

Supplementary Information

This supplement documents sensitivity analyses, parameter estimates, uncertainty intervals, and quality-control scenarios corresponding to the manuscript. The primary analysis uses 90 % annual and monthly completeness and a leave-one-year-out calendar-month climatological reference based on monthly means of daily maximum water level.

S1. SW244 data-quality audit and scenario sensitivity

The raw source value of 5.88 m on 26 June 1996 is preserved in the source/audit files, while the audited analysis path uses a documented 3.39 m QC override. No independent gauge-history document in the supplied package establishes the physical reason for the override. The primary analysis therefore retains the documented QC value and reports two transparent sensitivity scenarios. These scenarios are diagnostic envelopes, not alternative claims about the true water level.

Supplementary Table S1. SW244 QC scenarios

Scenario	AMS_n	Max_AMS	Normal_R_L100	Gumbel_R_L100	GEV_LM_R_L100	POT_RL100	MK_p	Sen_mm_yr	Pettitt_year	Pettitt_p	LR_p	M1_2025_R_L100
Primary_QC_3.39m	25	2.081	1.799	2.136	1.85	1.906	0.0005965	17.57	1995	0.005692	5.76×10^{-6}	2.499
Raw_5.88m_scenario	25	3.379	2.309	2.806	2.751	3.017	0.0005965	17.57	1995	0.005692	1.985e-06	3.142
Exclude_1995_1996	23	1.356	1.566	1.835	1.381	1.39	7.446e-05	18.87	1997	0.002216	5.158e-06	1.851

S2. MCHR reference-statistic sensitivity

The primary MCHR is the LOYO mean across eligible year-month means for the same calendar month. A LOYO median provides a robust alternative. Across stations, 100-year GEV-LM changes are within 2.79 % and POT-GPD changes within 3.48 % in absolute magnitude; the primary MK trend/no-trend pattern is unchanged.

Supplementary Table S2. Mean versus median LOYO MCHR

Station	AMS_n	Base_GE_V100	Median_GE_V100	GEV_change_pct	Base_PO_T100	Median_PO_T100	POT_change_pct	Base_M_K_p	Median_M_K_p	Base_Sen_m_yr	Median_Sen_mm_yr
SW107.2	30	1.969	1.991	1.119	2.129	2.055	-3.483	0.0457	0.02038	8.995	11.63
SW20	32	1.957	2.012	2.787	1.836	1.812	-1.313	0.000995	0.0006224	18.06	18.41
SW241	34	1.75	1.766	0.9334	1.609	1.565	-2.77	5.771e-08	9.46e-08	24.7	24.1
SW243	32	1.932	1.977	2.304	2.002	1.968	-1.739	0.2118	0.2002	6.459	5.702
SW244	25	1.85	1.846	-0.2429	1.906	1.857	-2.582	0.0005965	0.0001698	17.57	17.87

S3. Multiplicity and serial-dependence sensitivity

Benjamini-Hochberg false-discovery-rate adjustment was applied separately across the five stations for MK, Pettitt and LR tests. Trend-free prewhitening was used as a sensitivity analysis. SW107.2 becomes marginal under BH-adjusted MK ($q=0.0571$), but Pettitt and LR evidence remain significant; SW20 Pettitt is borderline after FDR ($q=0.0512$), while MK and LR remain significant. The prewhitened MK pattern remains increasing at SW107.2, SW20, SW241 and SW244 and non-significant at SW243.

Supplementary Table S3. Trend, multiplicity and dependence diagnostics

Station	MK_p	MK_q_BH	Pettitt_p	Pettitt_q_BH	Lag1_r	LjungBox_p	Detrended_lag1_r	TFPW_MK_p	LR_p	LR_q_BH
SW107.2	0.0457	0.05712	0.02617	0.04361	0.09345	0.5938	-0.09056	0.014	0.02881	0.03602
SW20	0.000995	0.001658	0.04092	0.05115	0.3554	0.03848	0.1605	0.001101	0.008072	0.01345
SW241	5.771e-08	2.886e-07	9.912e-06	4.956e-05	0.7403	2.015e-05	-0.07635	2.096e-07	4.88×10^{-13}	2.44×10^{-12}
SW243	0.2118	0.2118	0.1551	0.1551	0.2985	0.08057	0.2587	0.3587	0.06436	0.06436

