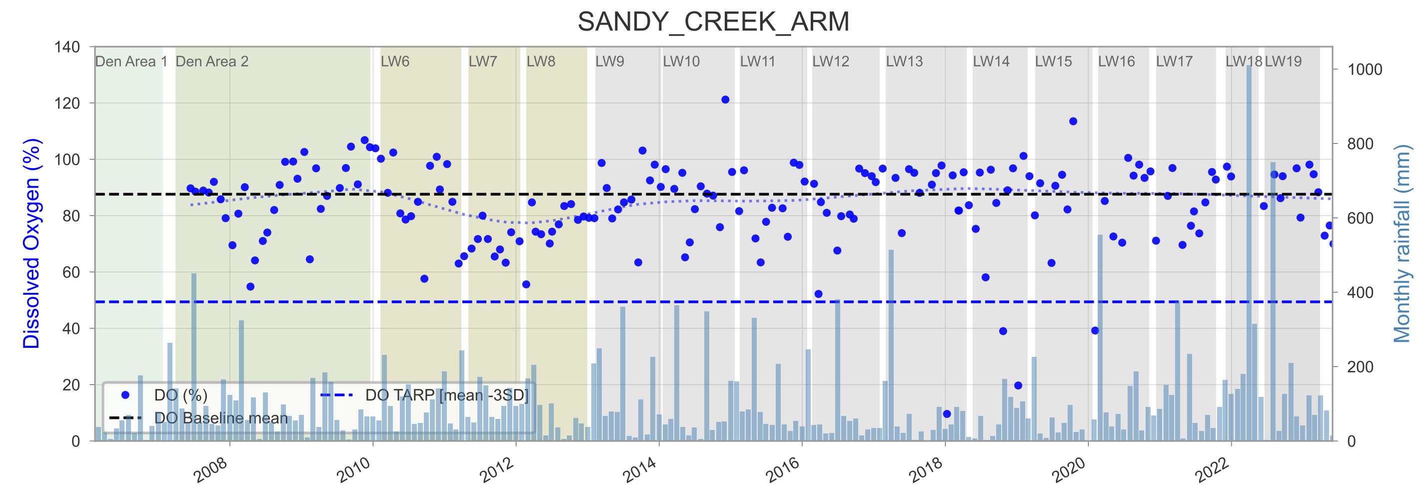


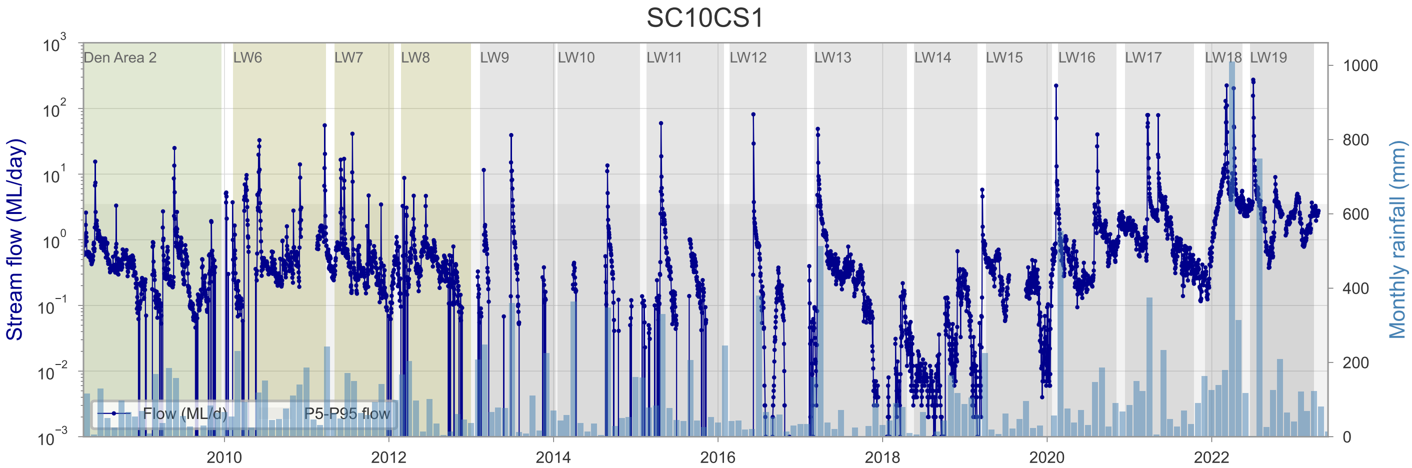
NDC_POOL7
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
P5-P95 WL
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
2004
2008
2012
2016
2020
NDC_POOL7
Electrical Conductivity (uS/cm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)
NDC_POOL7
pH units
pH
P5-P95 pH
Median (baseline)
NDC_POOL7
Dissolved Oxygen (%)
DO (%)
P5-P95 DO
Median (baseline)

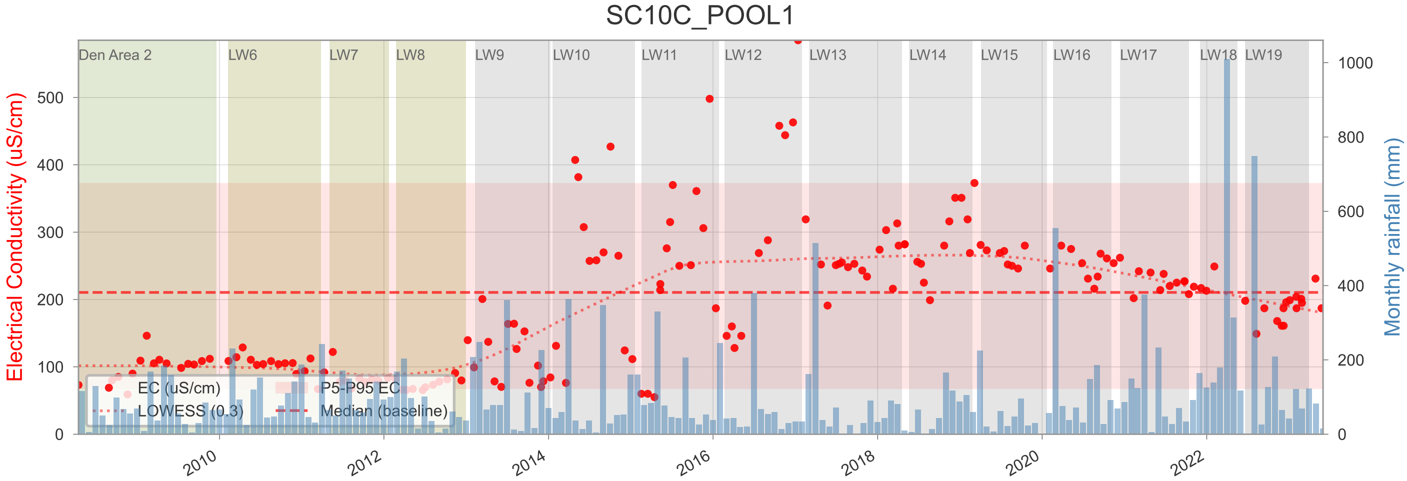

SANDY_CREEK_ARM
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
P5-P95 WL

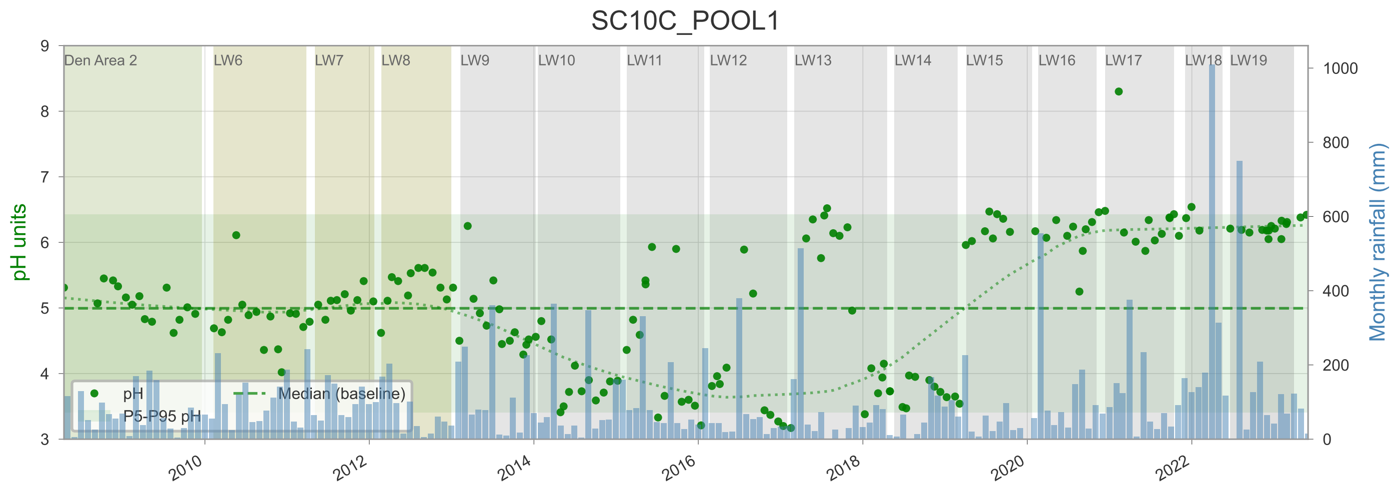

SANDY_CREEK_ARM
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
EC Baseline mean
EC TARP [mean +3SD]

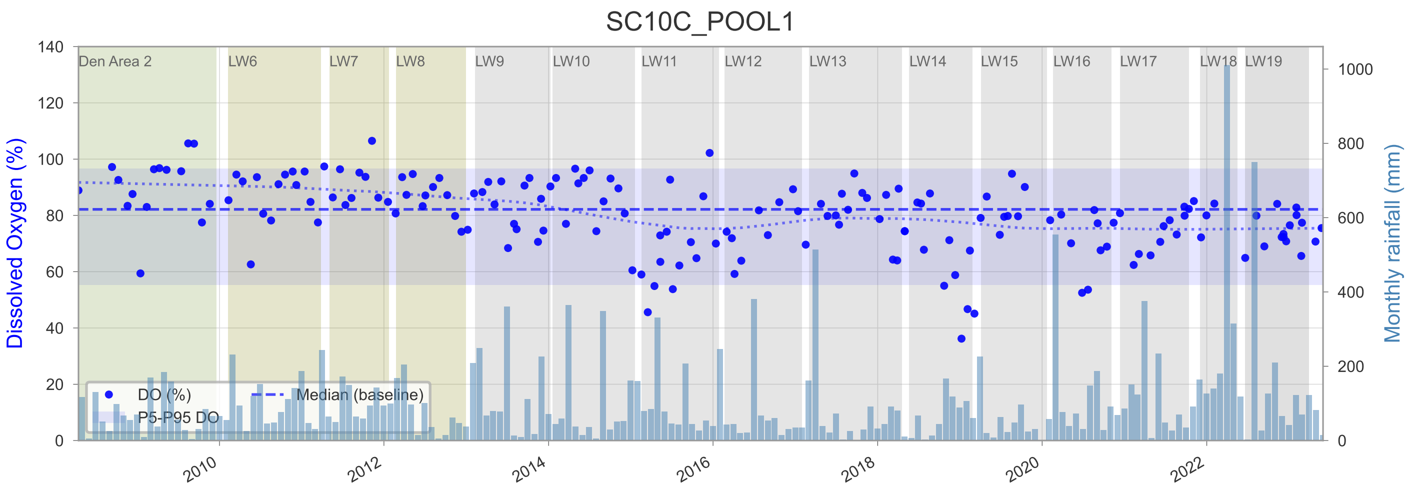

SANDY_CREEK_ARM
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH units
Monthly rainfall (mm)
pH
pH Baseline mean
pH TARP [mean -3SD]

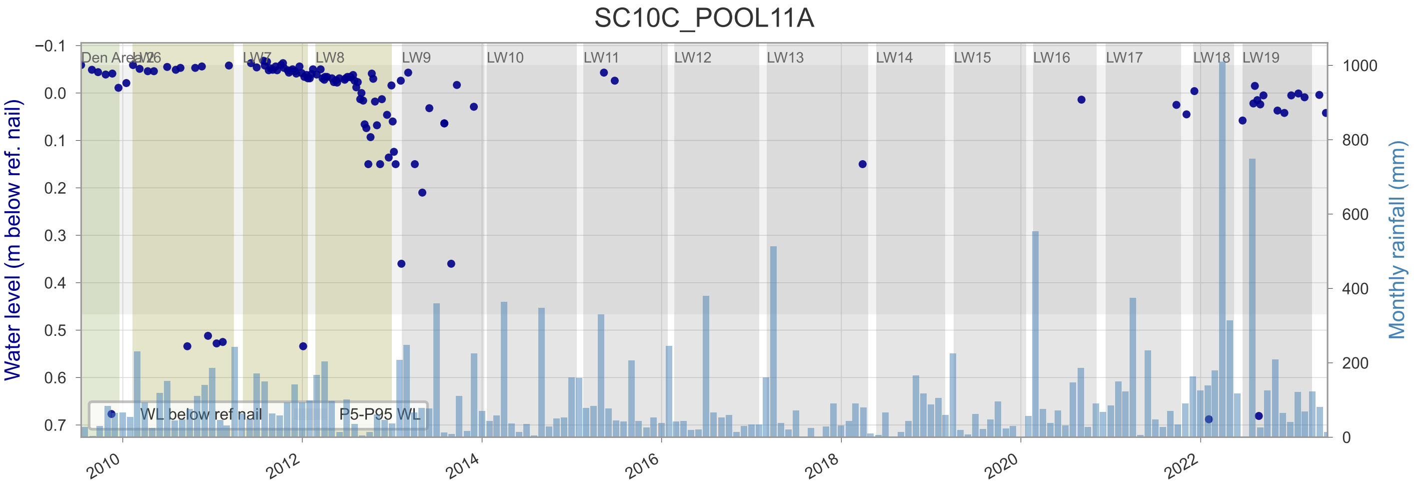

SANDY_CREEK_ARM
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
DO Baseline mean
DO TARP [mean -3SD]

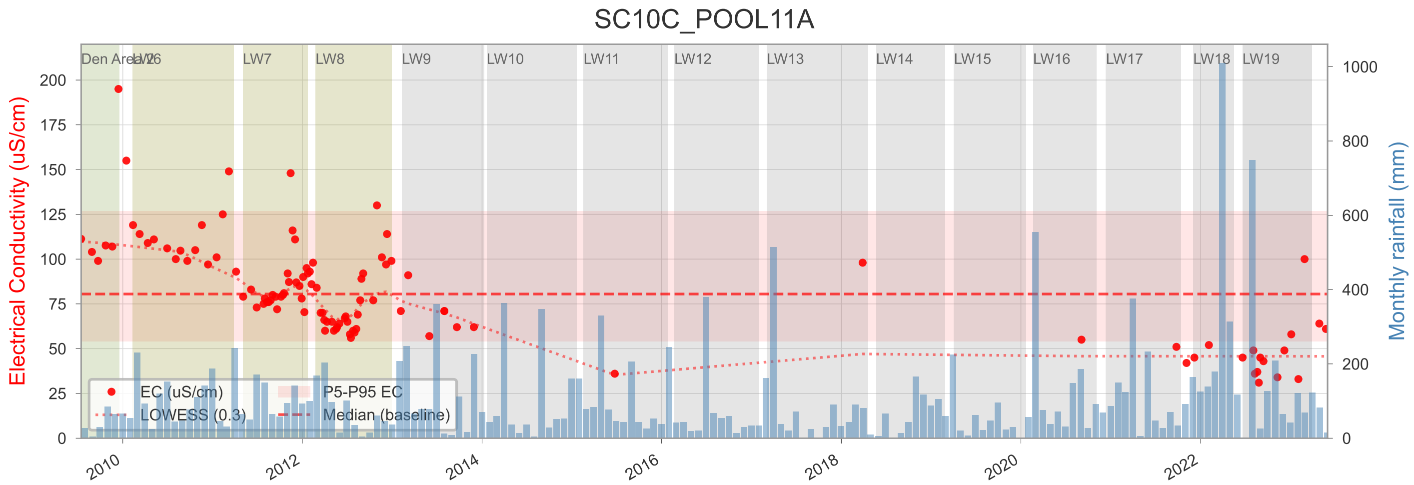

SC10CS1
Stream flow (ML/day)
Monthly rainfall (mm)
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Flow (ML/d)
P5-P95 flow
2010
2012
2014
2016
2018
2020
2022

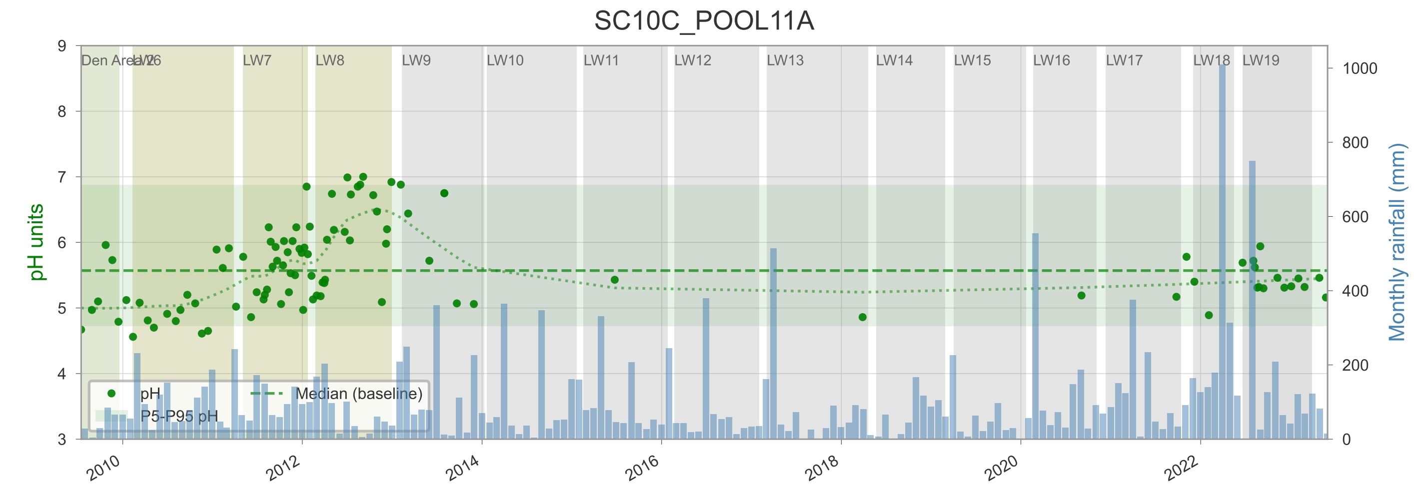

SC10C_POOL1
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)
2010
2012
2014
2016
2018
2020
2022

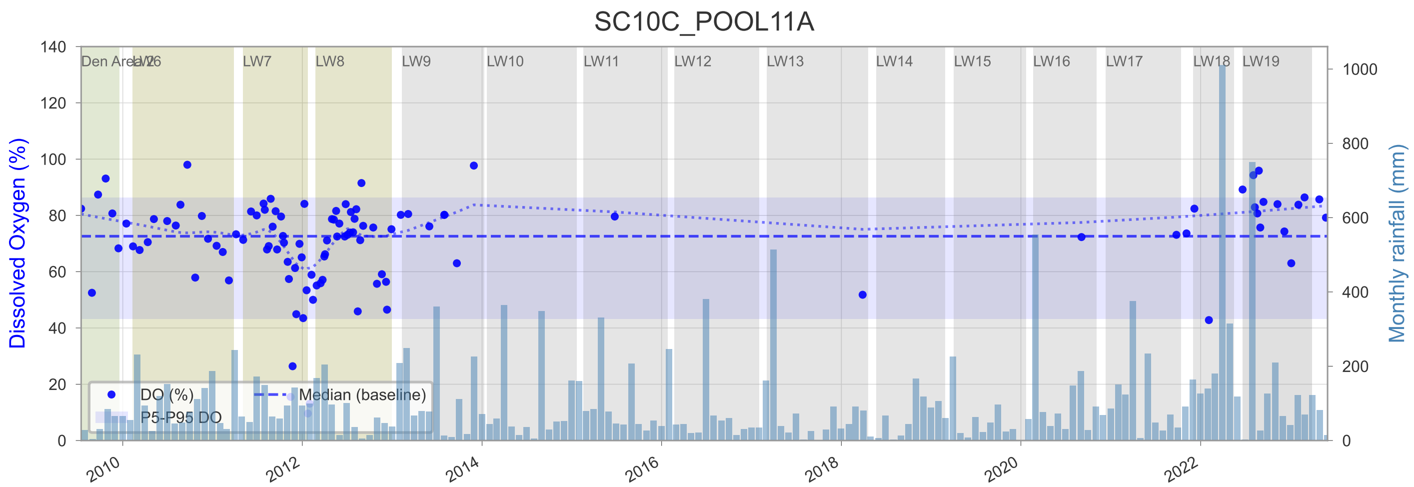

SC10C_POOL1
pH units
Monthly rainfall (mm)
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH
P5-P95 pH
Median (baseline)
2010
2012
2014
2016
2018
2020
2022

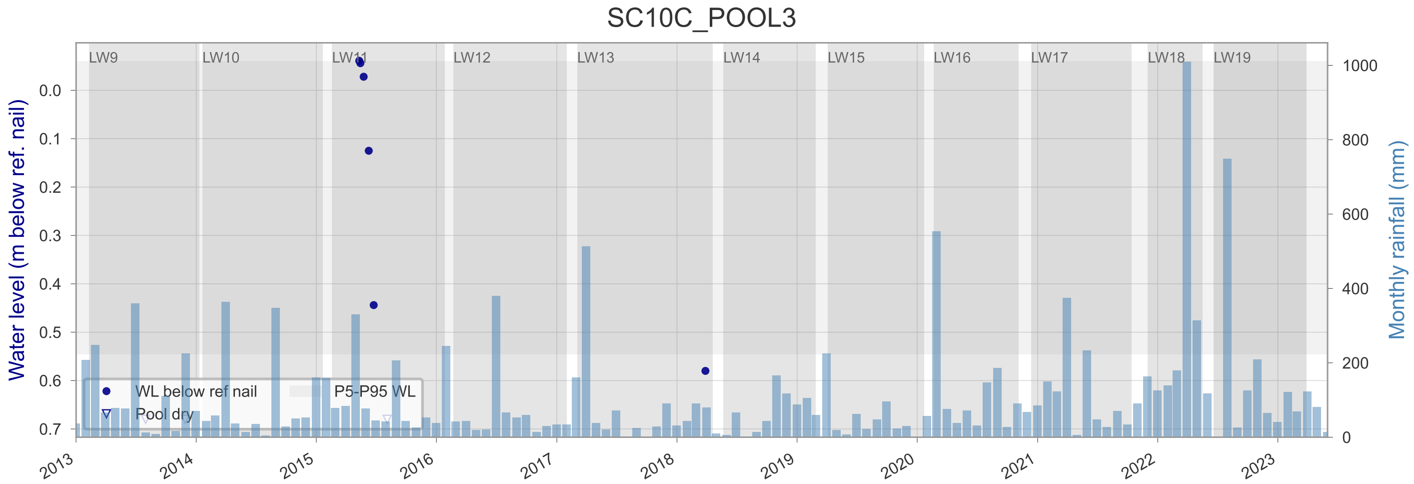

SC10C_POOL1
Dissolved Oxygen (%)
Monthly rainfall (mm)
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
DO (%)
P5-P95 DO
Median (baseline)
2010
2012
2014
2016
2018
2020
2022

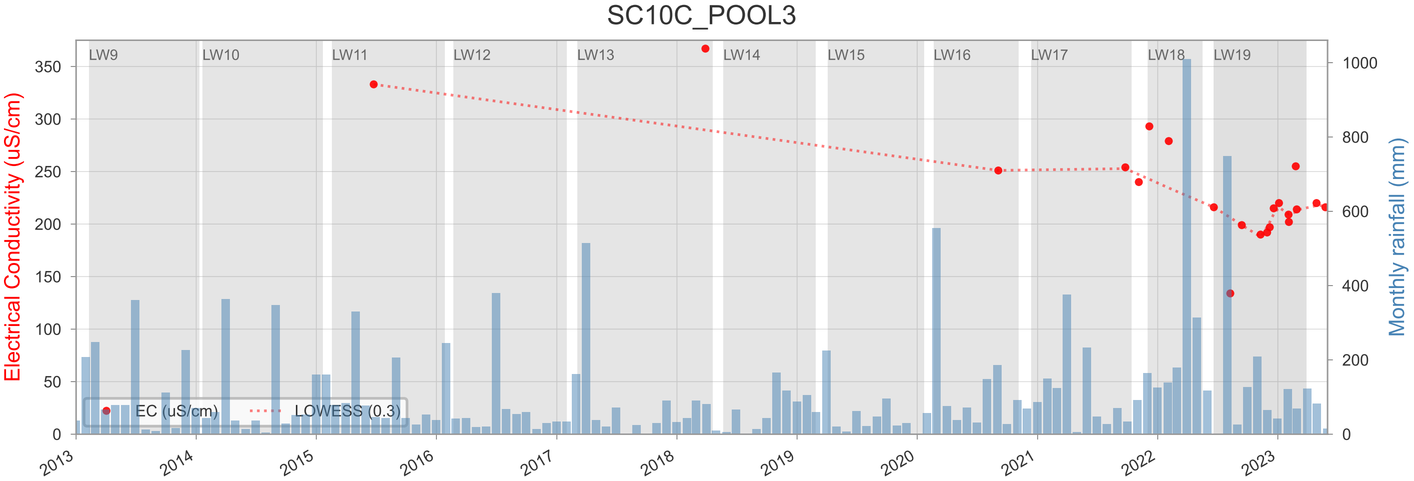

SC10C_POOL11A
Water level (m below ref. nail)
Monthly rainfall (mm)
Den Area LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
P5-P95 WL
−0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0
200
400
600
800
1000
2010
2012
2014
2016
2018
2020
2022