Station	MK_p	MK_q_BH	Pettitt_p	Pettitt_q_BH	Lag1_r	LjungBox_p	Detrended_lag1_r	TFPW_MK_p	LR_p	LR_q_BH
SW244	0.0005965	0.001491	0.005692	0.01423	0.1907	0.3376	0.002741	0.0009703	5.76×10^{-6}	1.44×10^{-5}

S4. Stationary and non-stationary GEV maximum-likelihood results

t_ref is the mean calendar year of accepted AMS observations. M0 and M1 are fitted under one likelihood framework; M1 varies only the location parameter. The profile interval is the primary likelihood-based interval for μ_1 . Conditional 2025 return levels freeze the fitted covariate at 2025 and are not forecasts under continued change.

Supplementary Table S4a. Stationary GEV-MLE (M0) parameter and fit results

Station	μ	σ	ξ	logL	AICc
SW107.2	0.7502	0.3256	-0.1151	-11.4	29.73
SW20	0.7624	0.3183	-0.1192	-11.97	30.81
SW241	0.6694	0.3361	-0.165	-13.6	34
SW243	0.8983	0.3985	-0.3057	-15.46	37.78
SW244	0.6564	0.3525	-0.08285	-12.07	31.29

Supplementary Table S4b. Non-stationary GEV-MLE (M1) parameter and fit results

Station	μ_0	μ_1 (mm yr ⁻¹)	σ	ξ	logL	AICc
SW107.2	0.7703	11.56	0.3101	-0.1728	-9.013	27.63
SW20	0.8001	12.71	0.3111	-0.2514	-8.466	26.41
SW241	0.7456	23.97	0.1519	-0.1112	12.53	-15.67
SW243	0.8743	11.14	0.3411	-0.1396	-13.75	36.99
SW244	0.6692	16.56	0.1983	0.1985	-1.789	13.58

Supplementary Table S4c. Likelihood comparison, 2025 return levels and profile interval

Station	LR	LR p	BH q	t_ref	M0 RL100	M1 2025 RL100	μ_1 profile 95 % CI
SW107.2	4.779	0.02881	0.03602	2003	1.913	2.01	[0.001361, 0.02246]
SW20	7.017	0.008072	0.01345	2006	1.89	1.894	[0.003606, 0.02181]
SW241	52.25	4.88×10^{-13}	2.44×10^{-12}	2005	1.753	1.781	[0.01987, 0.02927]
SW243	3.421	0.06436	0.06436	2006	1.882	2.245	[-0.000663, 0.02074]
SW244	20.57	5.76×10^{-6}	1.44×10^{-5}	2005	2.005	2.499	[0.01186, 0.02196]

S5. Completeness-screening sensitivity

The 85 % and 90 % settings retain identical AMS samples and key 100-year results. At 95 %, additional years are lost; SW243 is the most sensitive, with GEV-LM and POT-GPD 100-year estimates decreasing by about 19.6 % and 14.9 %. This is reported as a limitation rather than used to select a favorable threshold.

Supplementary Table S5. 85 %, 90 % and 95 % completeness sensitivity

Station	Completeness_threshold	AMS_n	GEV_LM_RL100	POT_GPD_RL100	GEV_change_pct_vs_90	POT_change_pct_vs_90
SW107.2	0.85	30	1.969	2.129	0	0

Station	Completeness_threshold	AMS_n	GEV_LM_RL100	POT_GPD_RL100	GEV_change_pct_vs_90	POT_change_pct_vs_90
SW20	0.85	32	1.957	1.836	0	0
SW241	0.85	34	1.75	1.609	0	0
SW243	0.85	32	1.932	2.002	0	0
SW244	0.85	25	1.85	1.906	0	0
SW107.2	0.9	30	1.969	2.129	0	0
SW20	0.9	32	1.957	1.836	0	0
SW241	0.9	34	1.75	1.609	0	0
SW243	0.9	32	1.932	2.002	0	0
SW244	0.9	25	1.85	1.906	0	0
SW107.2	0.95	29	1.972	2.115	0.1398	-0.6929
SW20	0.95	30	2.007	1.886	2.553	2.722
SW241	0.95	30	1.826	1.6	4.335	-0.5912
SW243	0.95	27	1.554	1.704	-19.56	-14.89
SW244	0.95	23	1.913	1.964	3.403	3.077

S6. GEV estimator sensitivity

The stationary four-method comparison uses GEV estimated by L-moments/PWM (GEV-LM), while M0/M1 likelihood comparison requires GEV maximum likelihood. Differences are small at four stations but reach 8.34 % at SW244, reinforcing the need to label the estimators separately.