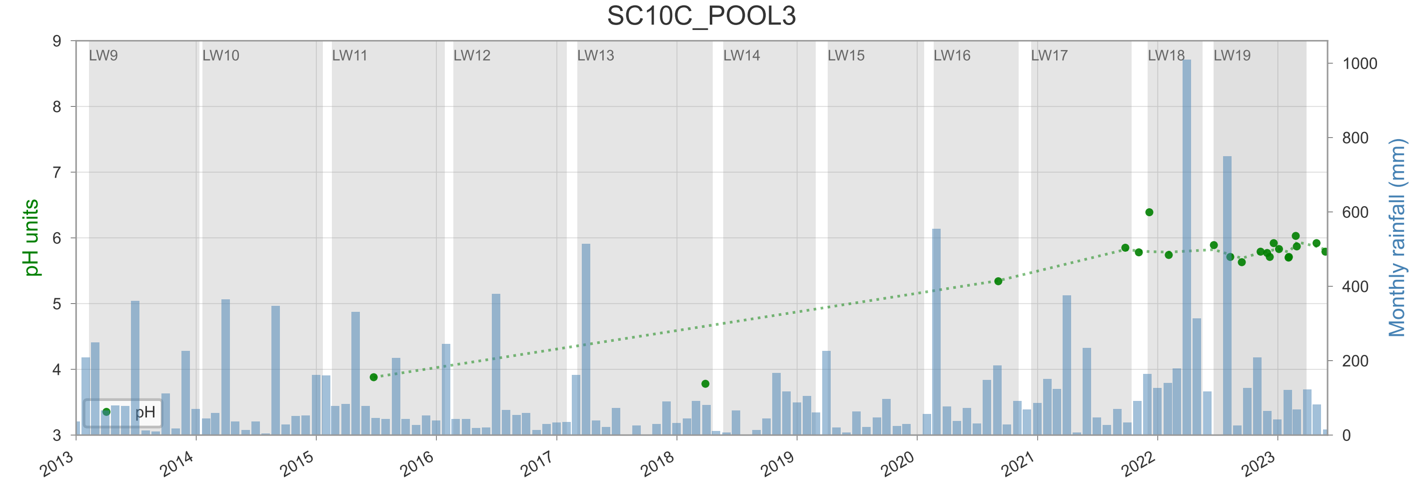

SC10C_POOL11A
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
Den Area LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)
0
25
50
75
100
125
150
175
200
0
200
400
600
800
1000
2010
2012
2014
2016
2018
2020
2022

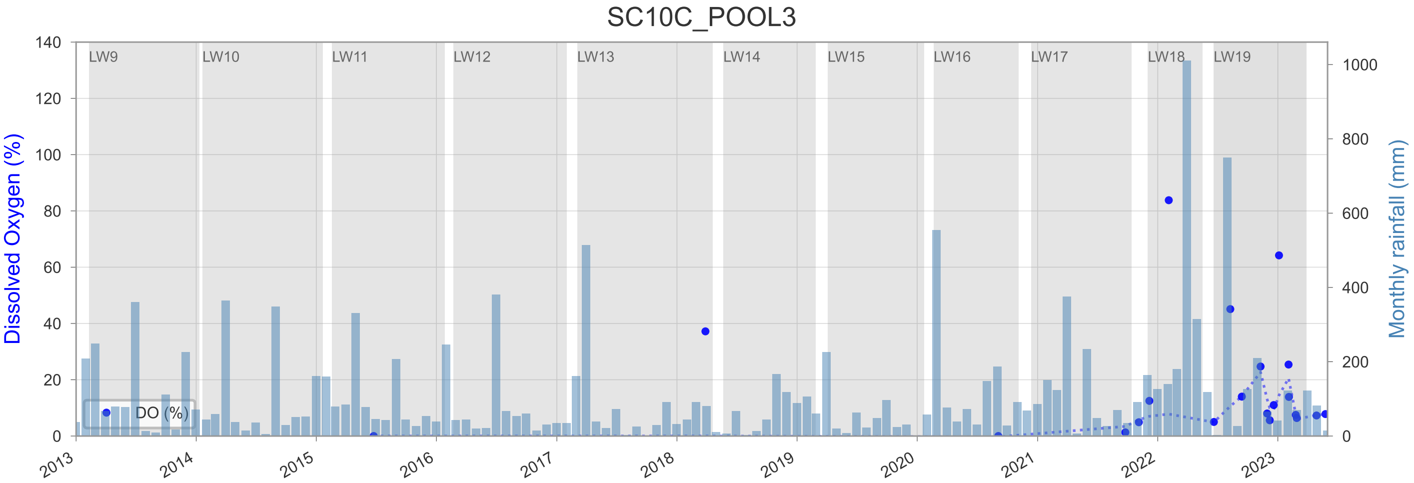

SC10C_POOL11A
pH units
Monthly rainfall (mm)
Den Area LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH
P5-P95 pH
Median (baseline)
3
4
5
6
7
8
9
0
200
400
600
800
1000
2010
2012
2014
2016
2018
2020
2022

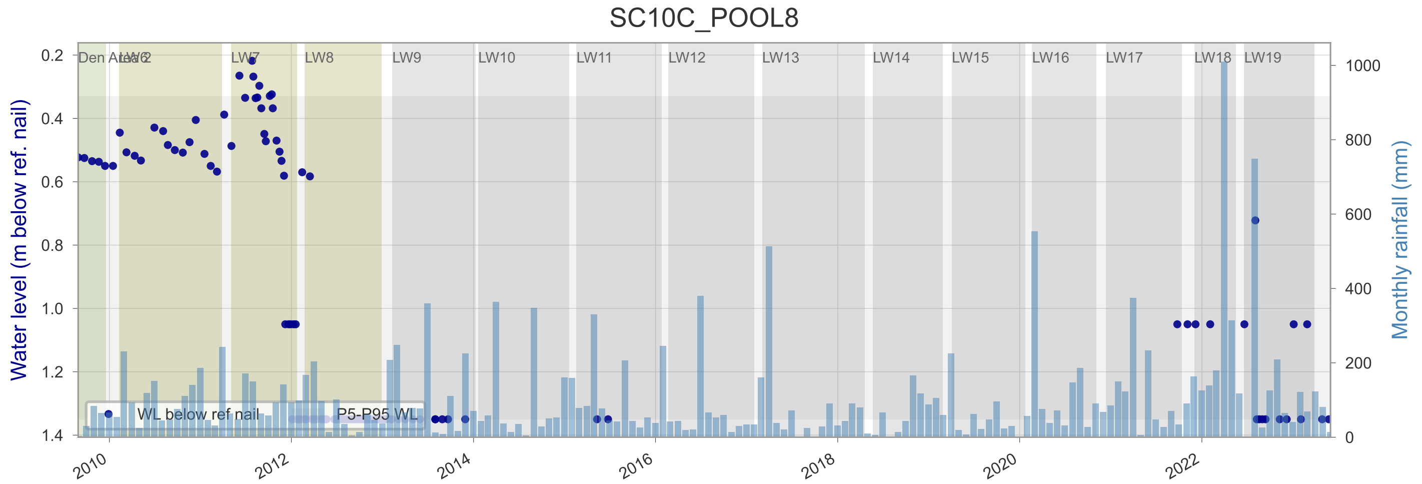

SC10C_POOL11A
Dissolved Oxygen (%)
Monthly rainfall (mm)
Den Area LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
DO (%)
P5-P95 DO
Median (baseline)
0
20
40
60
80
100
120
140
0
200
400
600
800
1000
2010
2012
2014
2016
2018
2020
2022

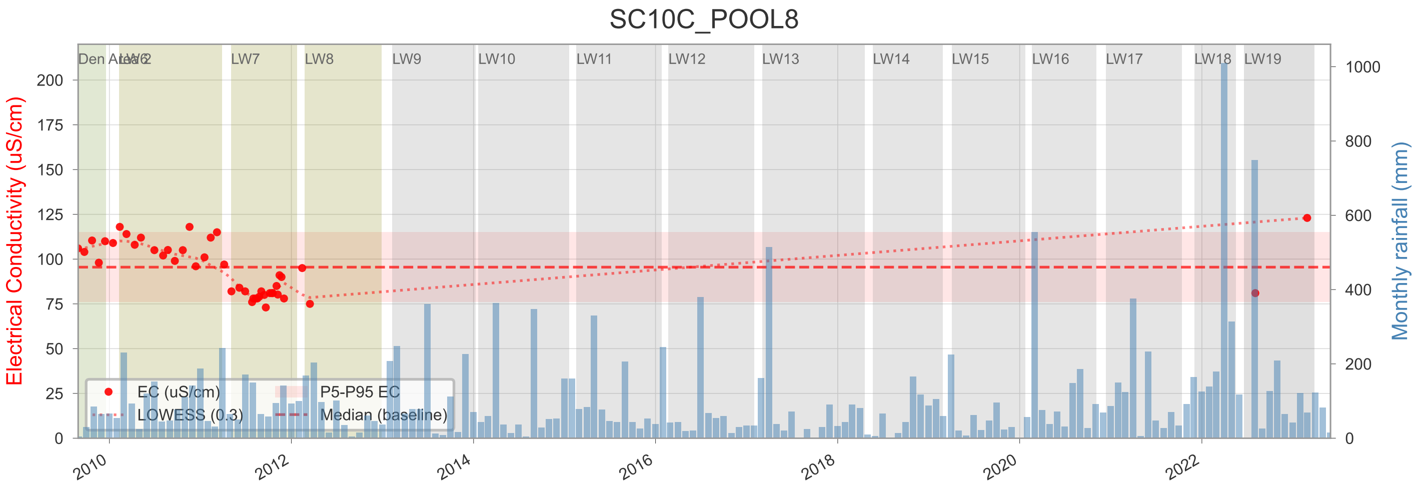

SC10C_POOL3
Water level (m below ref. nail)
Monthly rainfall (mm)
LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17 LW18 LW19
WL below ref nail
Pool dry
P5-P95 WL
2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023

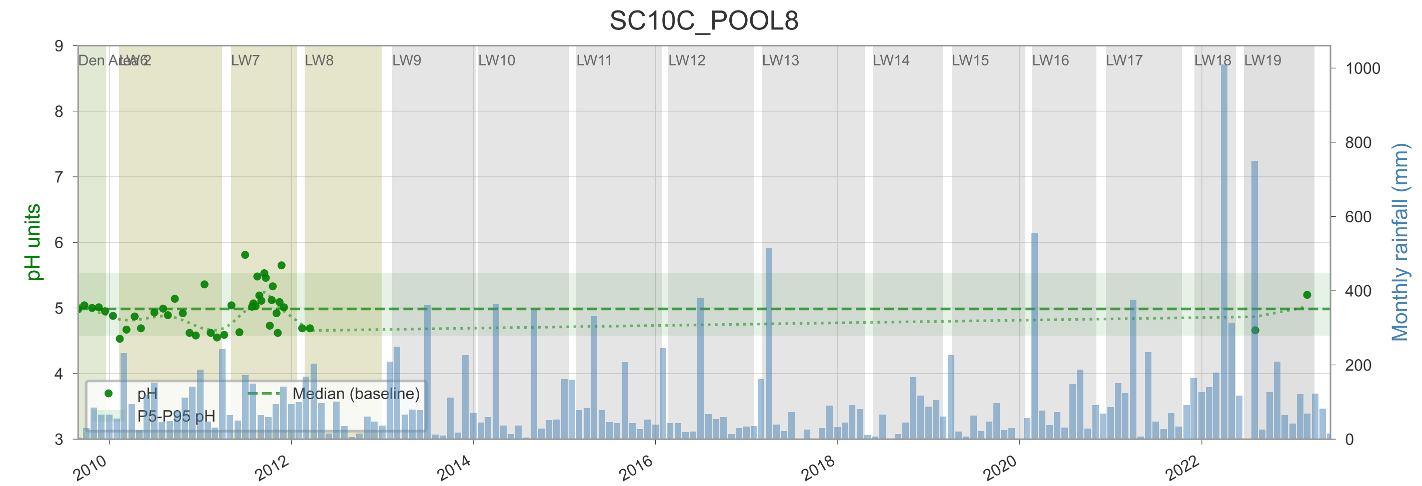

SC10C_POOL3
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17 LW18 LW19
EC (uS/cm)
LOWESS (0.3)
2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023

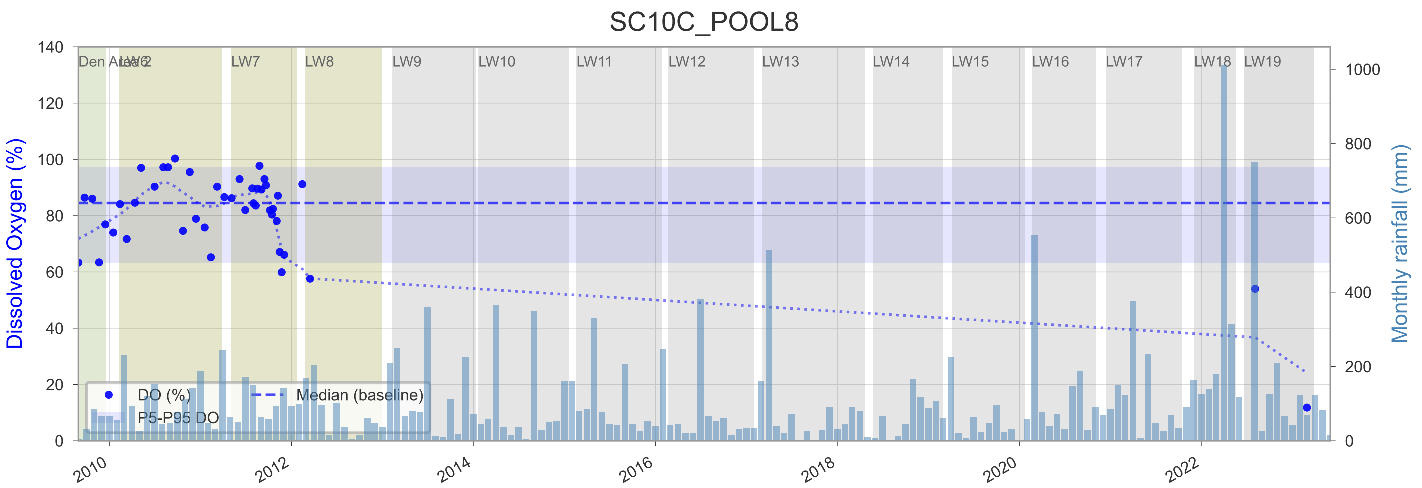

SC10C_POOL3
pH units
Monthly rainfall (mm)
LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17 LW18 LW19
pH
2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023

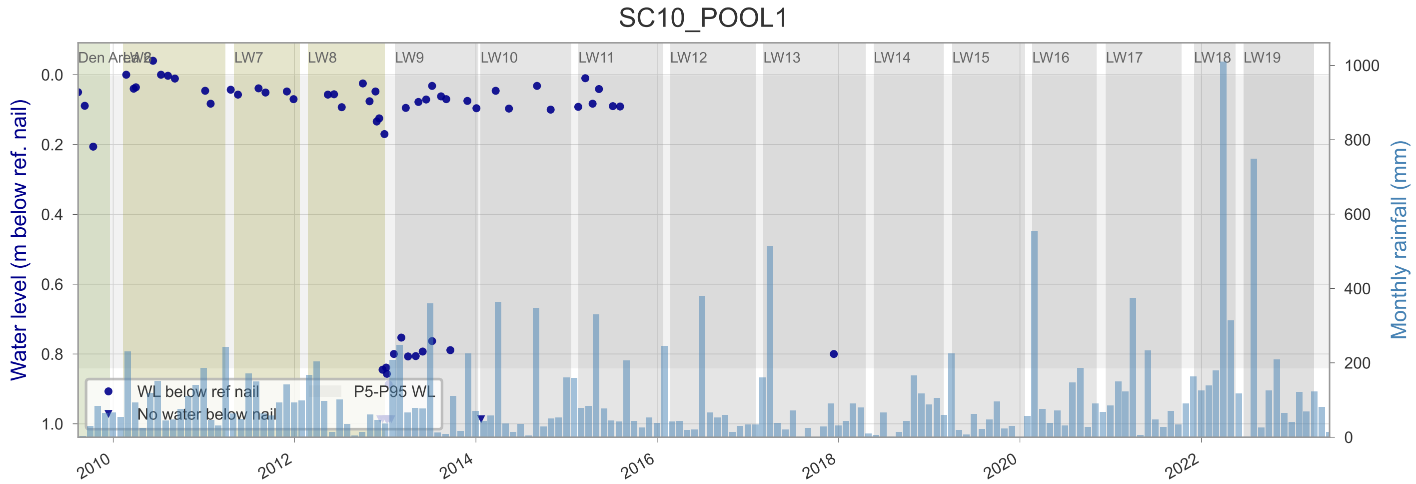

SC10C_POOL3
Dissolved Oxygen (%)
Monthly rainfall (mm)
LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17 LW18 LW19
DO (%)
2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023

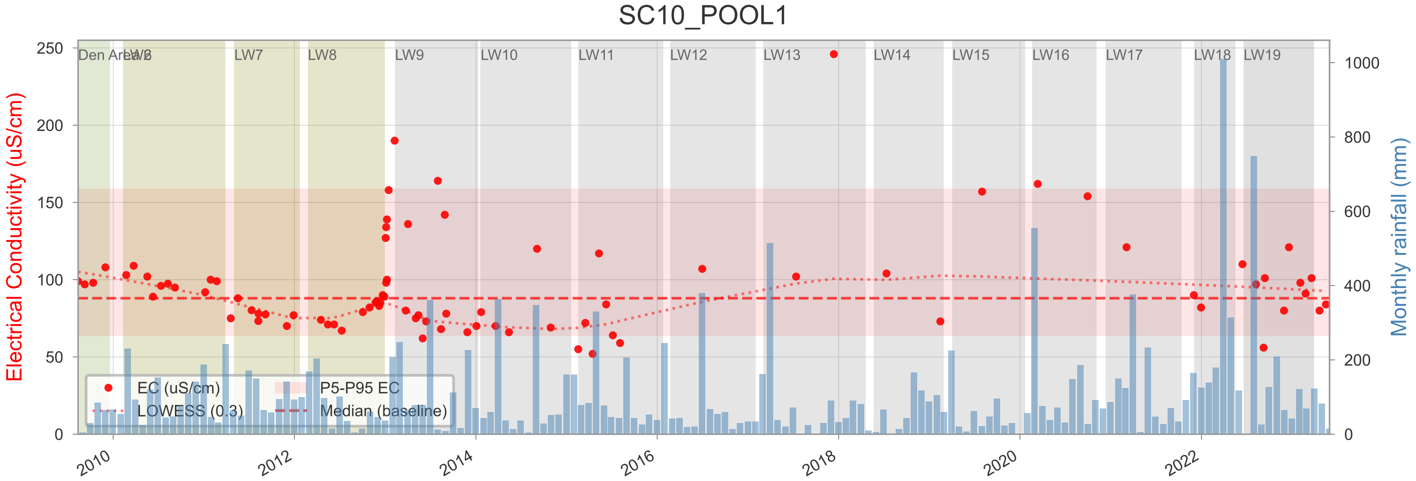

SC10C_POOL8
Water level (m below ref. nail)
Monthly rainfall (mm)
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
P5-P95 WL

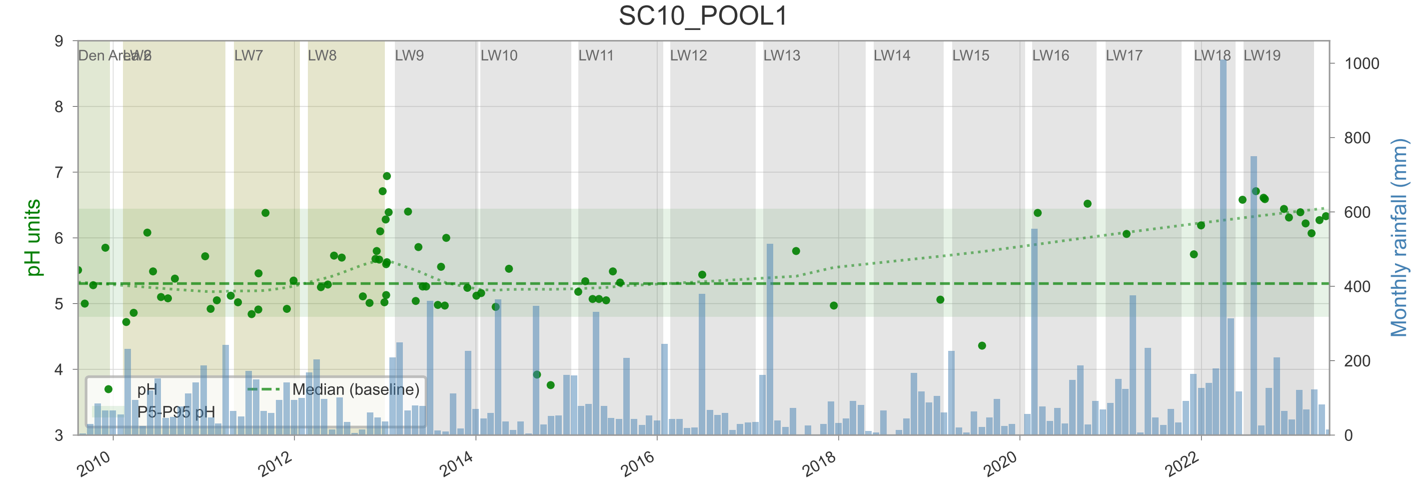

SC10C_POOL8
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

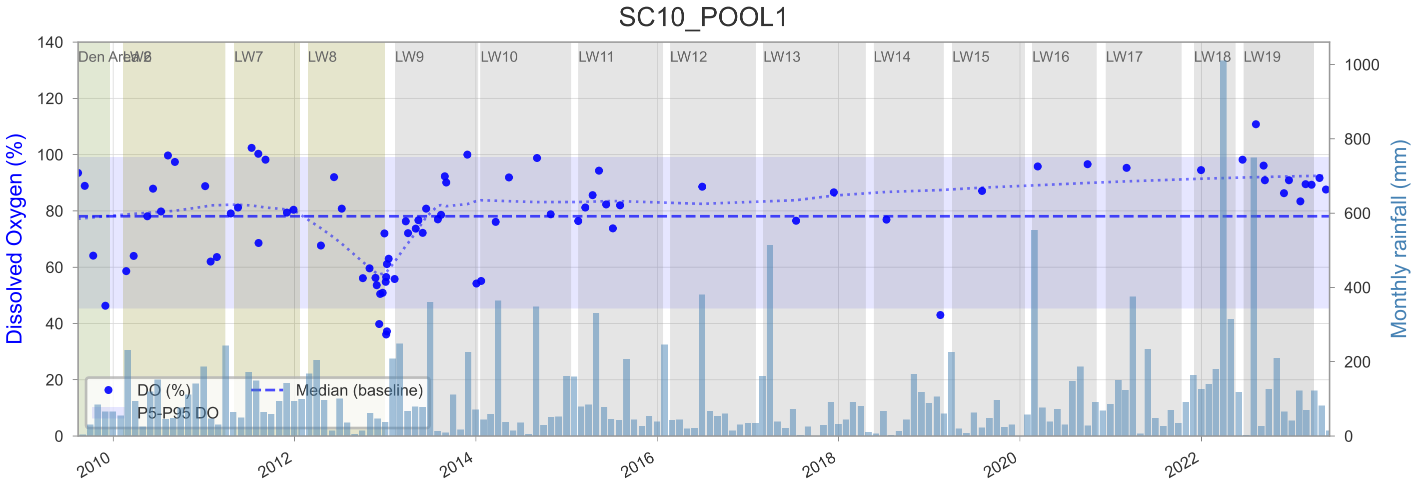

SC10C_POOL8
pH units
Monthly rainfall (mm)
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH
P5-P95 pH
Median (baseline)

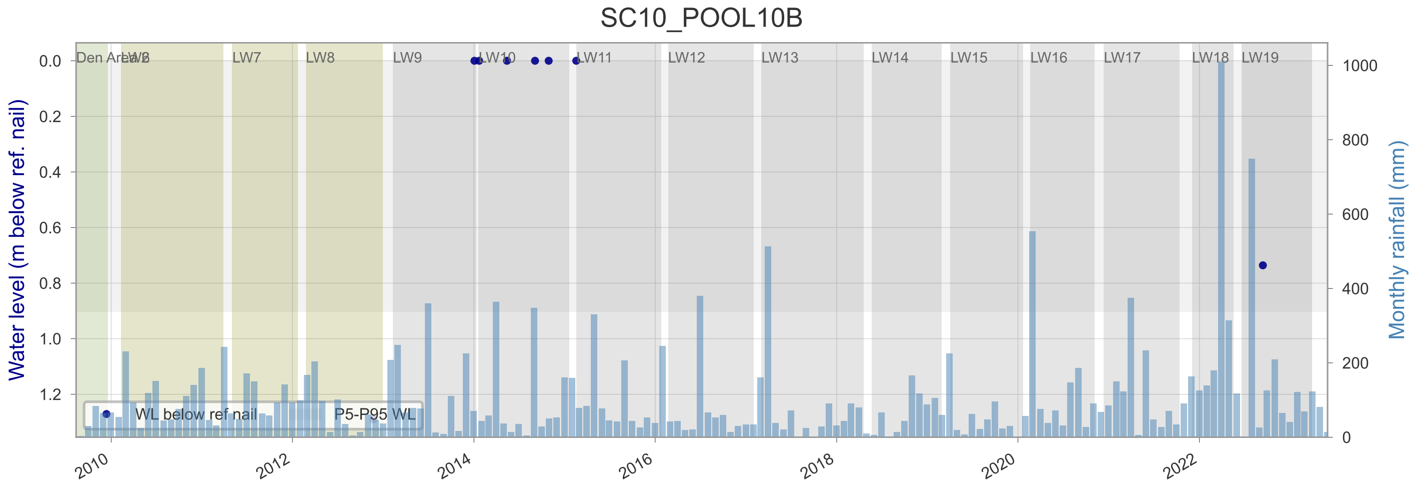

SC10C_POOL8
Dissolved Oxygen (%)
Monthly rainfall (mm)
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
DO (%)
P5-P95 DO
Median (baseline)

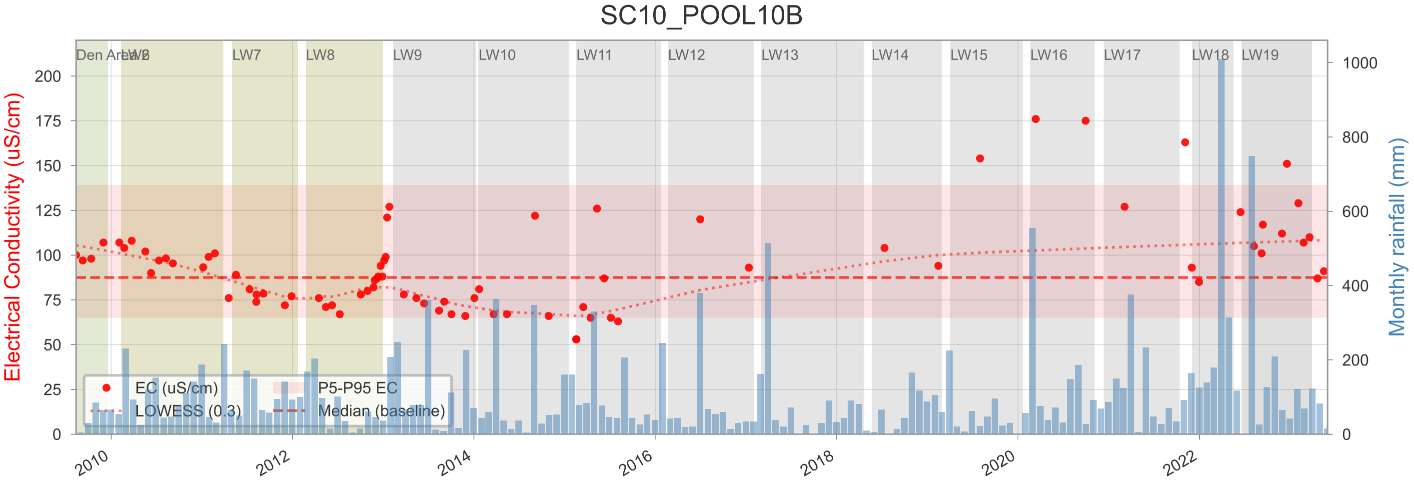

SC10_POOL1
Water level (m below ref. nail)
Monthly rainfall (mm)
Den Area
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
No water below nail
P5-P95 WL

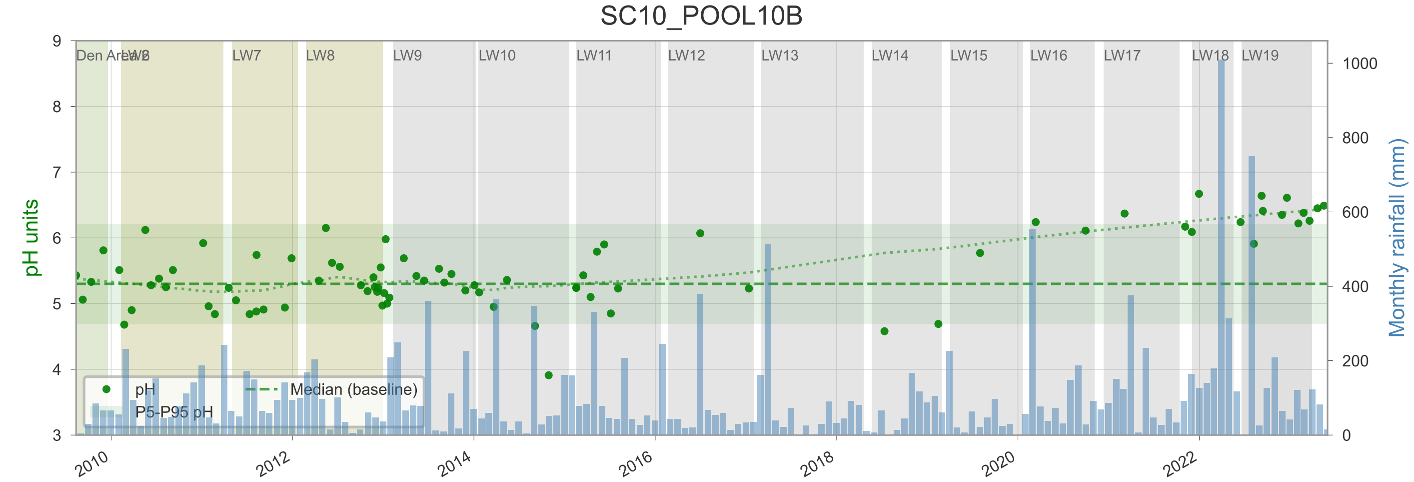

SC10_POOL1
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

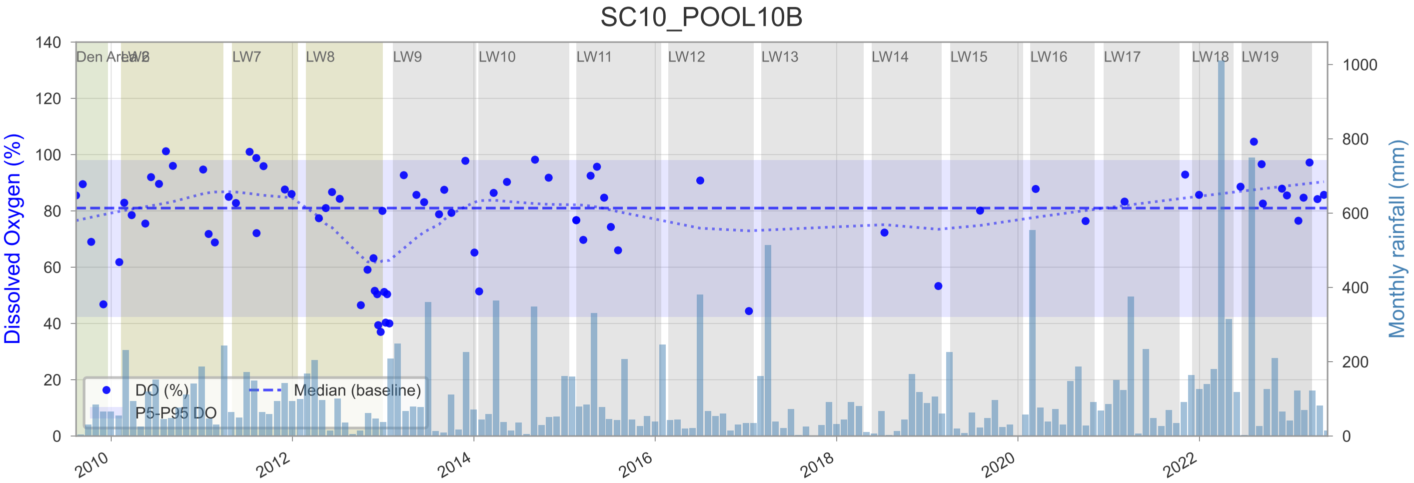

SC10_POOL1
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)

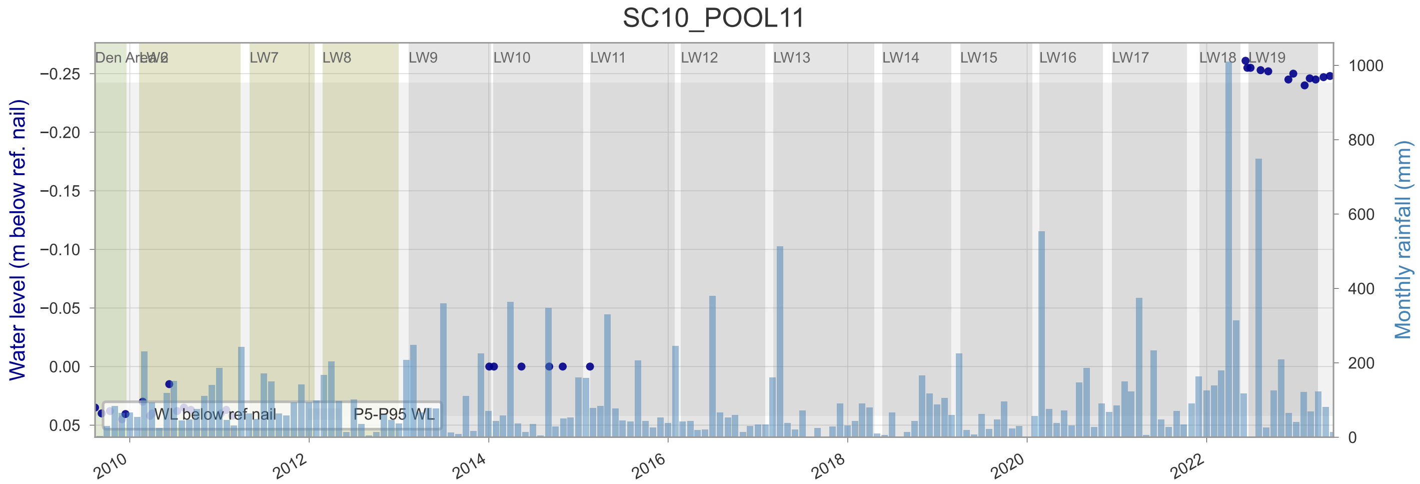

SC10_POOL1
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)

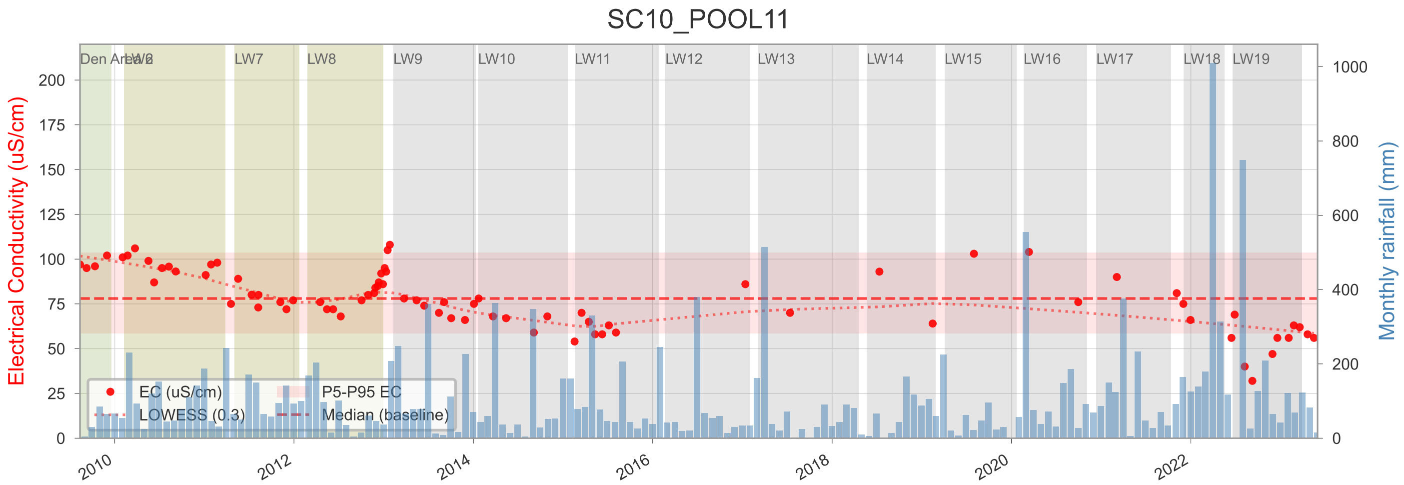

SC10_POOL10B
Water level (m below ref. nail)
Monthly rainfall (mm)
Den Area
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
P5-P95 WL

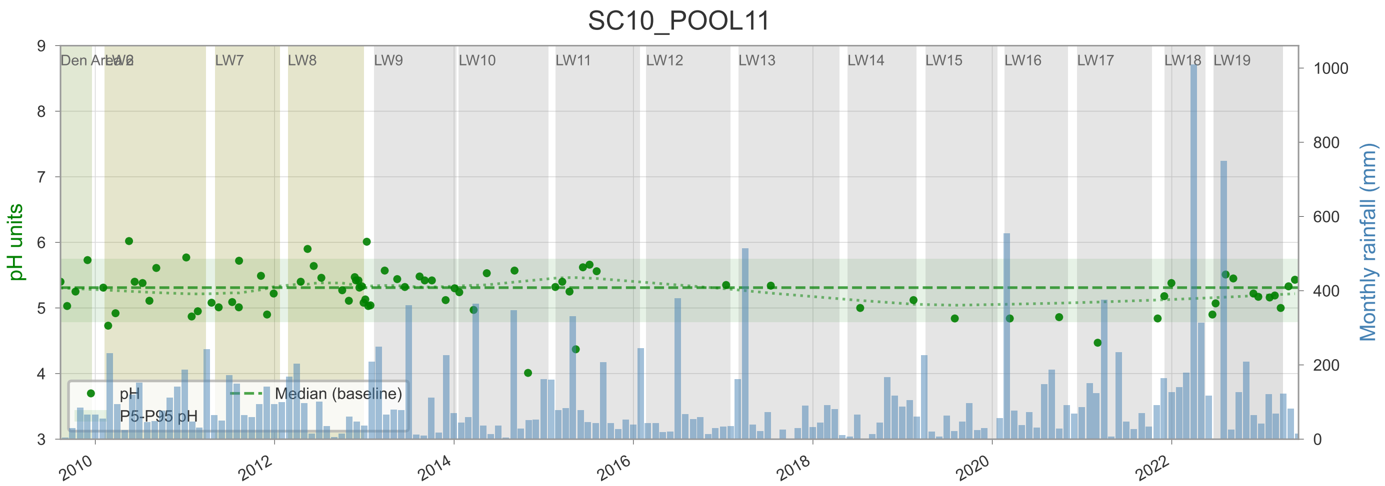

SC10_POOL10B
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

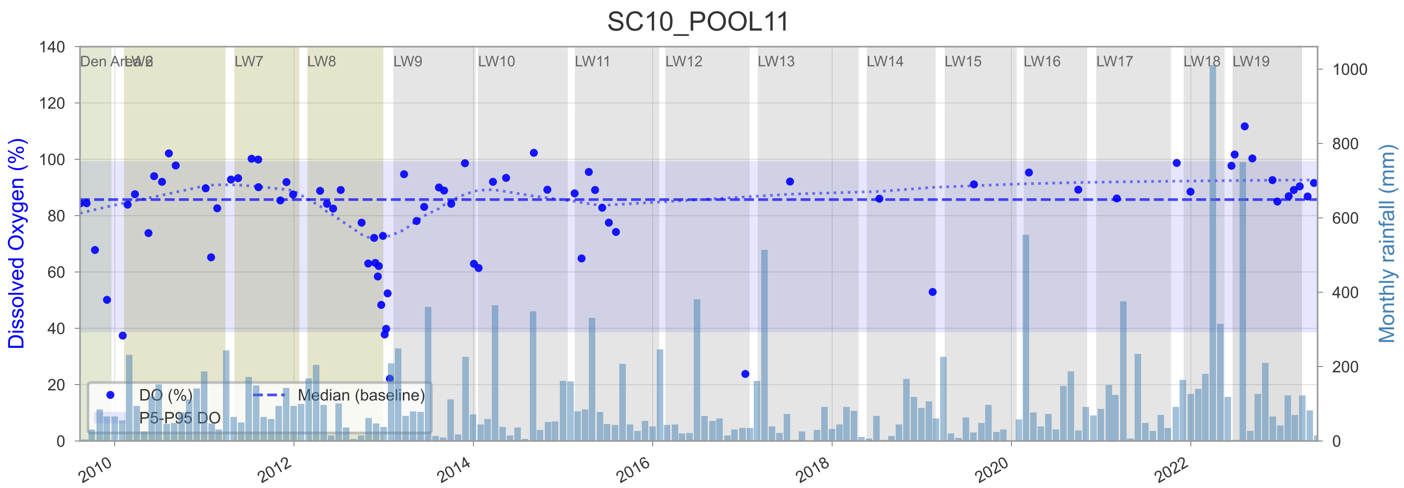

SC10_POOL10B
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)

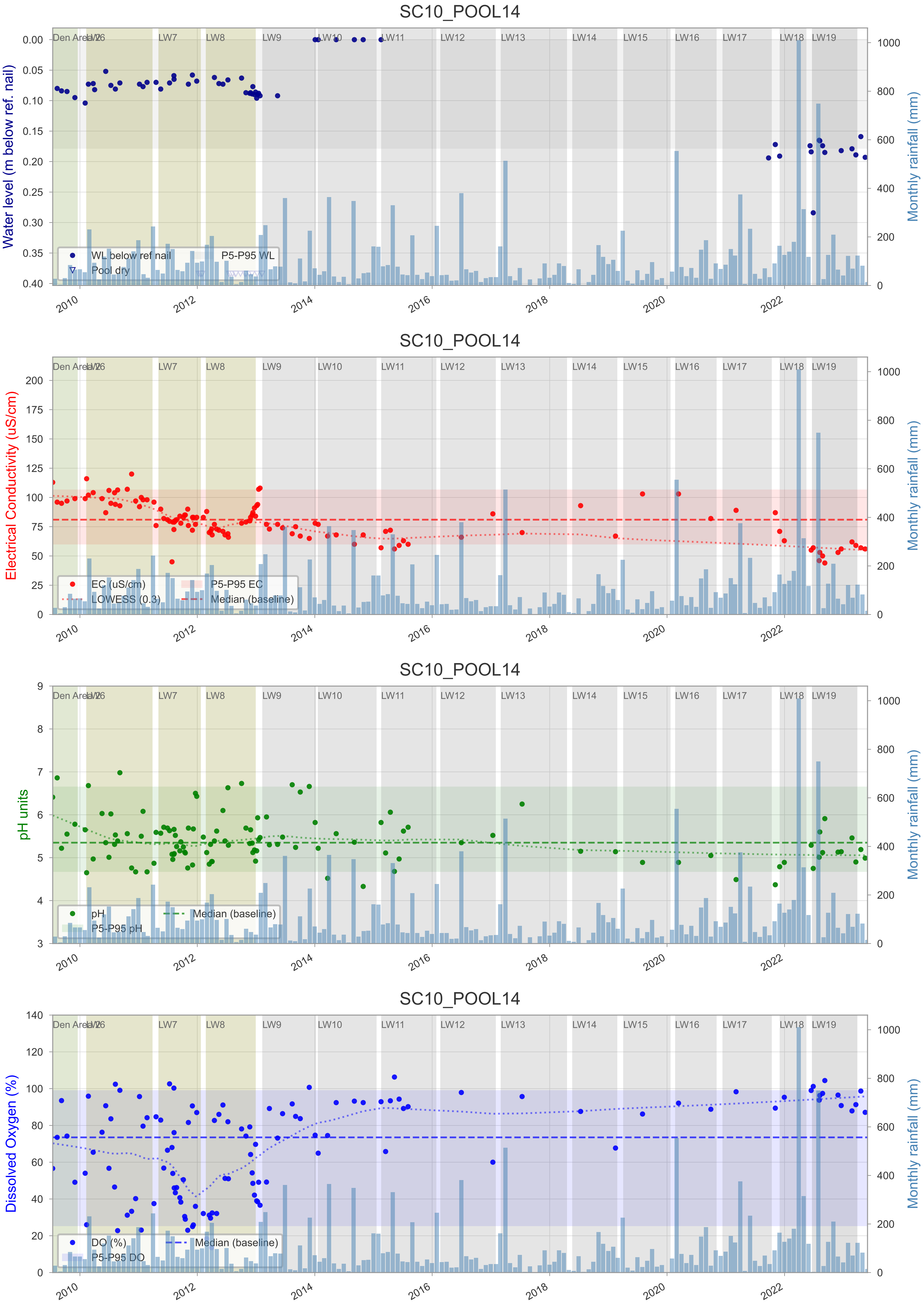

SC10_POOL10B
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)

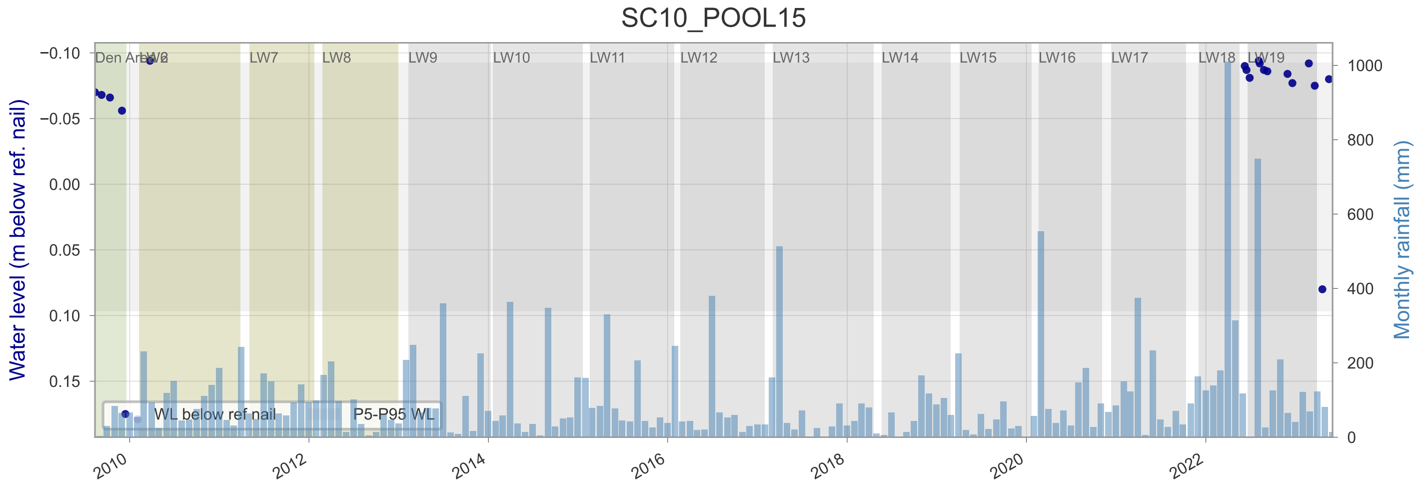

SC10_POOL11
Water level (m below ref. nail)
Monthly rainfall (mm)
Den Area
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
P5-P95 WL

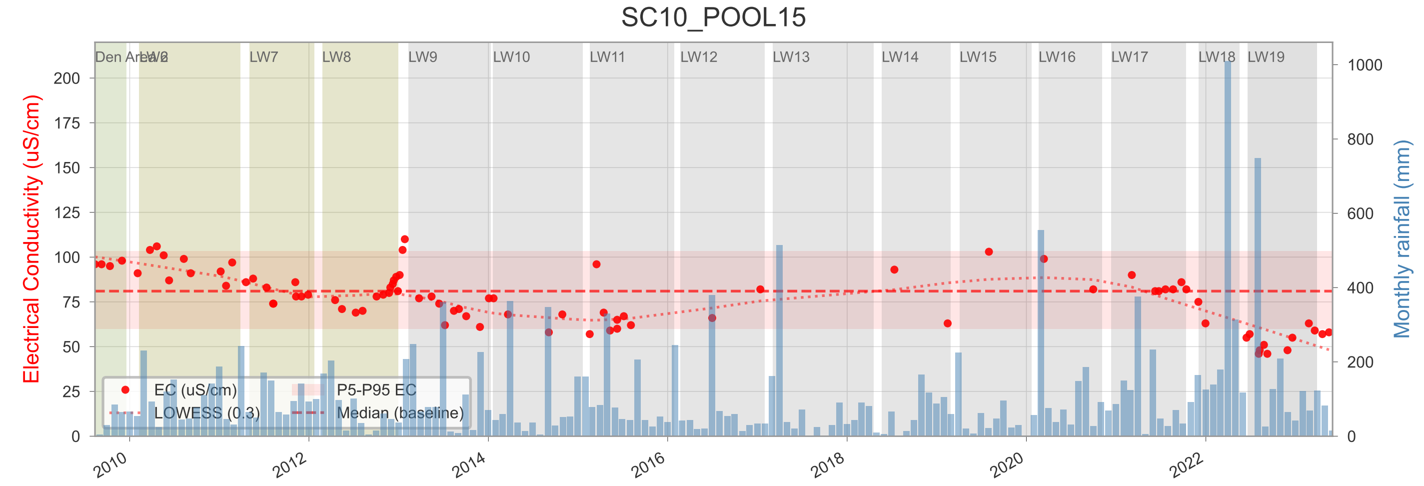

SC10_POOL11
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

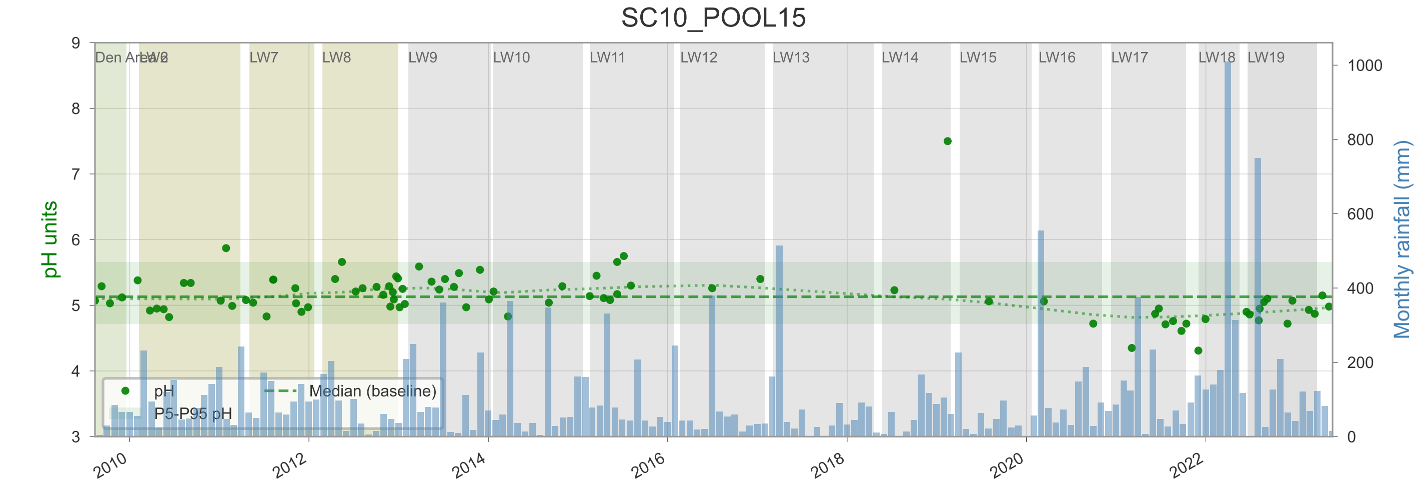

SC10_POOL11
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)

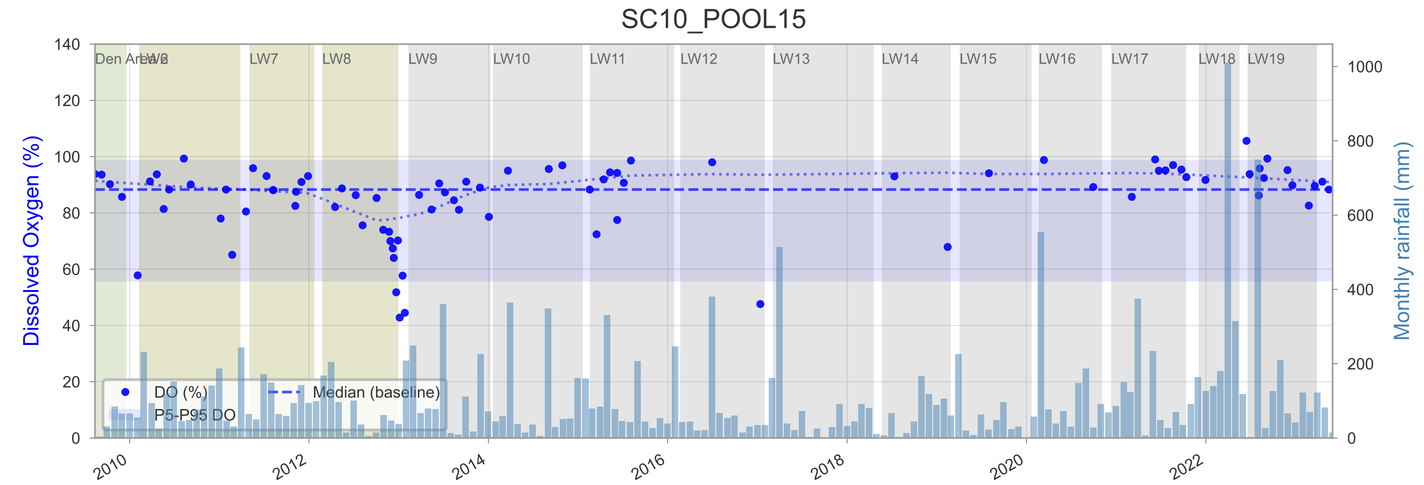

SC10_POOL11
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)

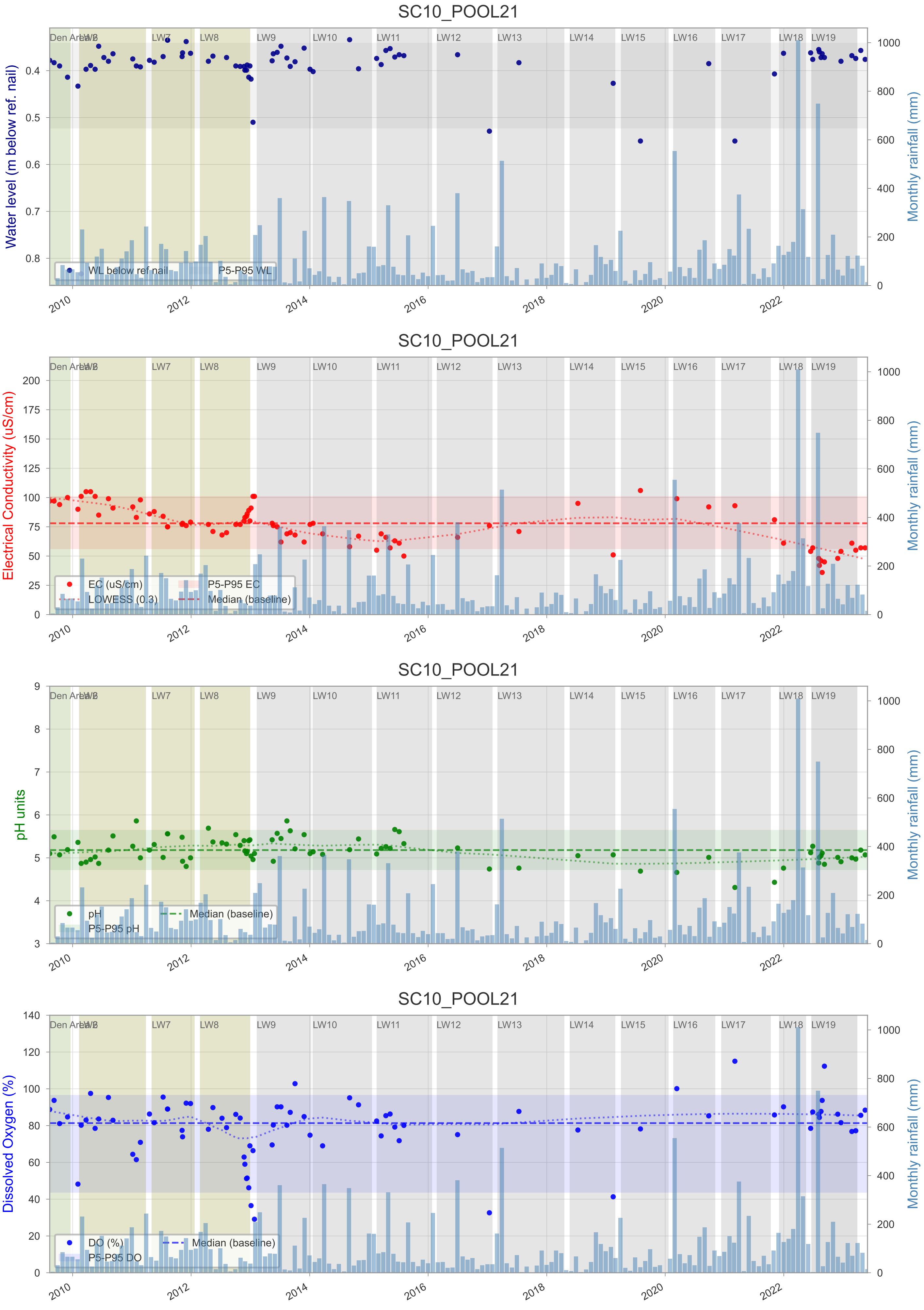

SC10_POOL14
Water level (m below ref. nail)
Monthly rainfall (mm)
Den Area LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
Pool dry
P5-P95 WL
SC10_POOL14
Electrical Conductivity (uS/cm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)
SC10_POOL14
pH units
pH
P5-P95 pH
Median (baseline)
SC10_POOL14
Dissolved Oxygen (%)
DO (%)
P5-P95 DO
Median (baseline)

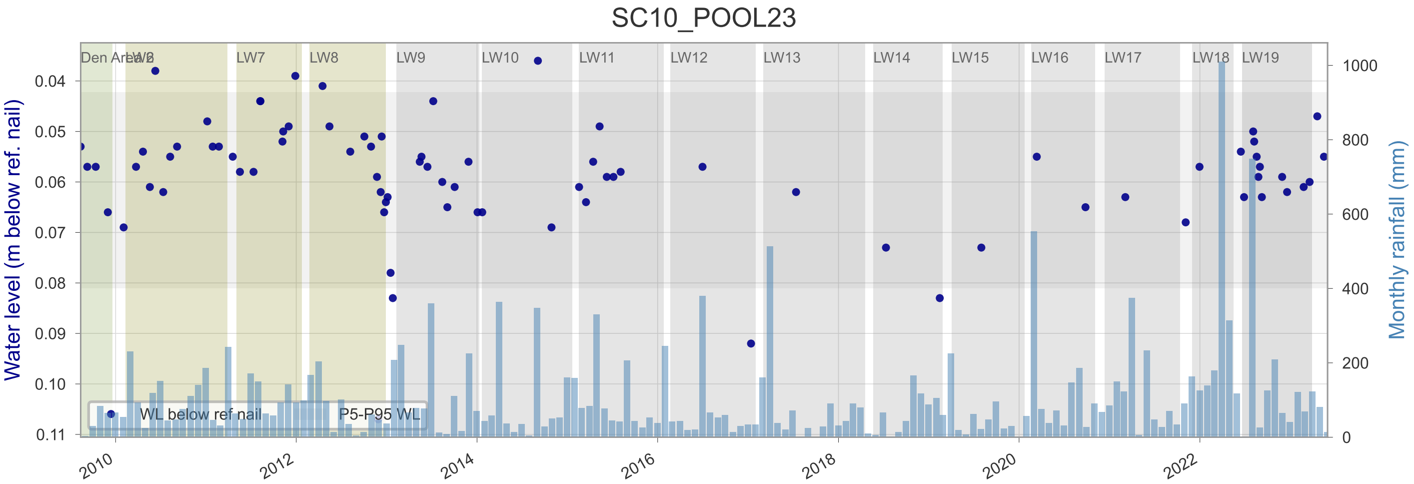

SC10_POOL15
Den Area
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
P5-P95 WL

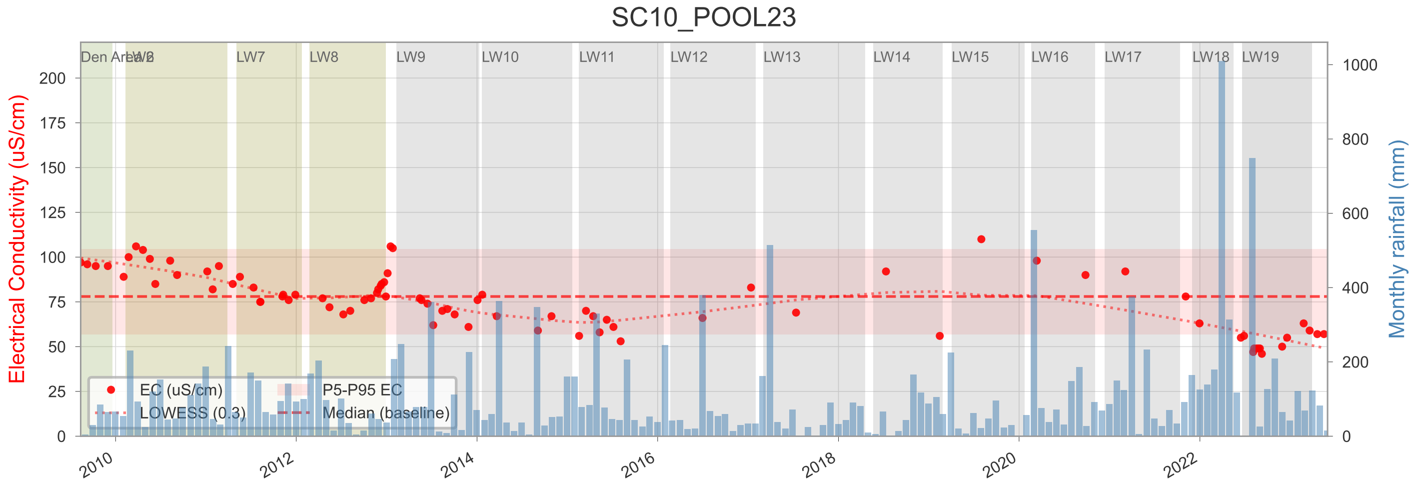

SC10_POOL15
Den Area
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

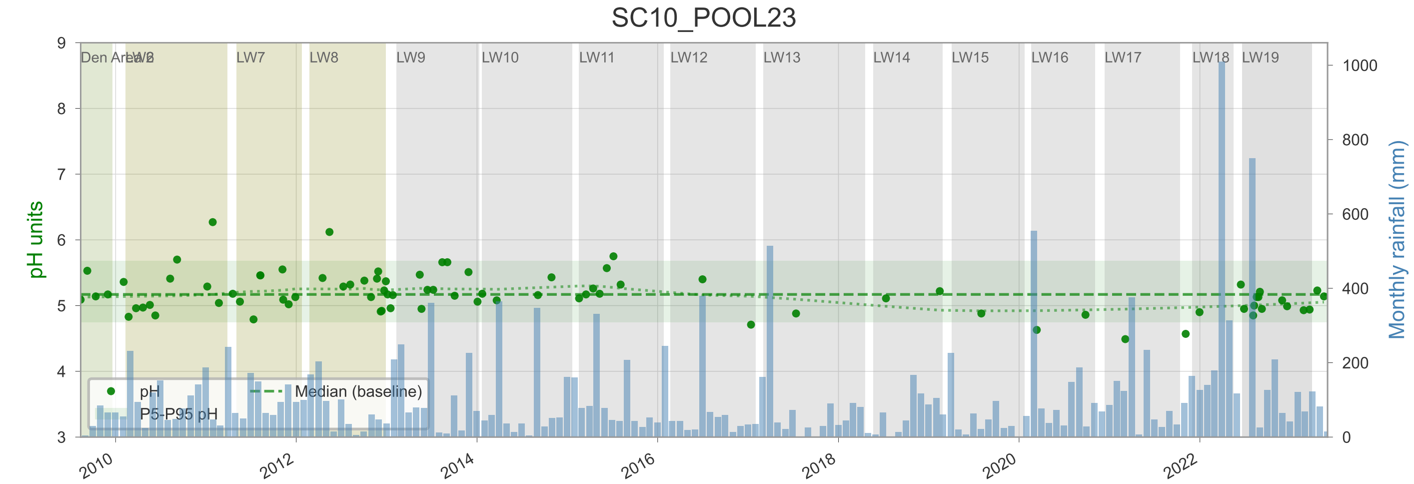

SC10_POOL15
Den Area
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)

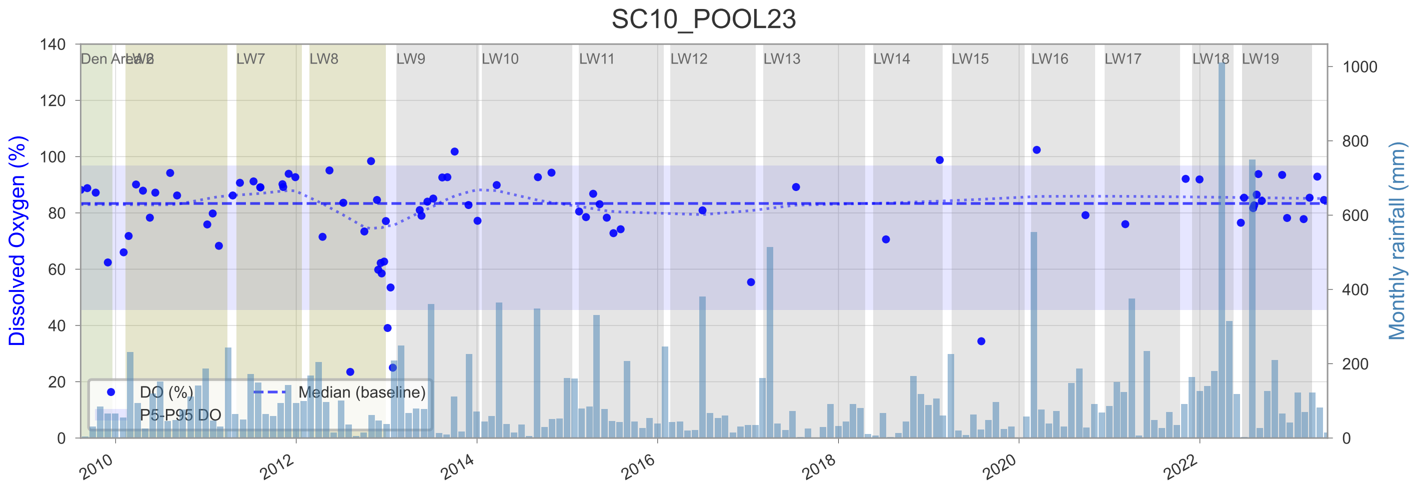

SC10_POOL15
Den Area
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)

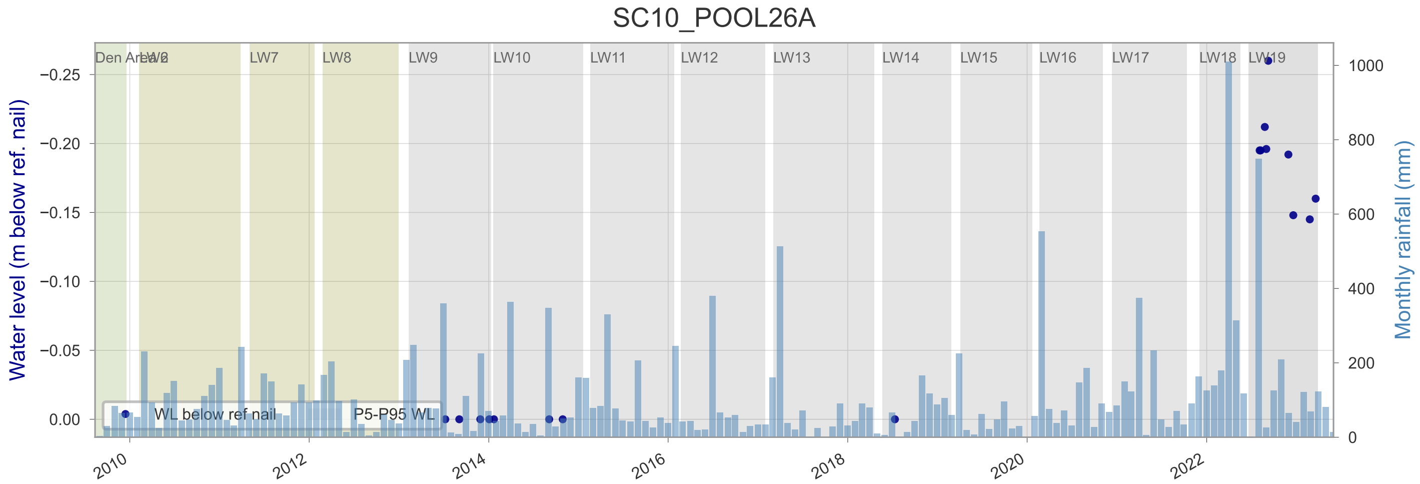

SC10_POOL21
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
P5-P95 WL
2010
2012
2014
2016
2018
2020
2022
SC10_POOL21
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)
SC10_POOL21
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)
SC10_POOL21
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)

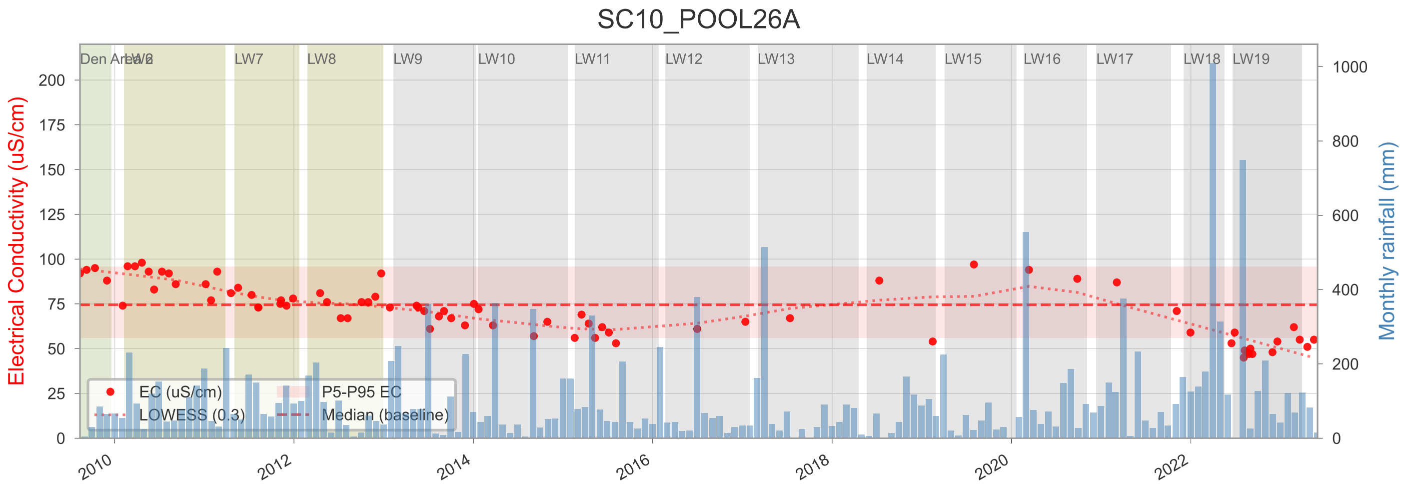

SC10_POOL23
Water level (m below ref. nail)
Monthly rainfall (mm)
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
P5-P95 WL

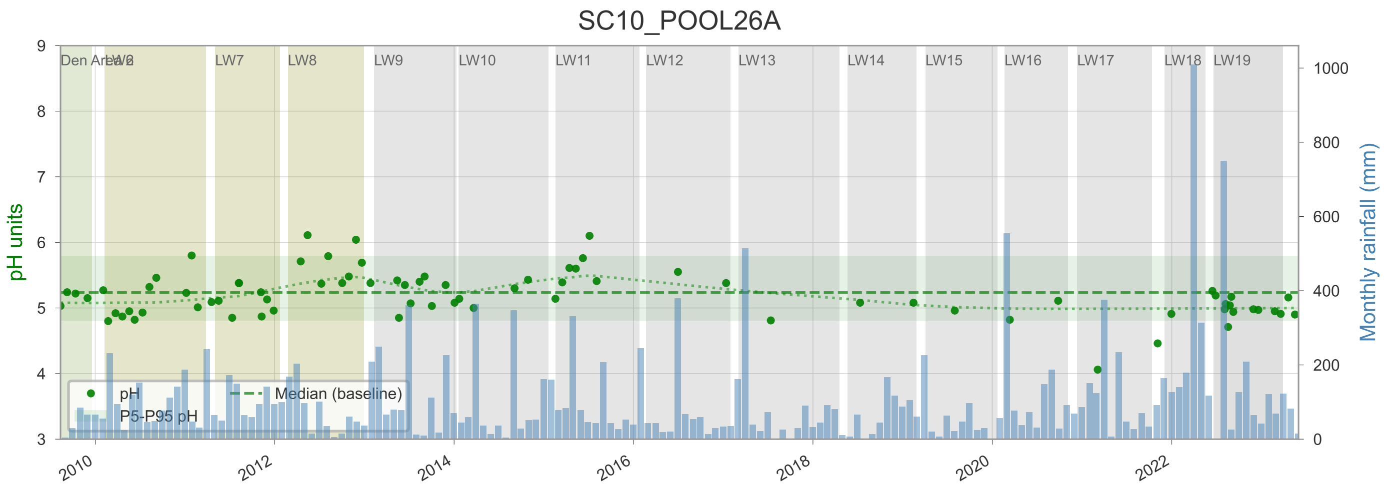

SC10_POOL23
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

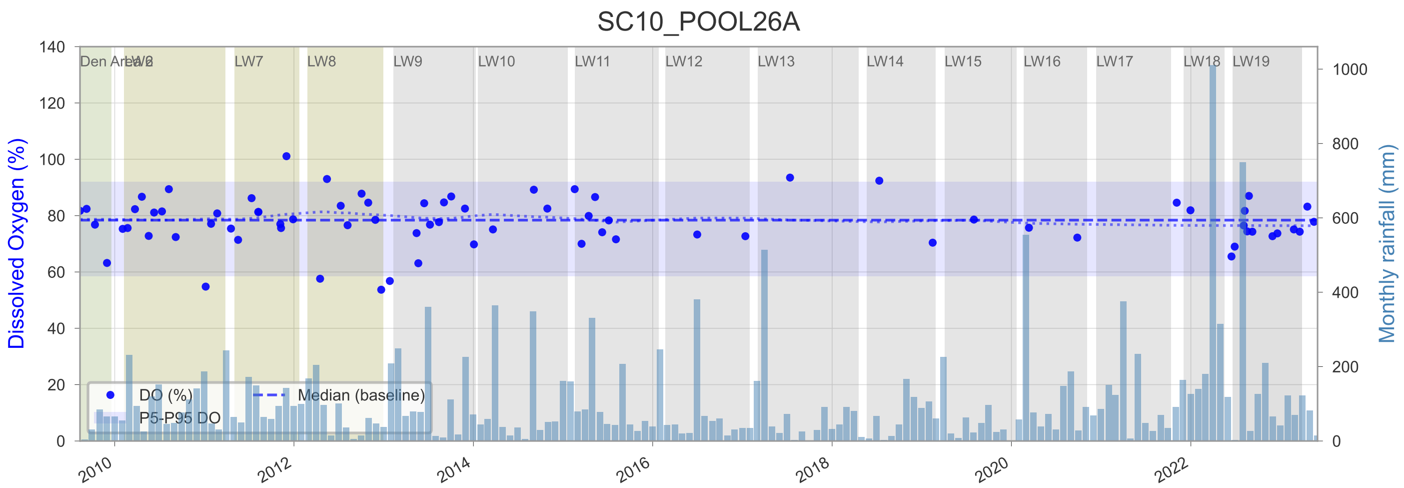

SC10_POOL23
pH units
Monthly rainfall (mm)
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH
P5-P95 pH
Median (baseline)

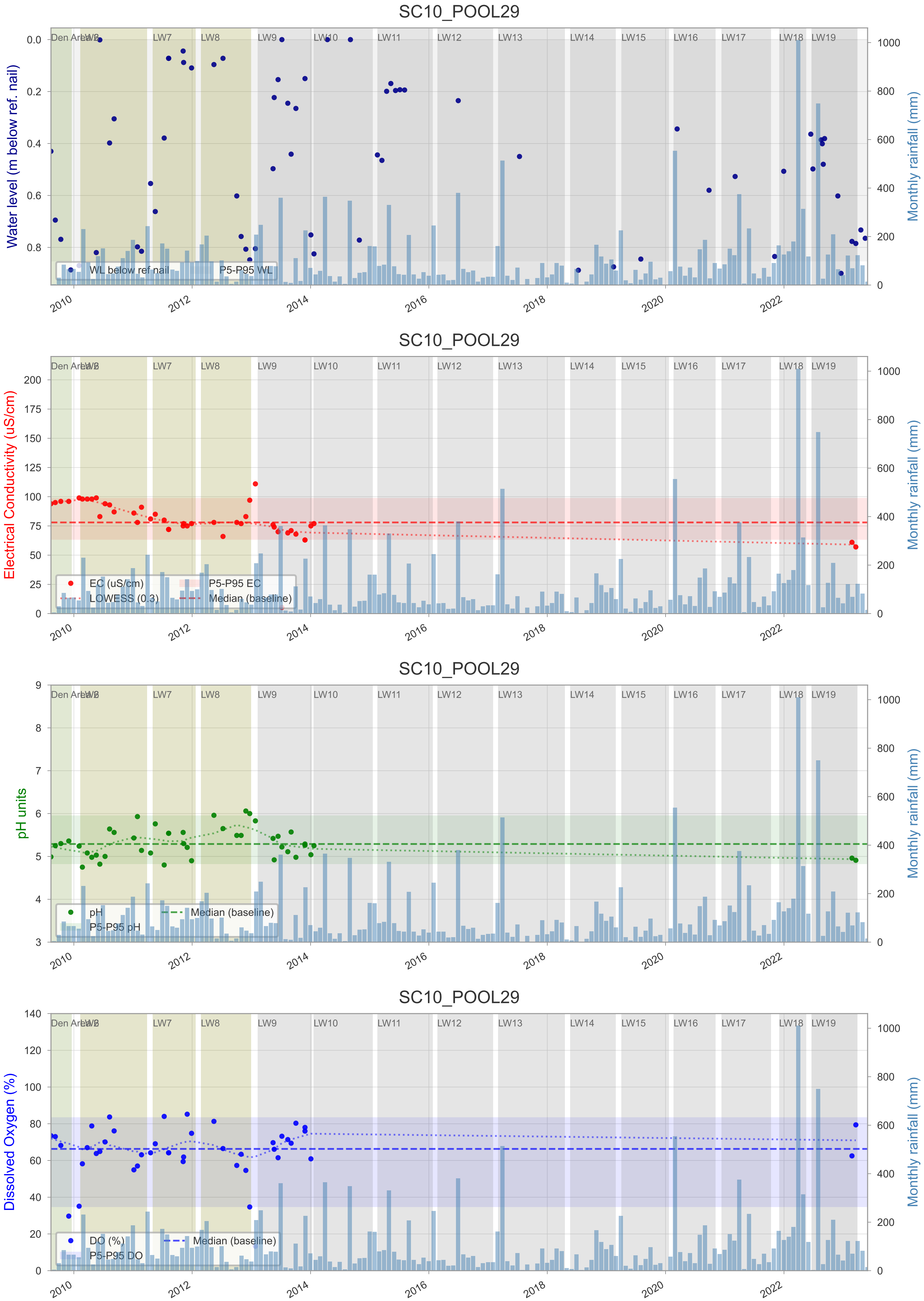

SC10_POOL23
Dissolved Oxygen (%)
Monthly rainfall (mm)
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
DO (%)
P5-P95 DO
Median (baseline)


SC10_POOL26A
Water level (m below ref. nail)
Monthly rainfall (mm)
Den Area
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
P5-P95 WL

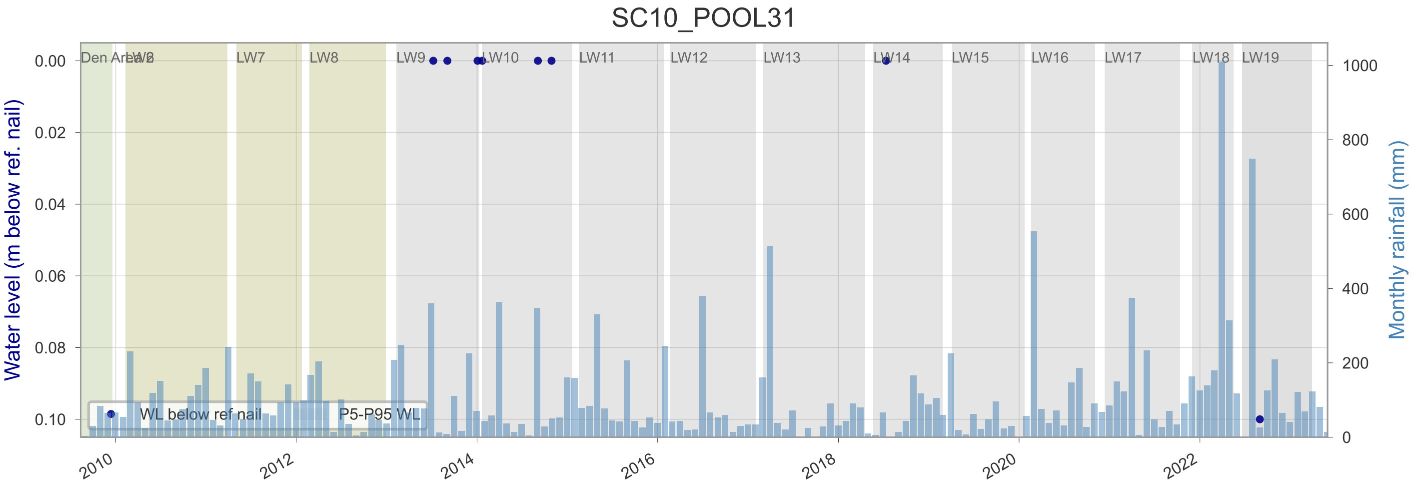

SC10_POOL26A
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

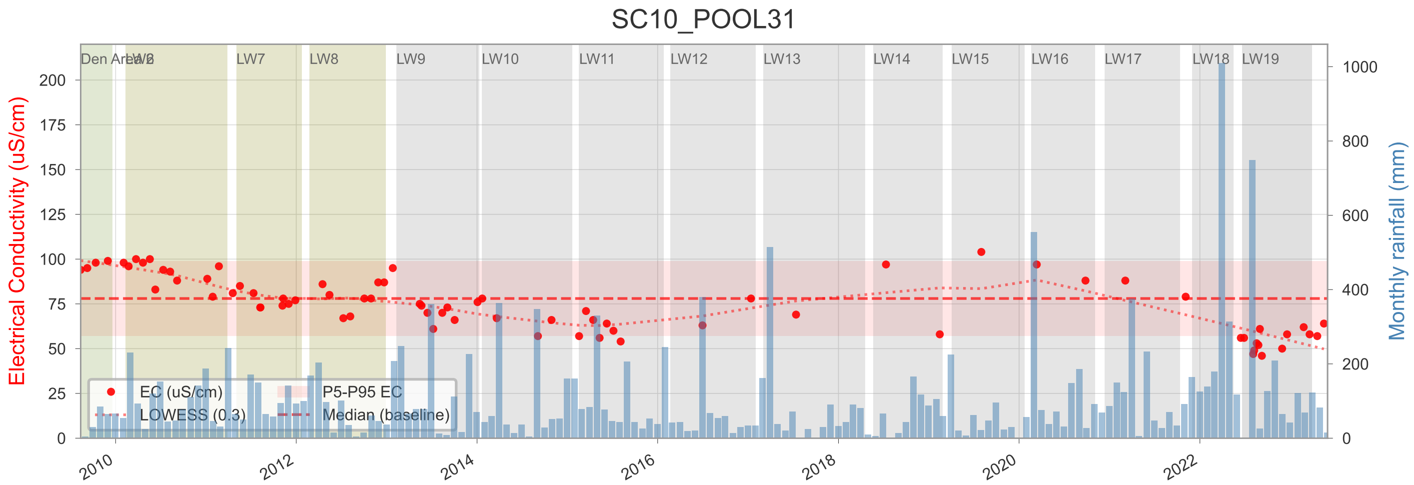

SC10_POOL26A
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)

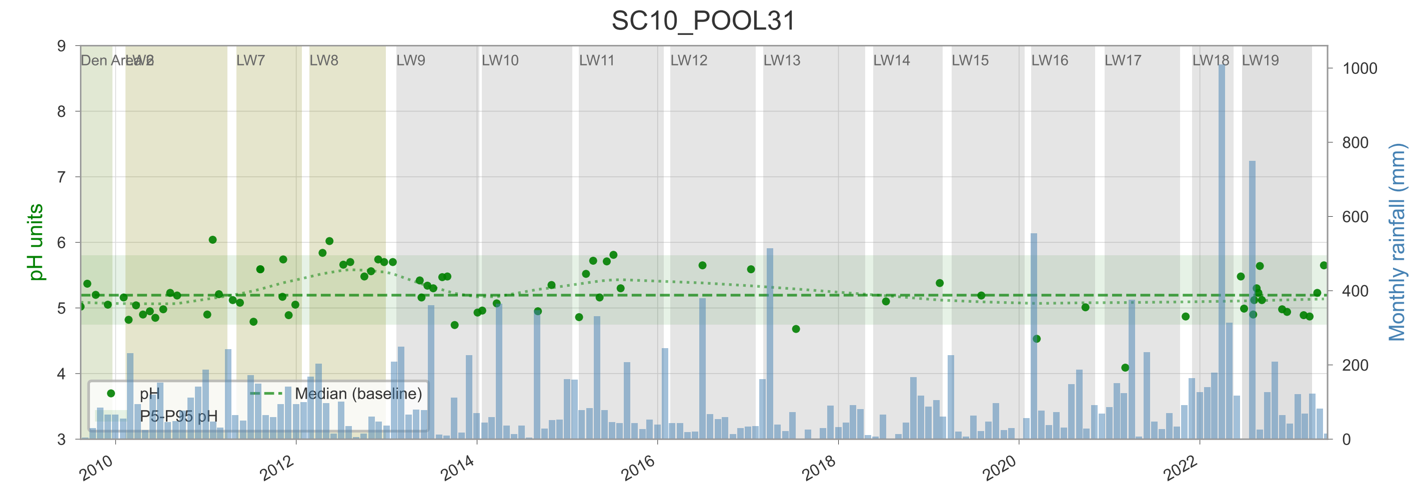

SC10_POOL26A
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)

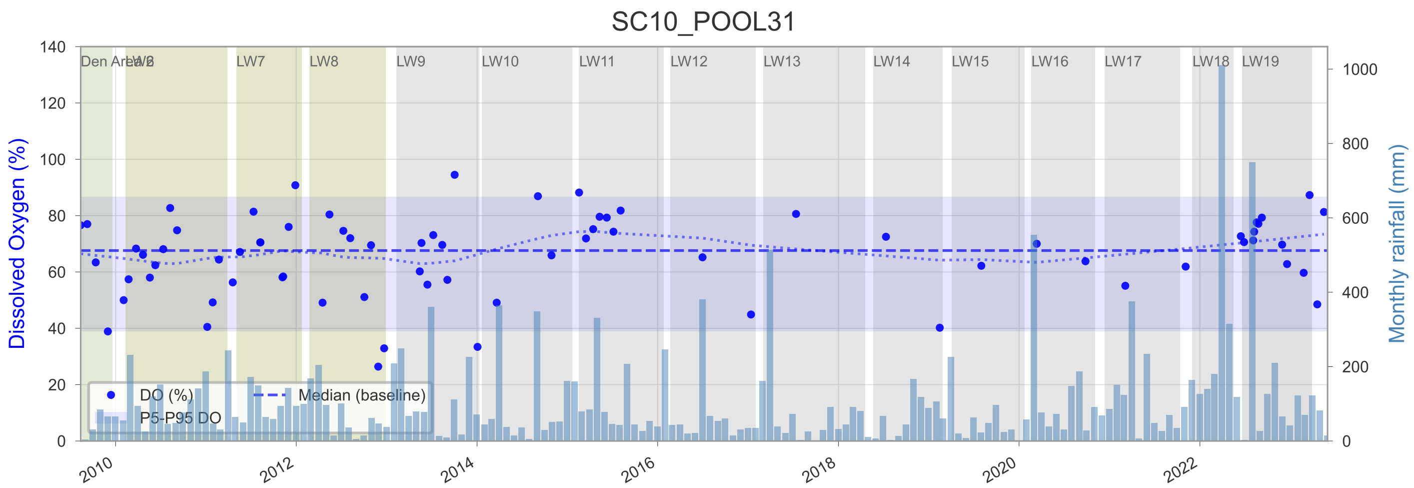


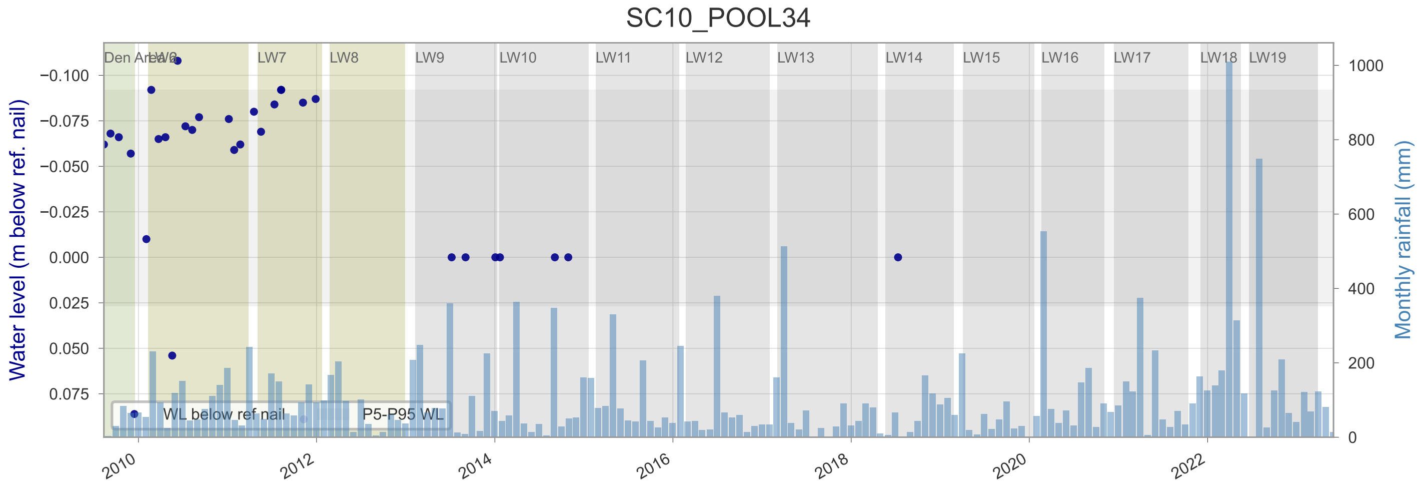
SC10_POOL29
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
P5-P95 WL
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
SC10_POOL29
Electrical Conductivity (uS/cm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)
SC10_POOL29
pH units
pH
P5-P95 pH
Median (baseline)
SC10_POOL29
Dissolved Oxygen (%)
DO (%)
P5-P95 DO
Median (baseline)
2010
2012
2014
2016
2018
2020
2022

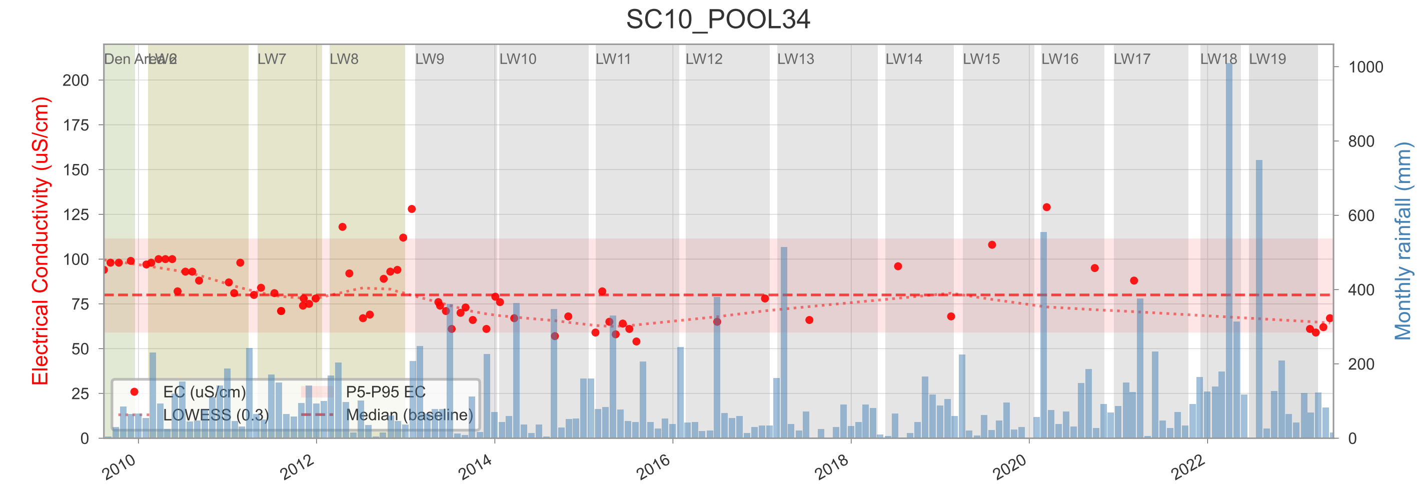

SC10_POOL31
Water level (m below ref. nail)
Monthly rainfall (mm)
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
P5-P95 WL

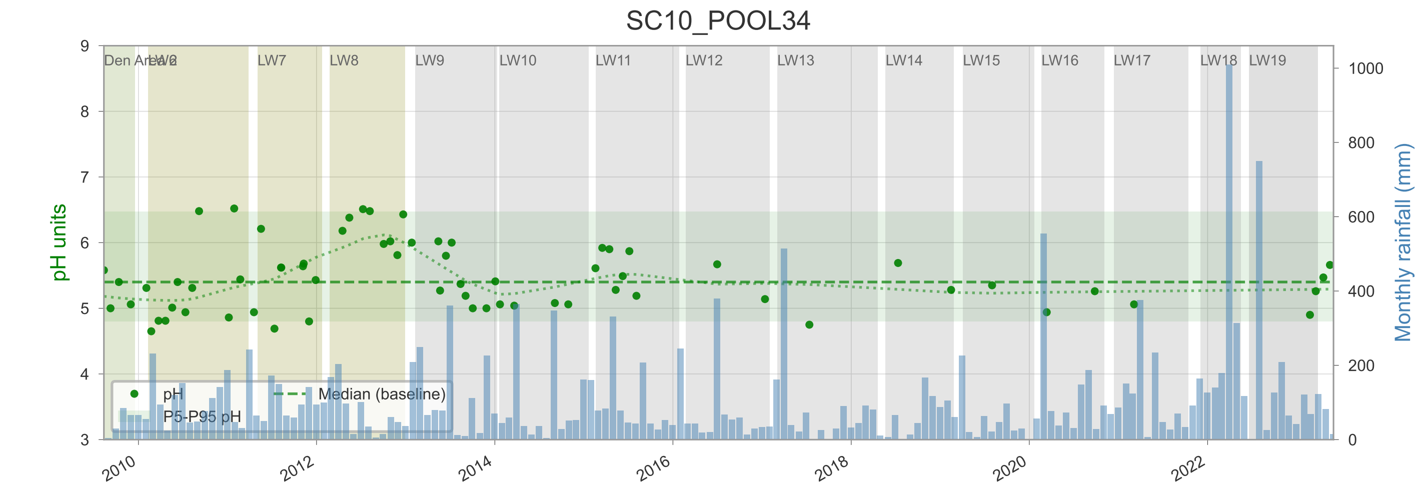

SC10_POOL31
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

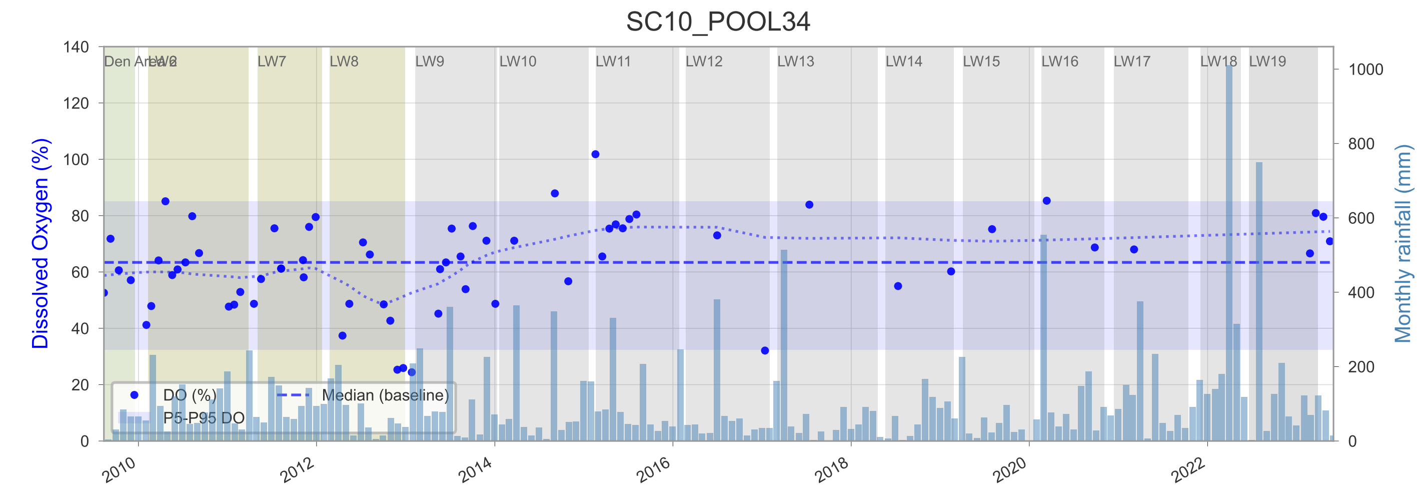

SC10_POOL31
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)

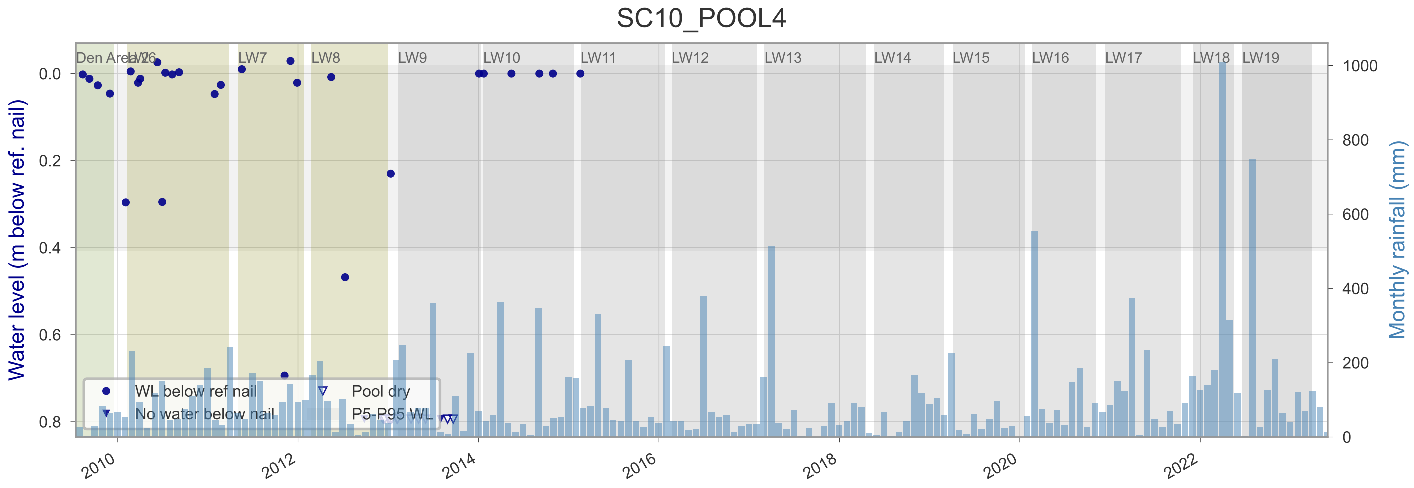

SC10_POOL31
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)

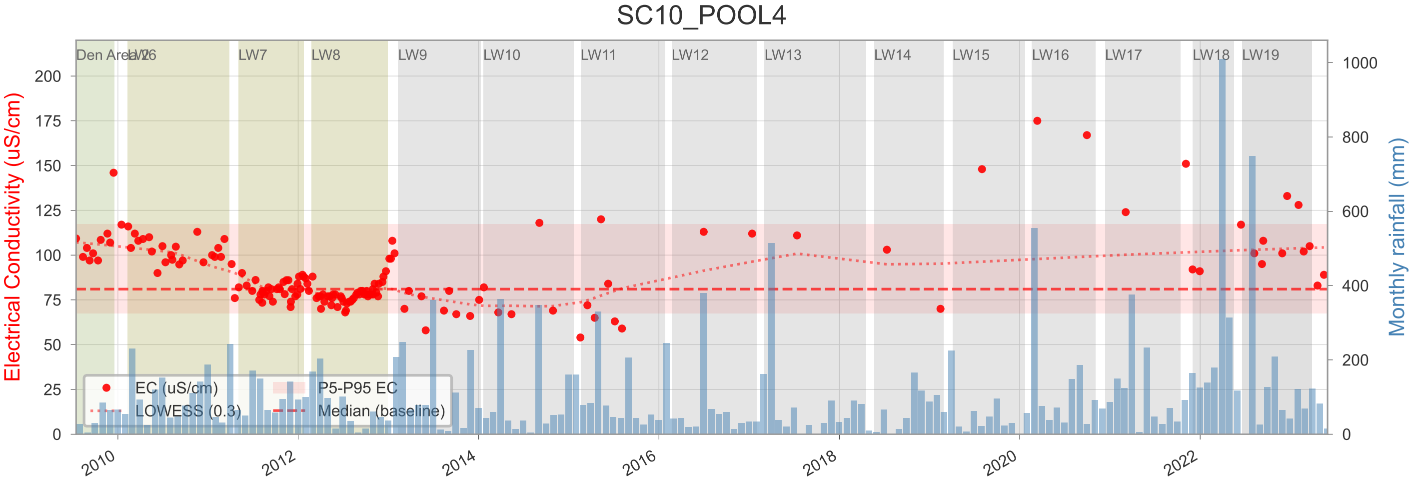

SC10_POOL34
Water level (m below ref. nail)
Monthly rainfall (mm)
Den Area LW6 LW7 LW8 LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17 LW18 LW19
WL below ref nail
P5-P95 WL

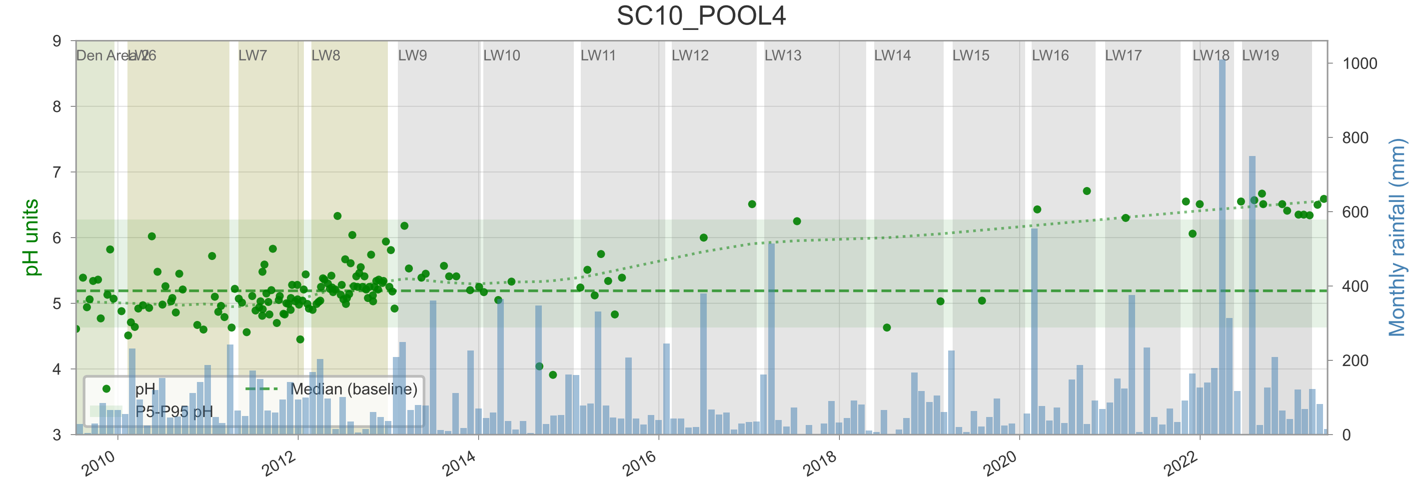

SC10_POOL34
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
Den Area LW6 LW7 LW8 LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17 LW18 LW19
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

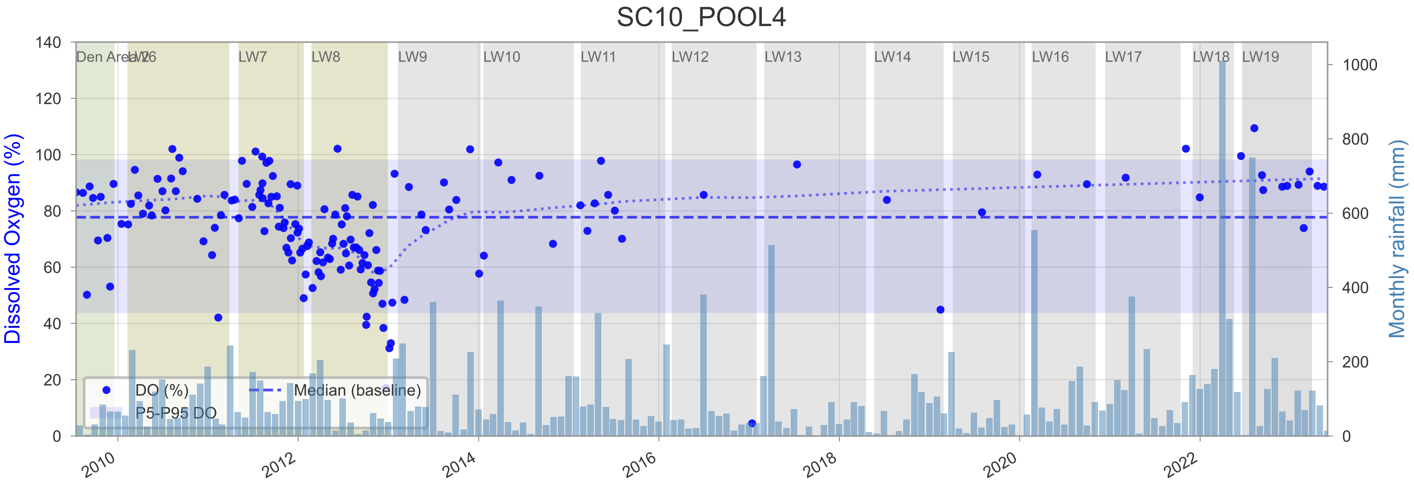

SC10_POOL34
pH units
Monthly rainfall (mm)
Den Area LW6 LW7 LW8 LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17 LW18 LW19
pH
P5-P95 pH
Median (baseline)

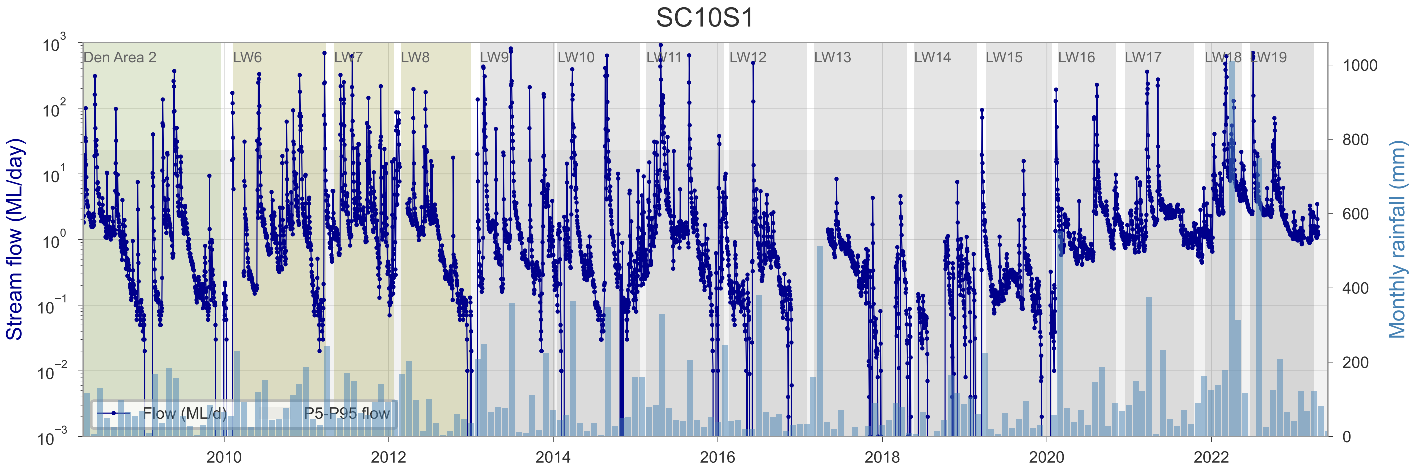

SC10_POOL34
Dissolved Oxygen (%)
Monthly rainfall (mm)
Den Area LW6 LW7 LW8 LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17 LW18 LW19
DO (%)
P5-P95 DO
Median (baseline)

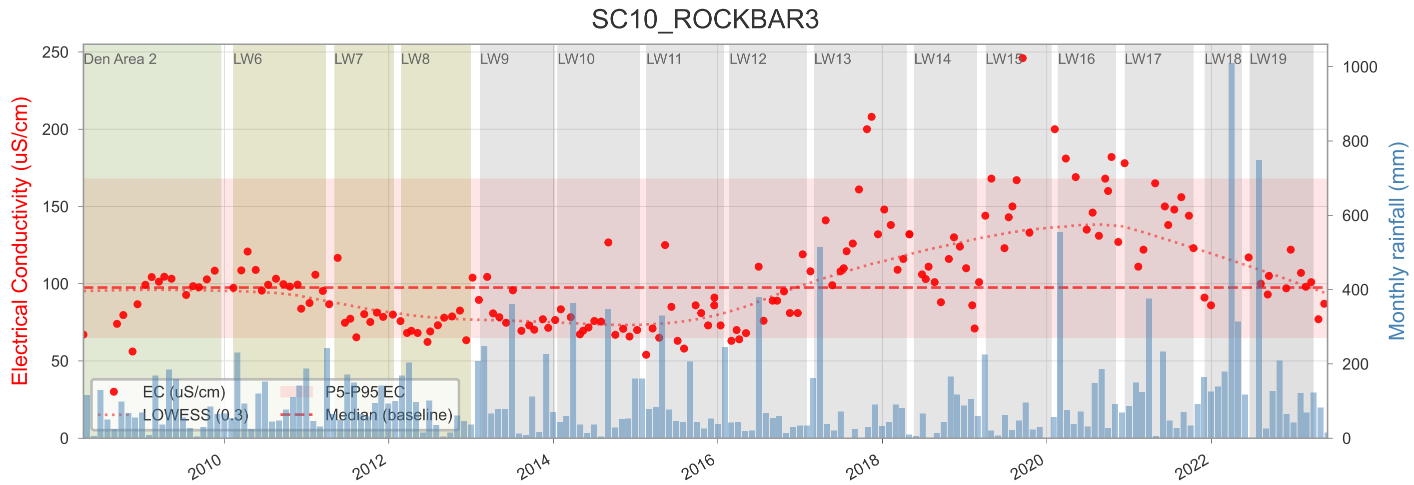

SC10_POOL4
Water level (m below ref. nail)
Monthly rainfall (mm)
Den Area LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
No water below nail
Pool dry
P5-P95 WL

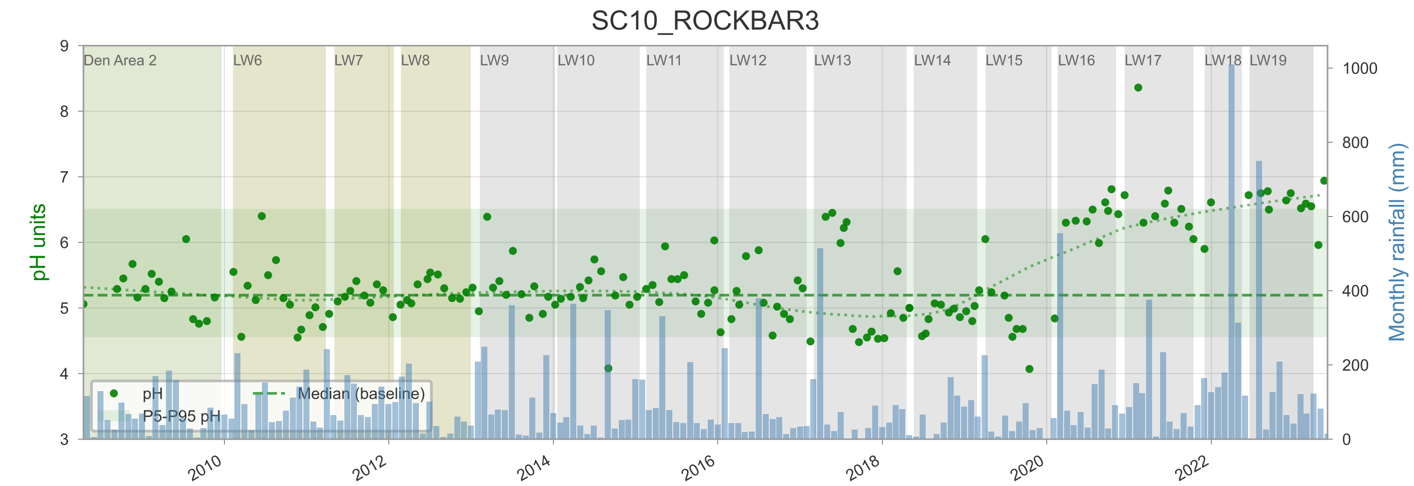

SC10_POOL4
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

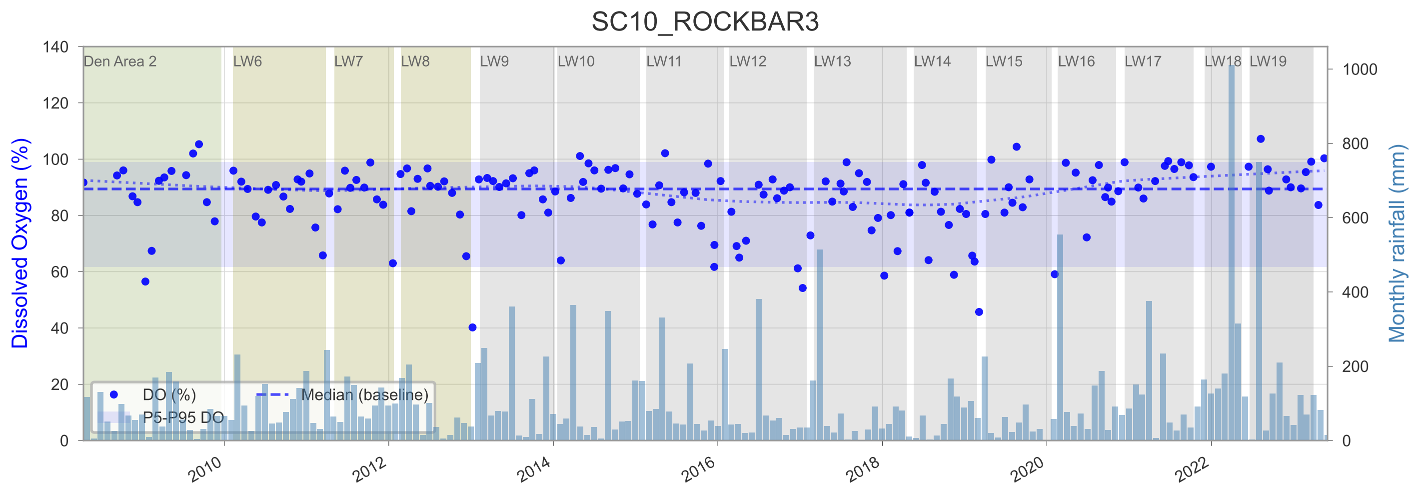

SC10_POOL4
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)

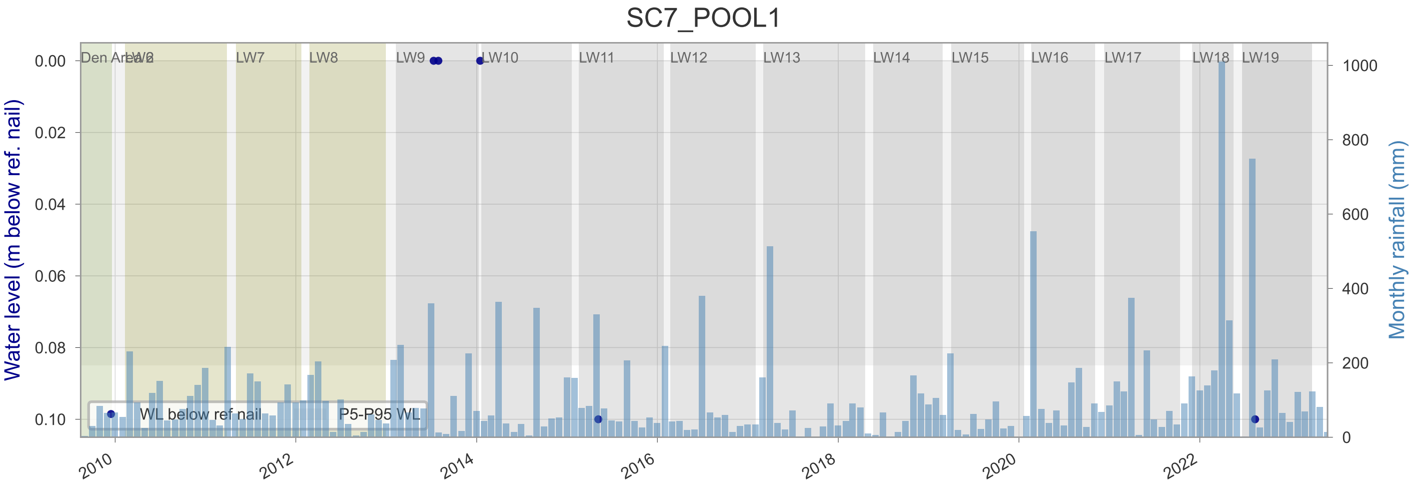

SC10_POOL4
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)

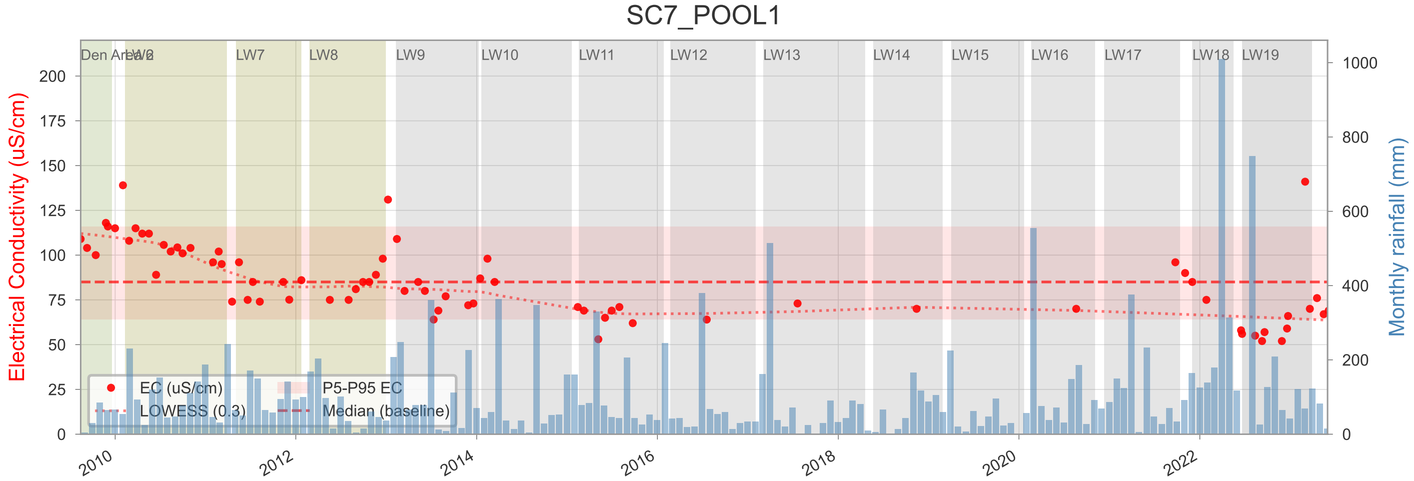

SC10S1
Stream flow (ML/day)
Monthly rainfall (mm)
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Flow (ML/d)
P5-P95 flow

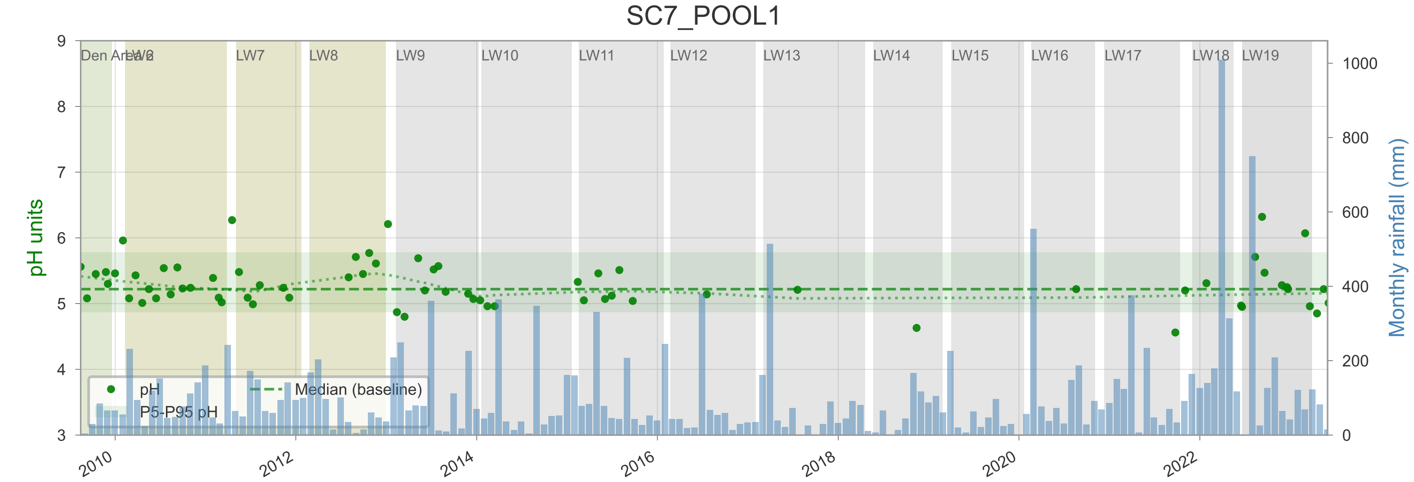

SC10_ROCKBAR3
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

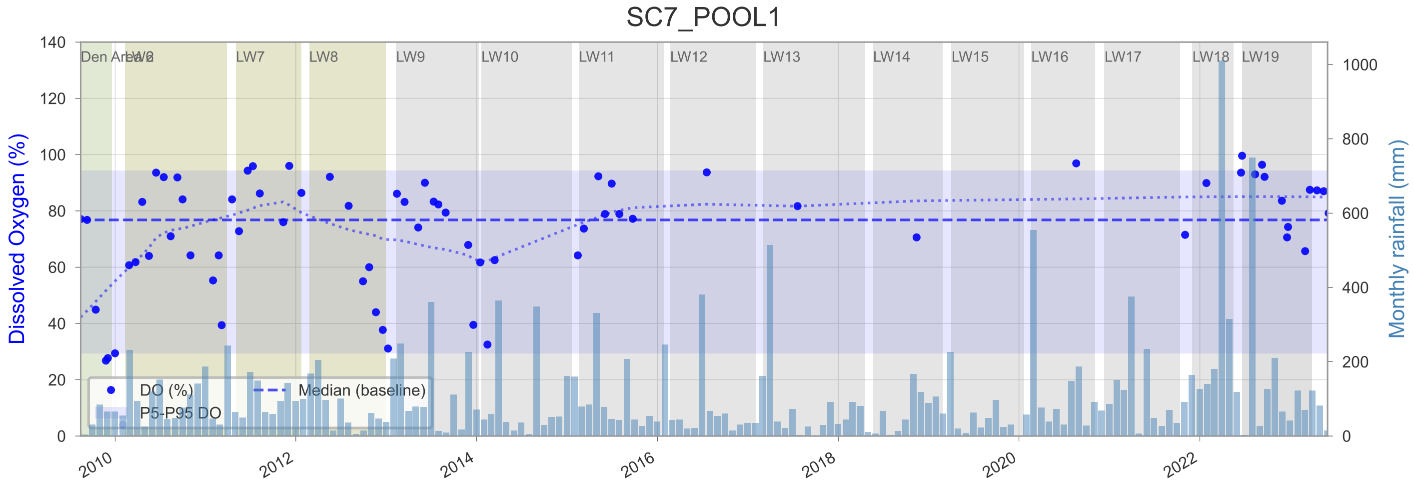

SC10_ROCKBAR3
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)

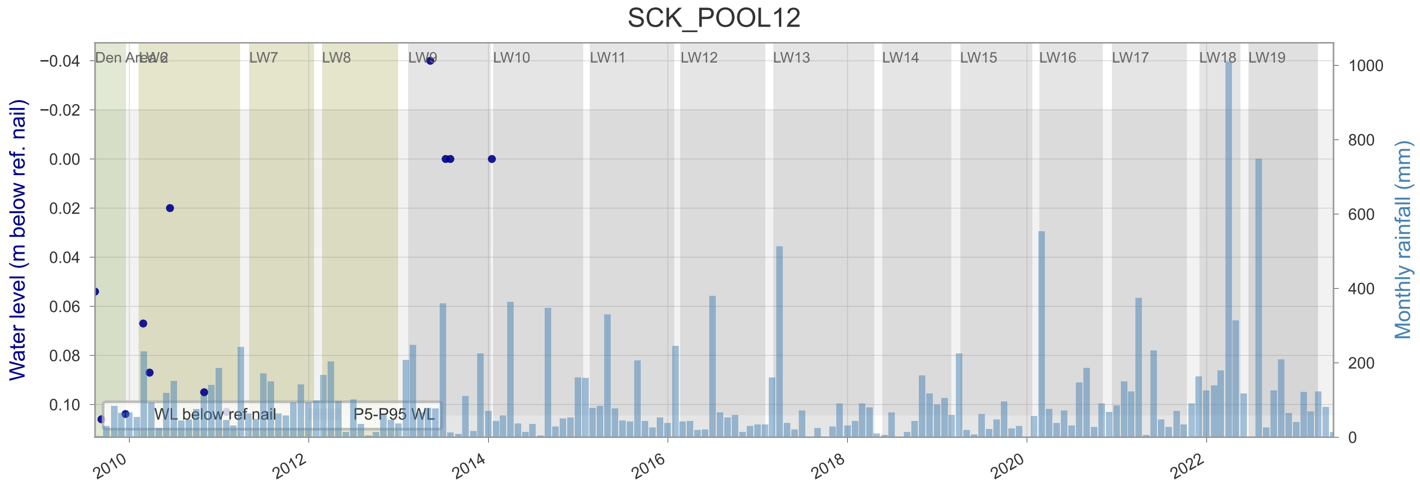

SC10_ROCKBAR3
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)

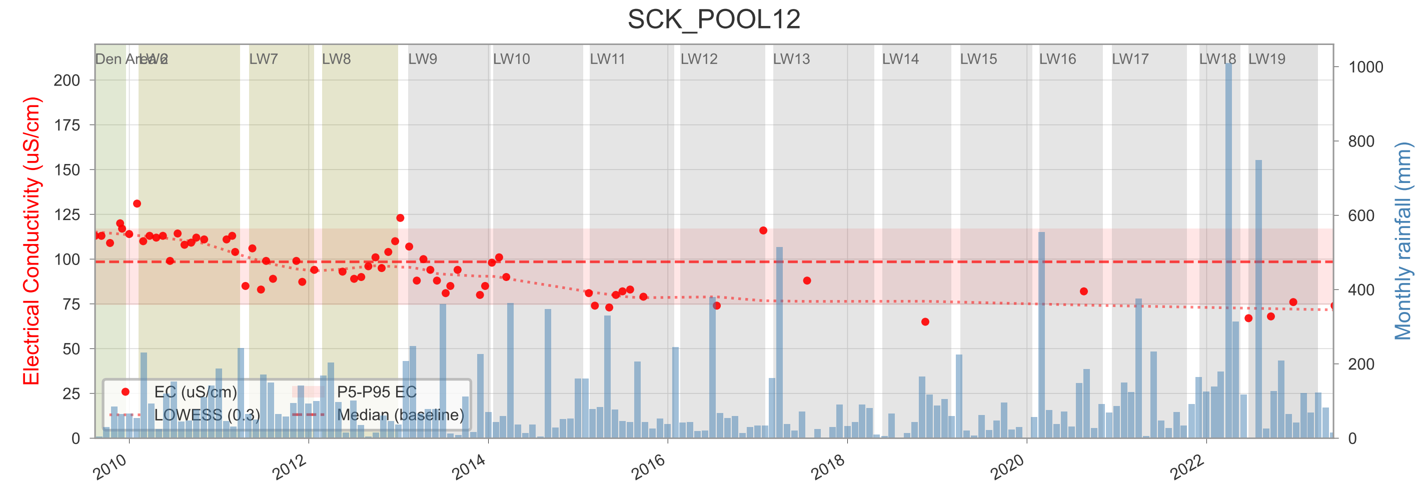

SC7_POOL1
Den Area LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
P5-P95 WL
0.00
0.02
0.04
0.06
0.08
0.10
0
200
400
600
800
1000
2010
2012
2014
2016
2018
2020
2022

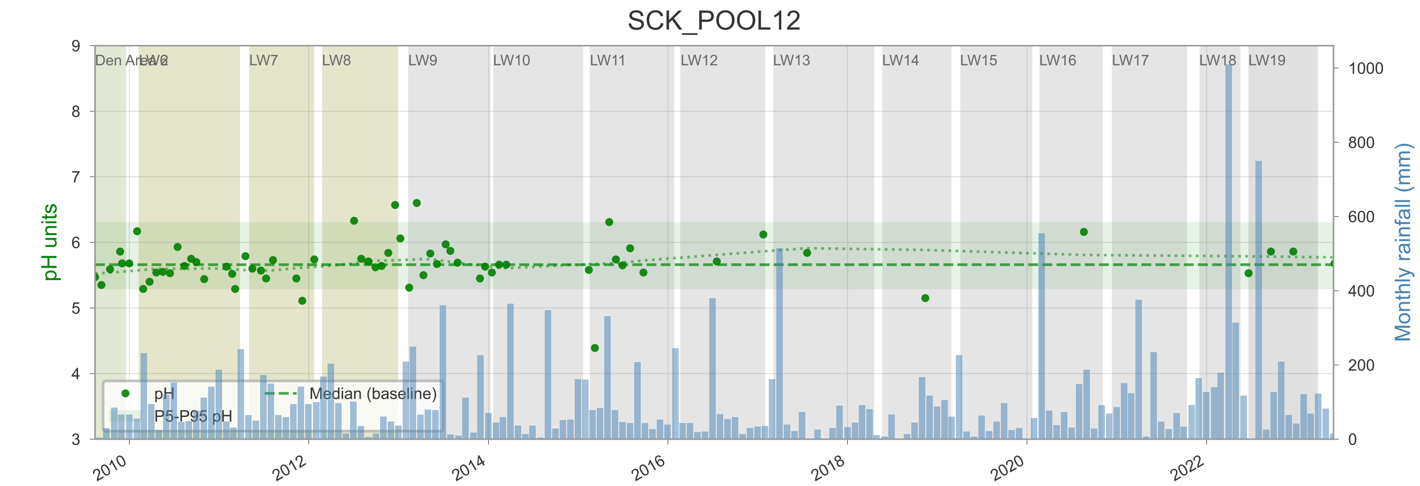

SC7_POOL1
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)
0
25
50
75
100
125
150
175
200

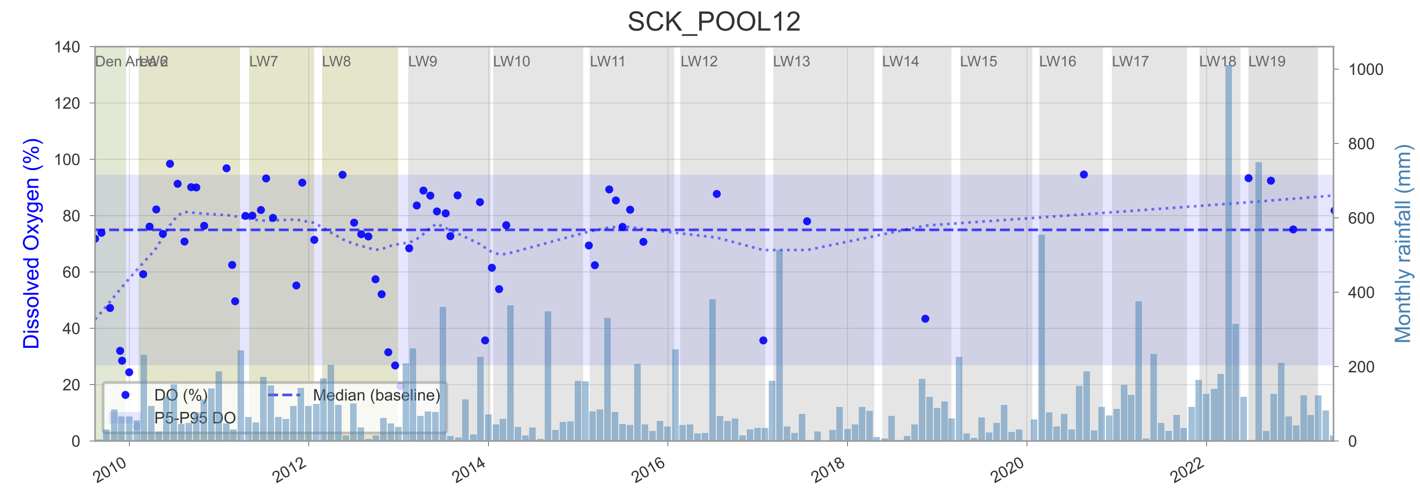

SC7_POOL1
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)
3
4
5
6
7
8
9

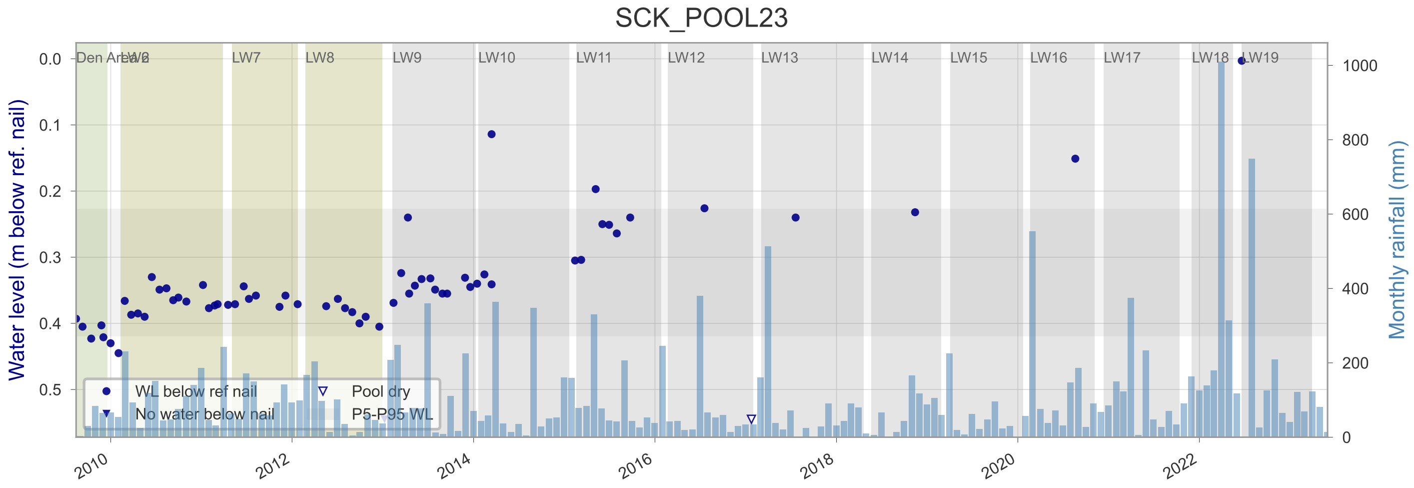

SC7_POOL1
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)
0
20
40
60
80
100
120
140

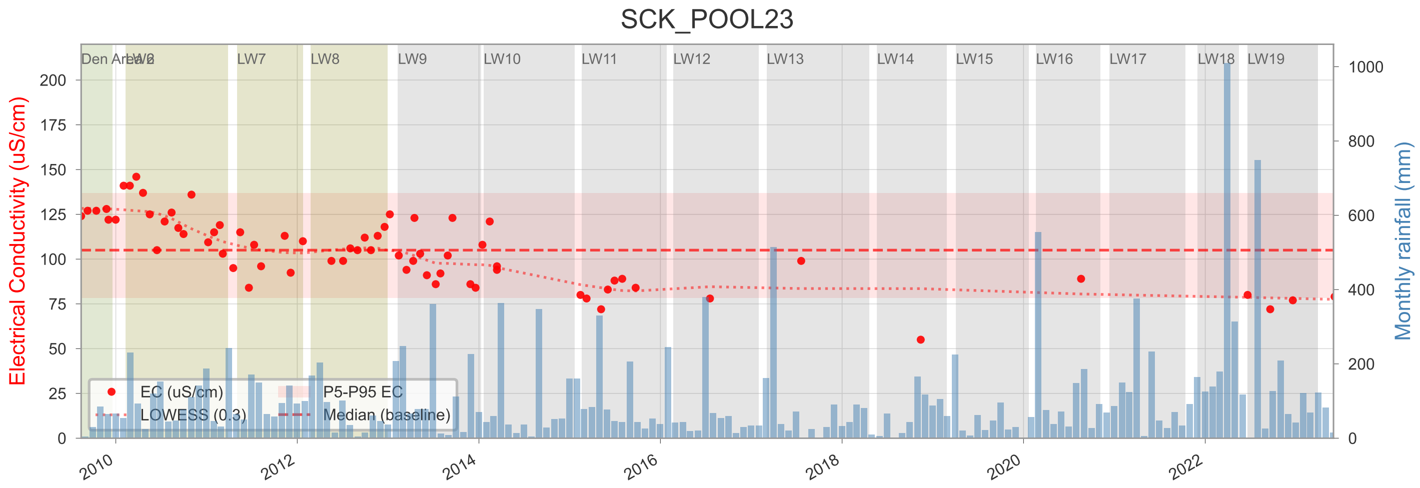

SCK_POOL12
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
P5-P95 WL

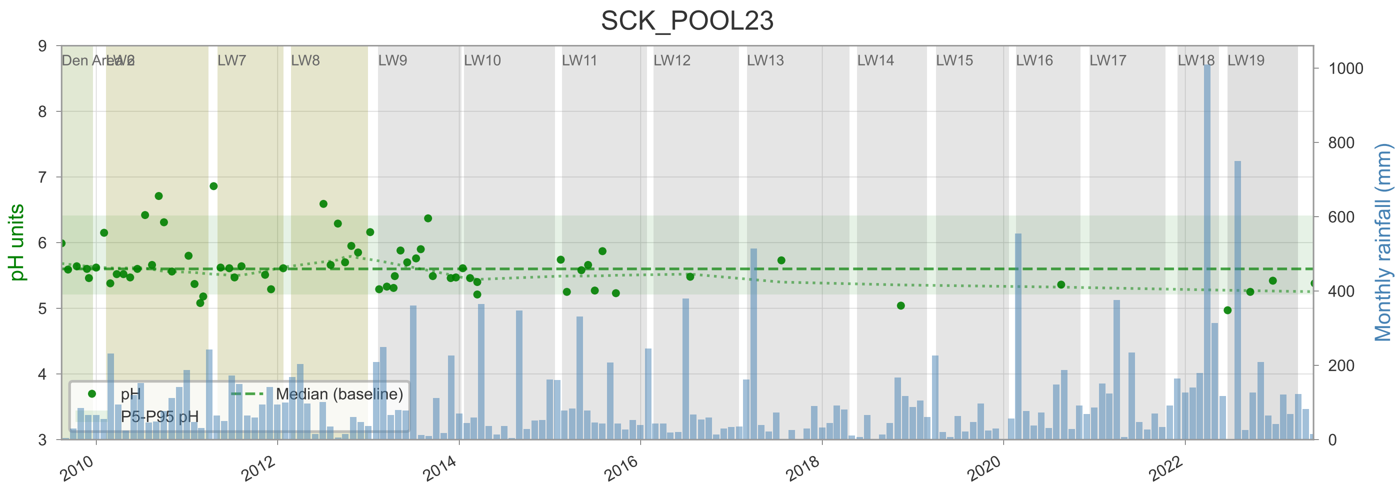

SCK_POOL12
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

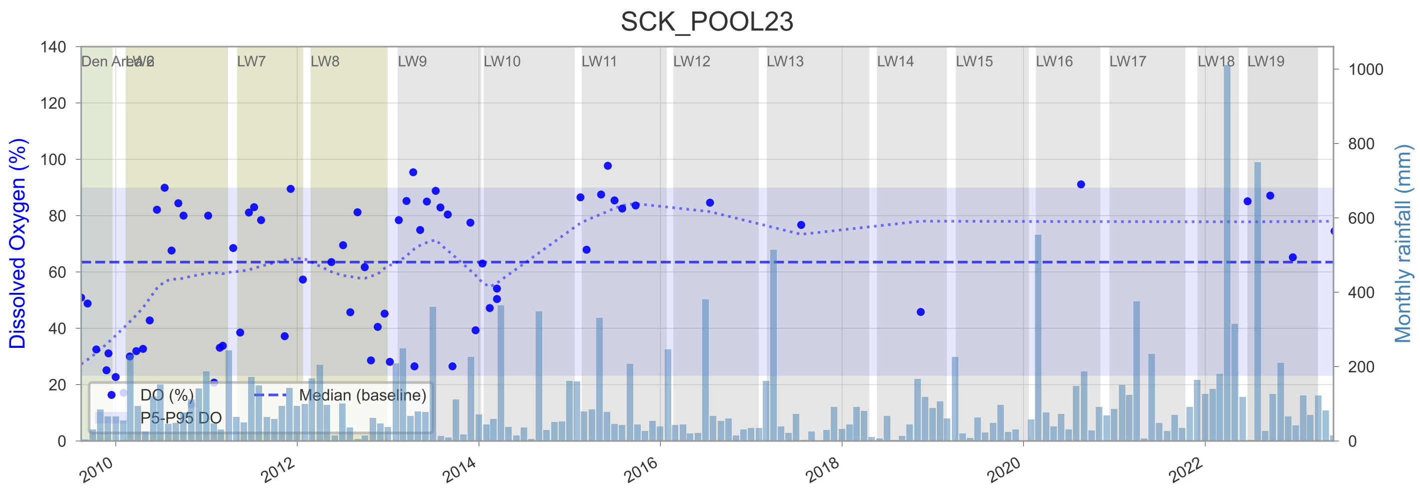

SCK_POOL12
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)

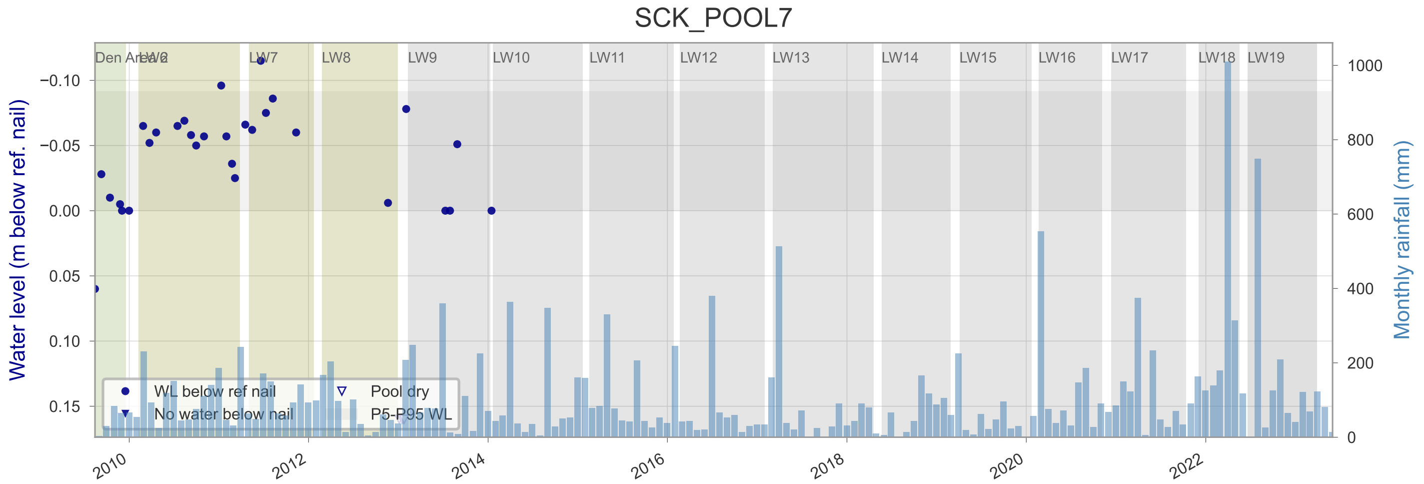

SCK_POOL12
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)

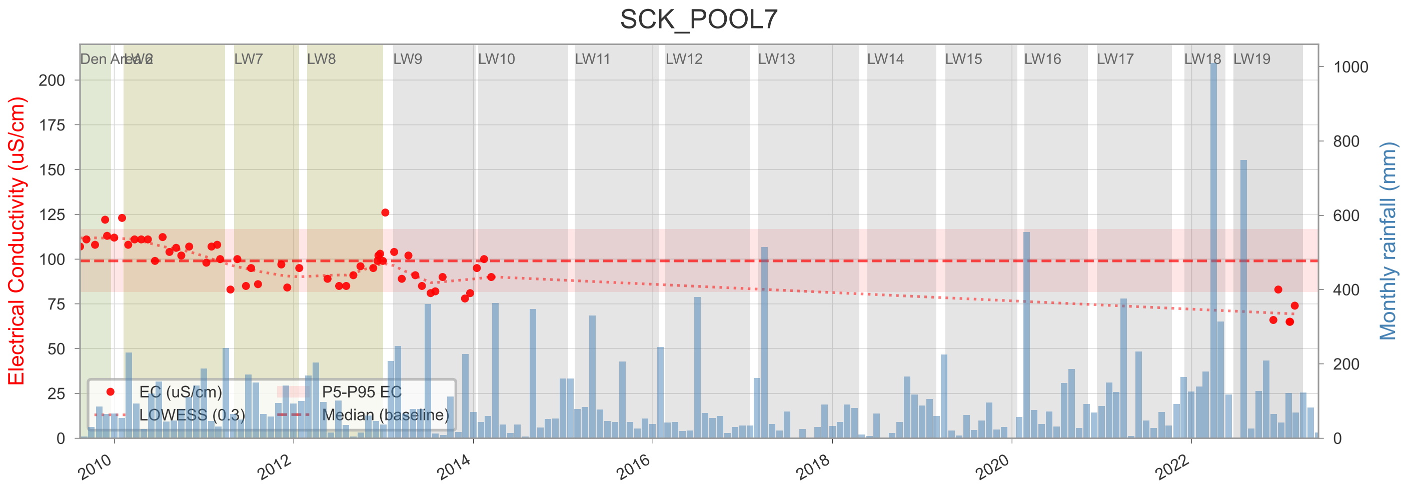

SCK_POOL23
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
No water below nail
Pool dry
P5-P95 WL

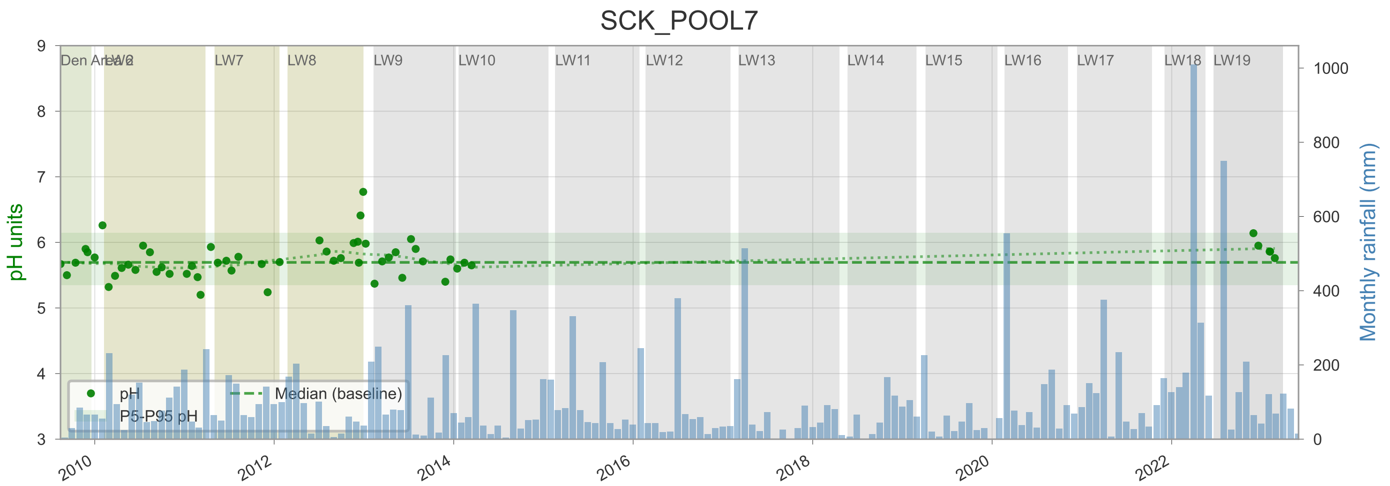

SCK_POOL23
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

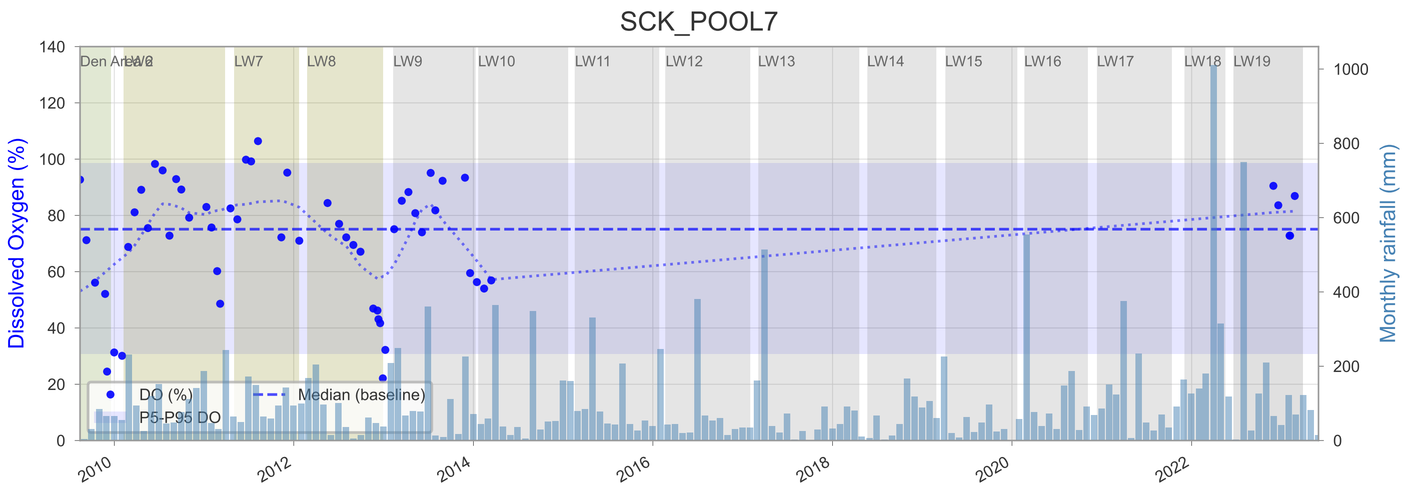

SCK_POOL23
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)

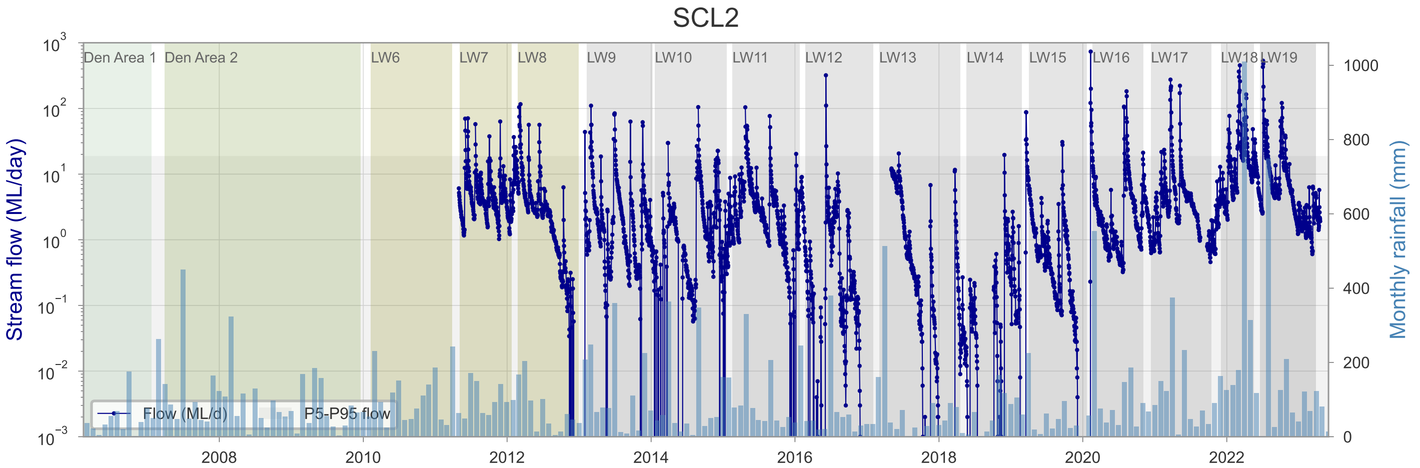

SCK_POOL23
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)

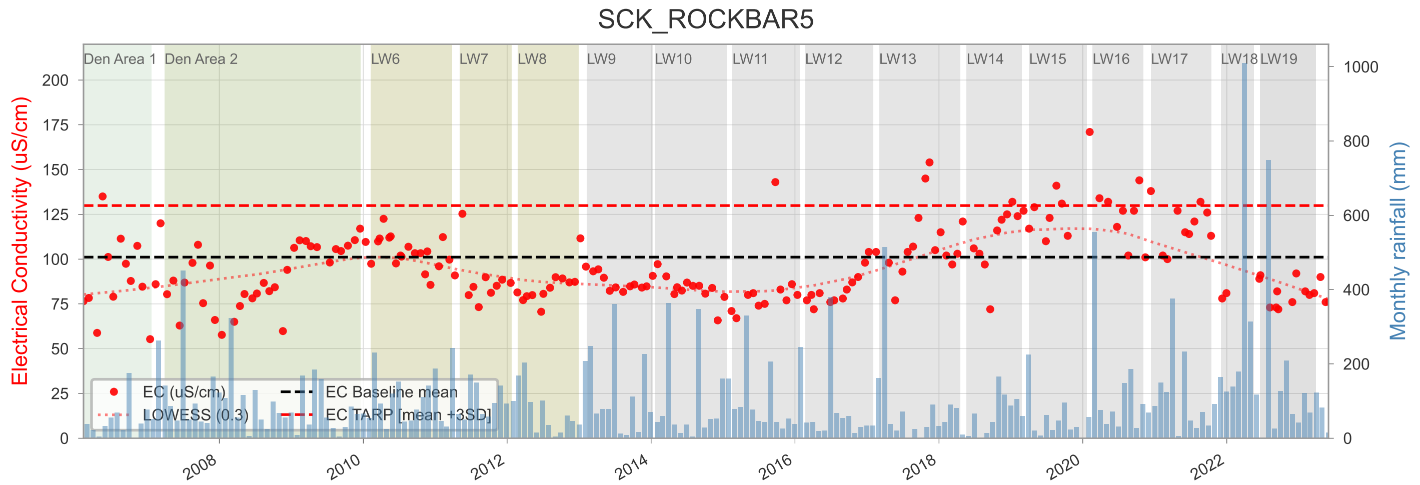

SCK_POOL7
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
No water below nail
Pool dry
P5-P95 WL
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19

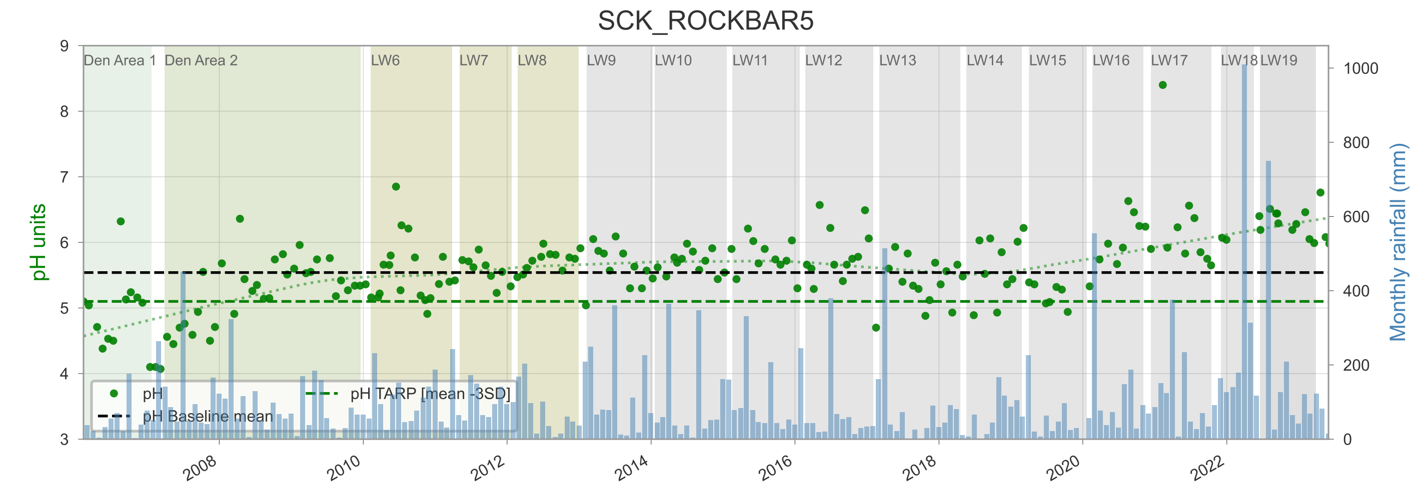

SCK_POOL7
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

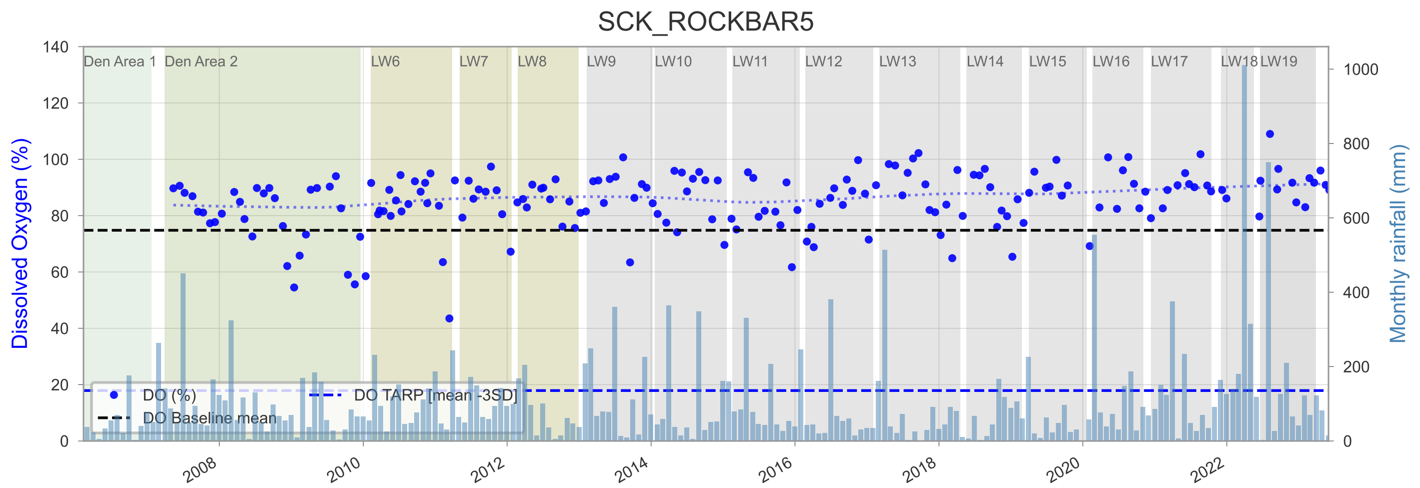

SCK_POOL7
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)

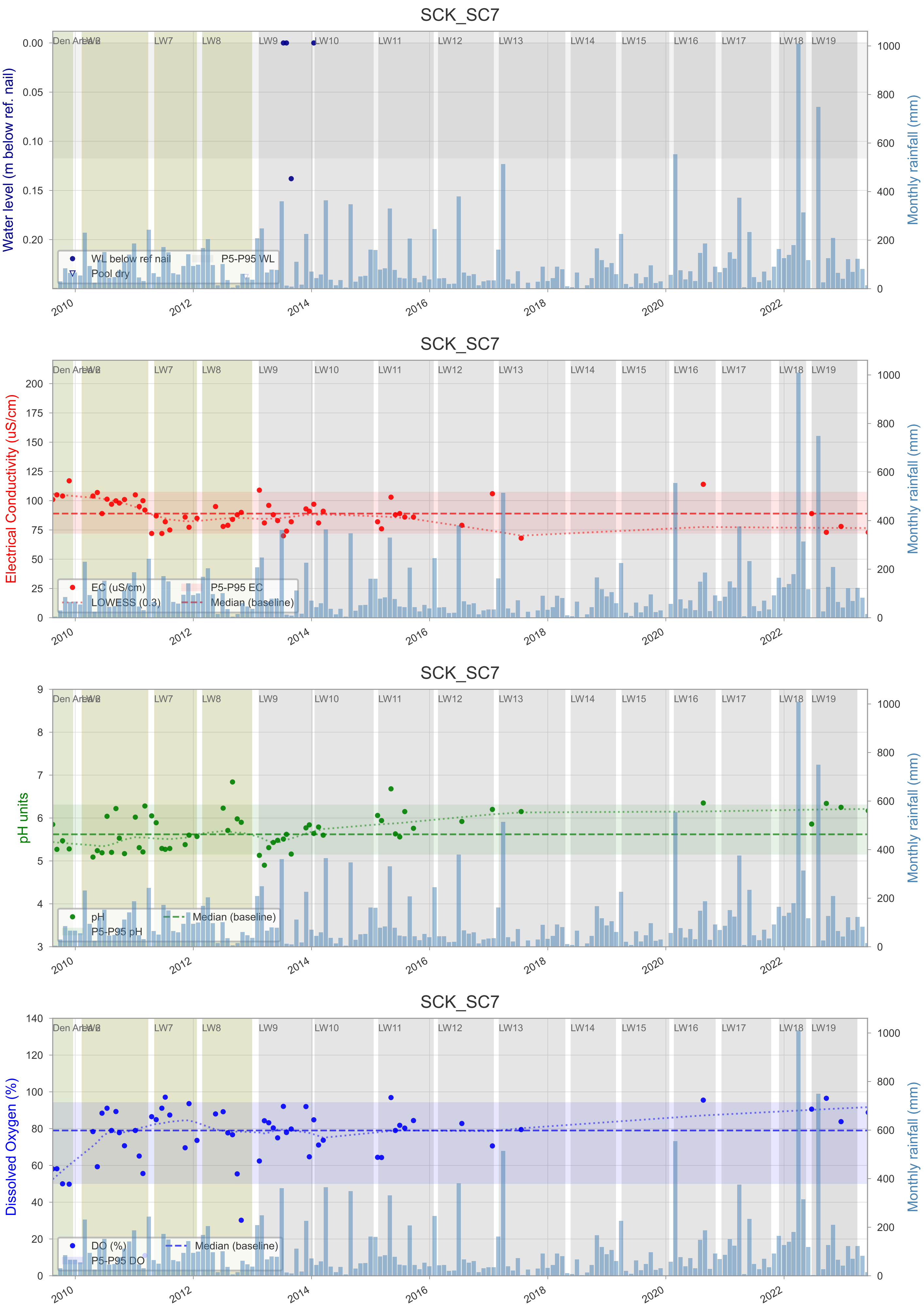

SCK_POOL7
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)

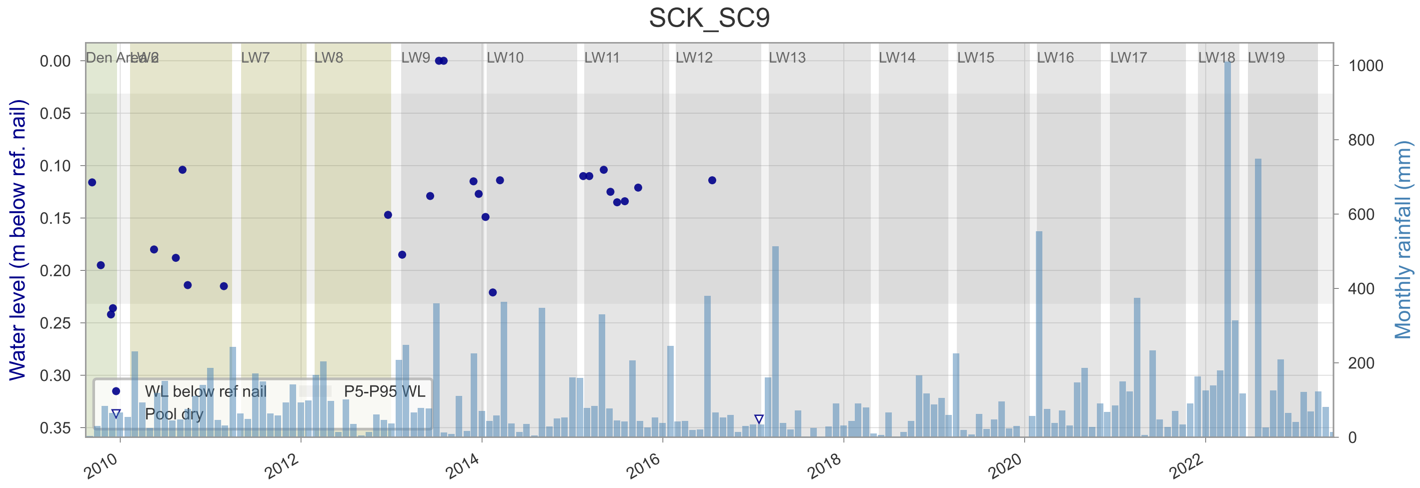

SCL2
Stream flow (ML/day)
Monthly rainfall (mm)
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Flow (ML/d)
P5-P95 flow

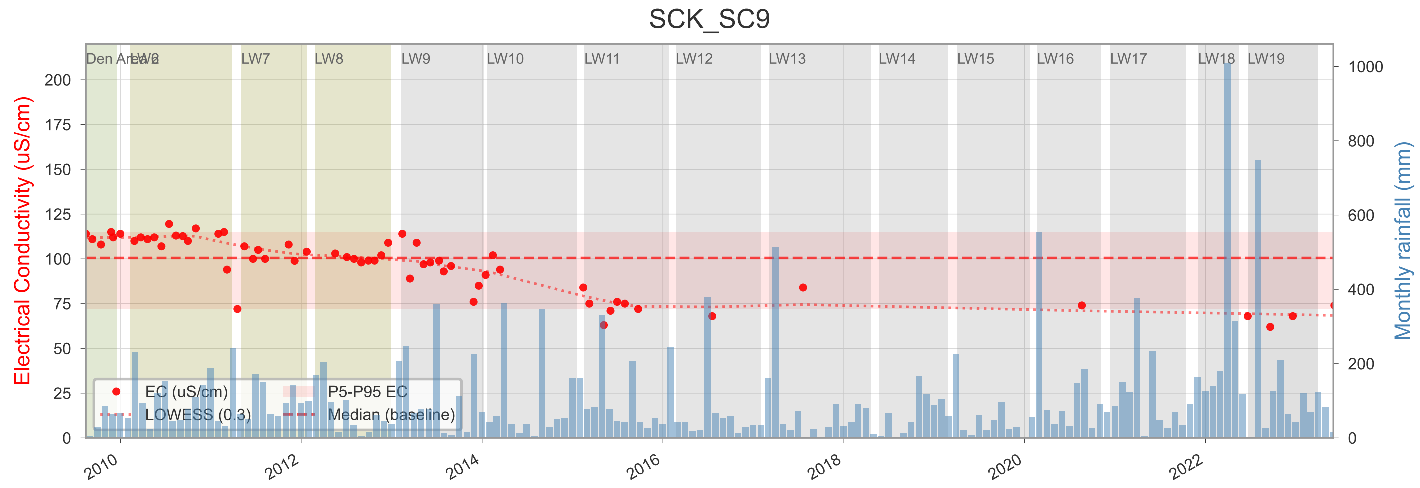

SCK_ROCKBAR5
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
EC (uS/cm)
LOWESS (0.3)
EC Baseline mean
EC TARP [mean +3SD]

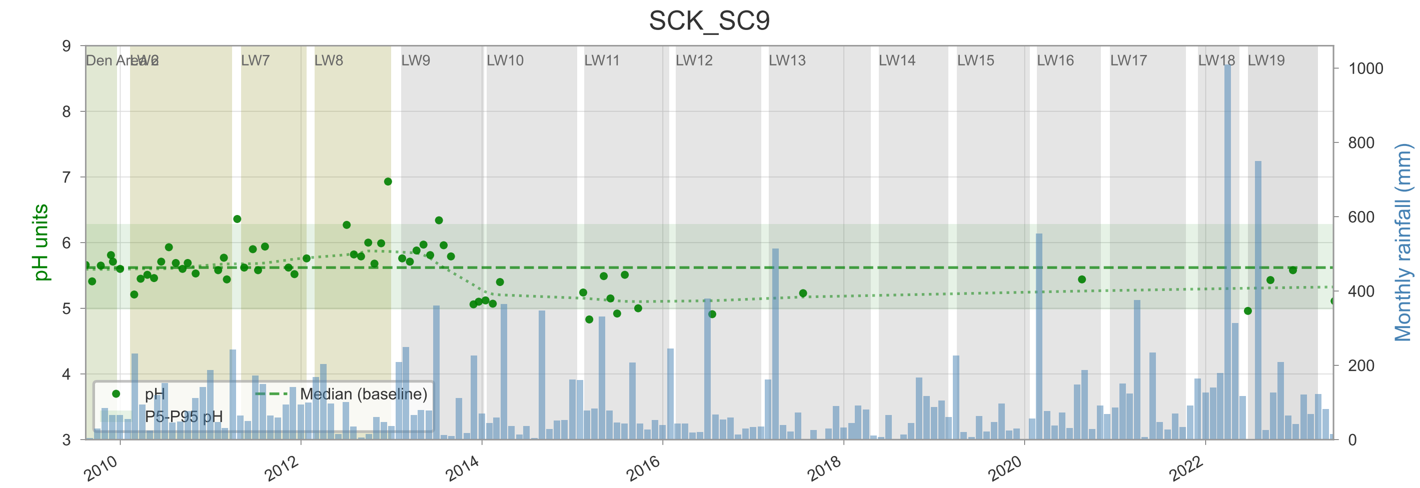

SCK_ROCKBAR5
pH units
Monthly rainfall (mm)
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
pH
pH Baseline mean
pH TARP [mean -3SD]

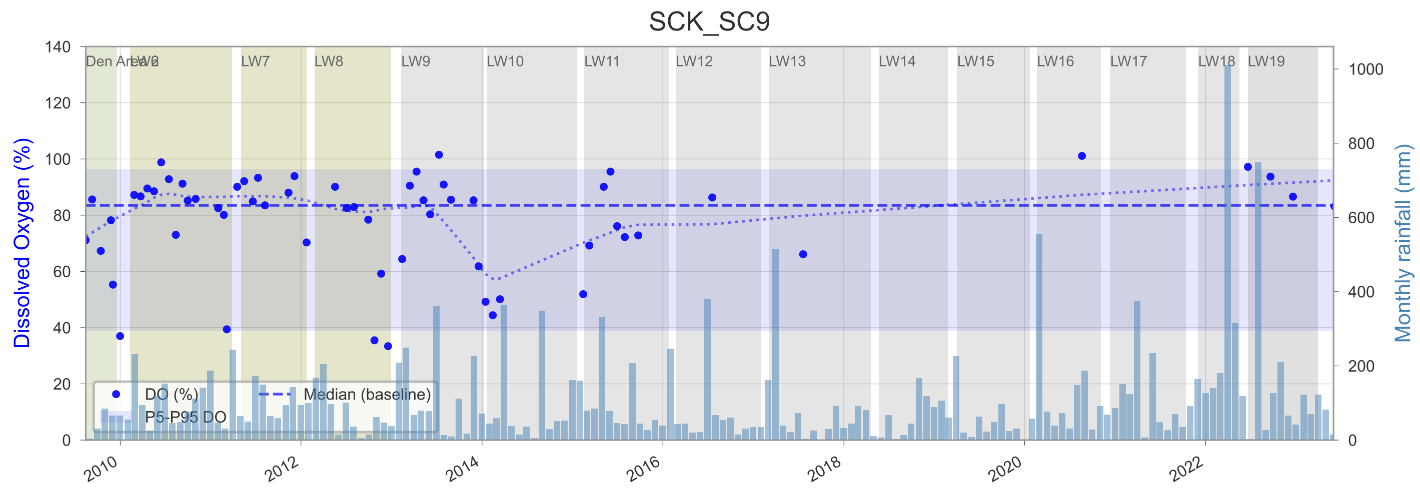

SCK_ROCKBAR5
Dissolved Oxygen (%)
Monthly rainfall (mm)
Den Area 1
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
DO (%)
DO Baseline mean
DO TARP [mean -3SD]

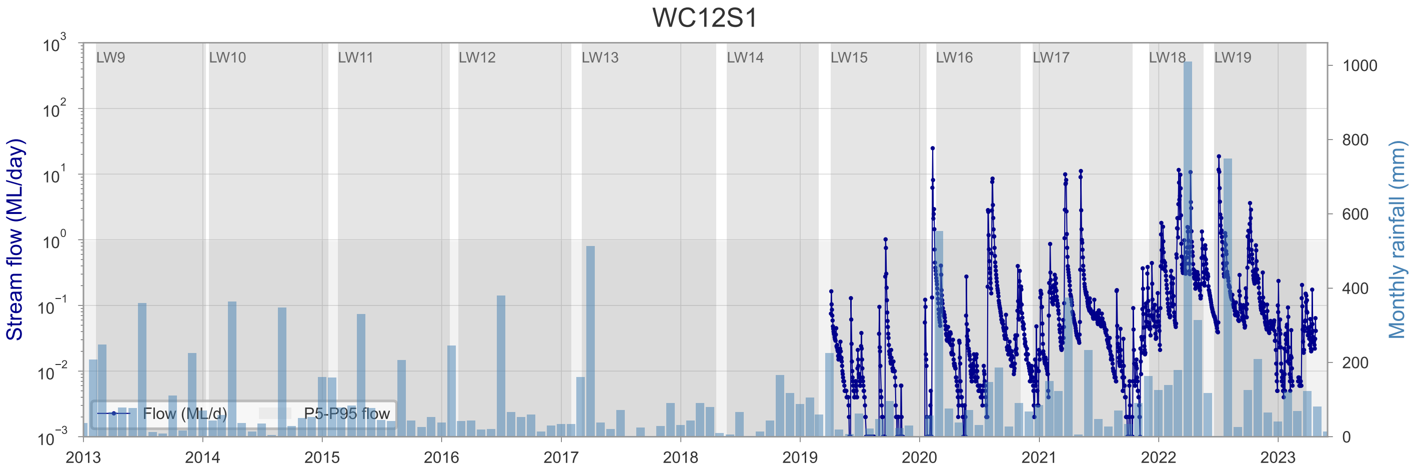

SCK_SC7
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
Pool dry
P5-P95 WL
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
0.00
0.05
0.10
0.15
0.20
0
200
400
600
800
1000
2010
2012
2014
2016
2018
2020
2022
SCK_SC7
Electrical Conductivity (uS/cm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)
0
25
50
75
100
125
150
175
200
SCK_SC7
pH units
pH
P5-P95 pH
Median (baseline)
3
4
5
6
7
8
9
SCK_SC7
Dissolved Oxygen (%)
DO (%)
P5-P95 DO
Median (baseline)
0
20
40
60
80
100
120
140

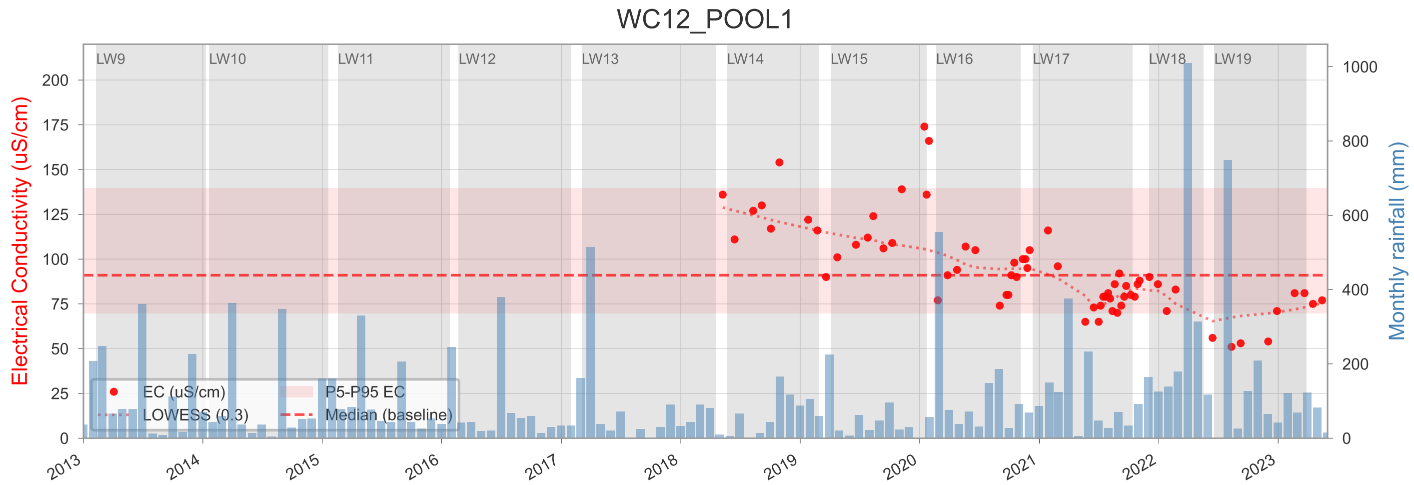

SCK_SC9
Water level (m below ref. nail)
Monthly rainfall (mm)
Den Area 2
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
WL below ref nail
Pool dry
P5-P95 WL
2010
2012
2014
2016
2018
2020
2022

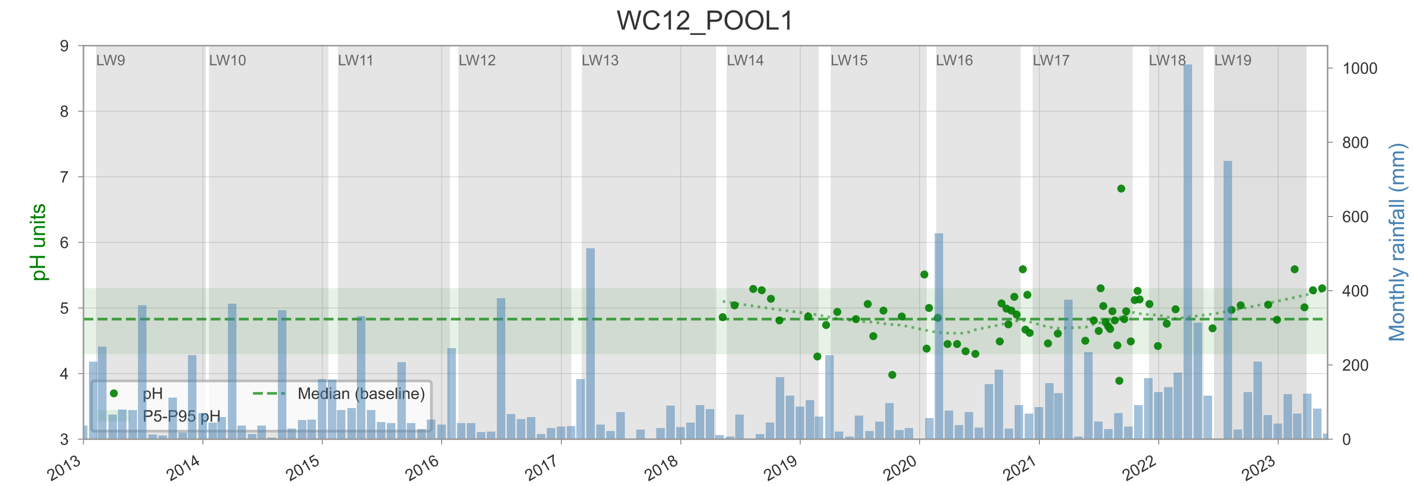

SCK_SC9
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)

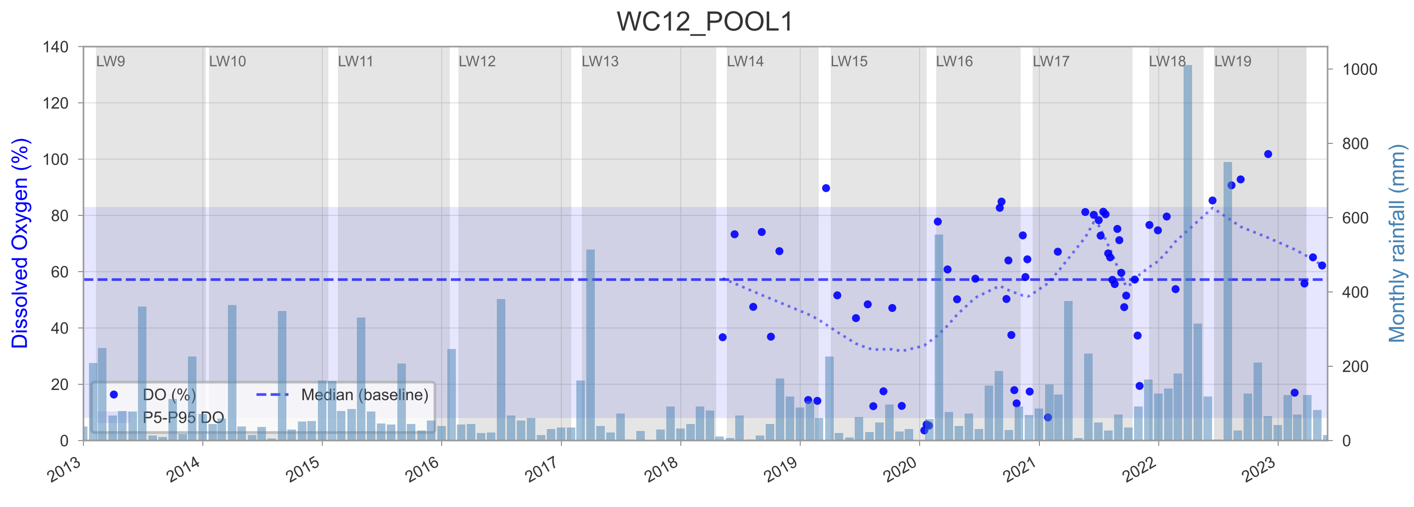

SCK_SC9
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)


SCK_SC9
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)


WC12S1
Stream flow (ML/day)
Monthly rainfall (mm)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Flow (ML/d)
P5-P95 flow


WC12_POOL1
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
P5-P95 EC
Median (baseline)


WC12_POOL1
pH units
Monthly rainfall (mm)
pH
P5-P95 pH
Median (baseline)


WC12_POOL1
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
P5-P95 DO
Median (baseline)