Supplementary Table S6. GEV-LM versus stationary GEV-MLE 100-year levels

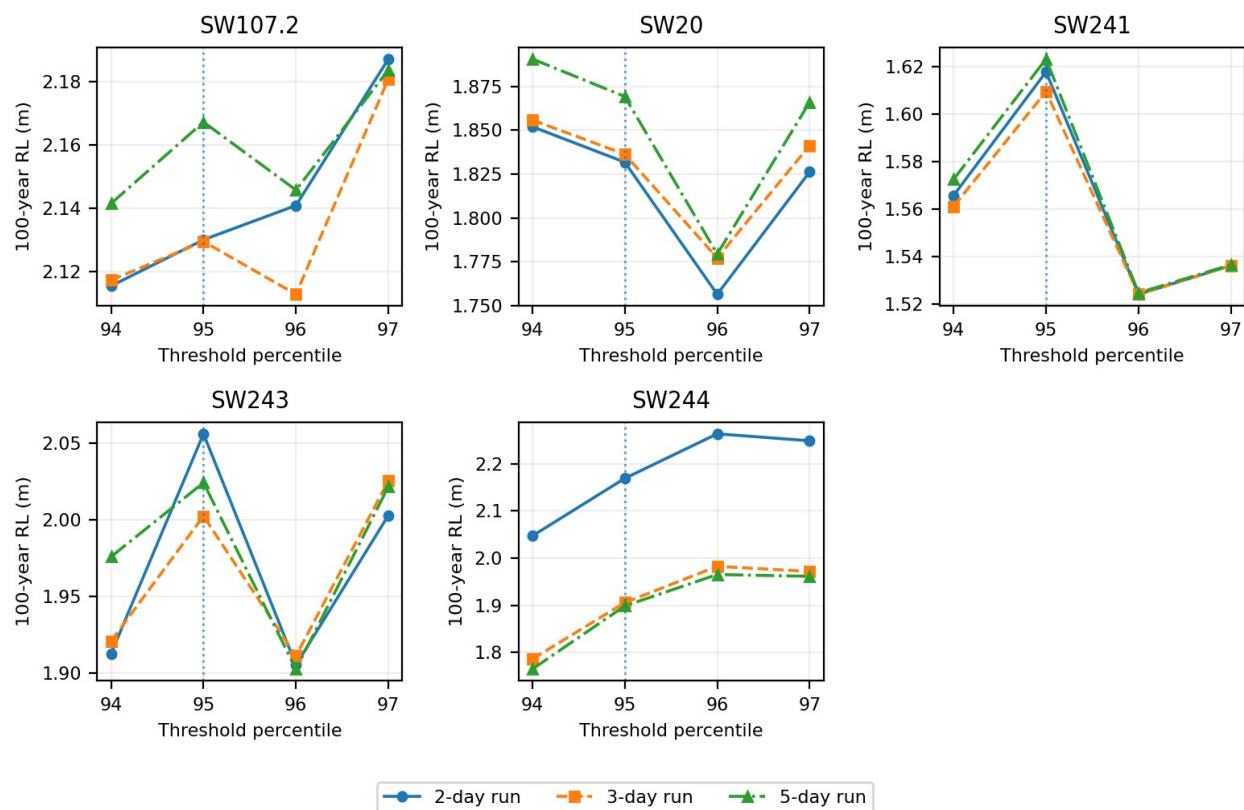
Station	GEV_LM	M0_RL100	Pct_difference_MLE_vs_LM
SW107.2	1.969	1.913	-2.836
SW20	1.957	1.89	-3.467
SW241	1.75	1.753	0.1538
SW243	1.932	1.882	-2.576
SW244	1.85	2.005	8.344

S7. POT threshold and declustering sensitivity

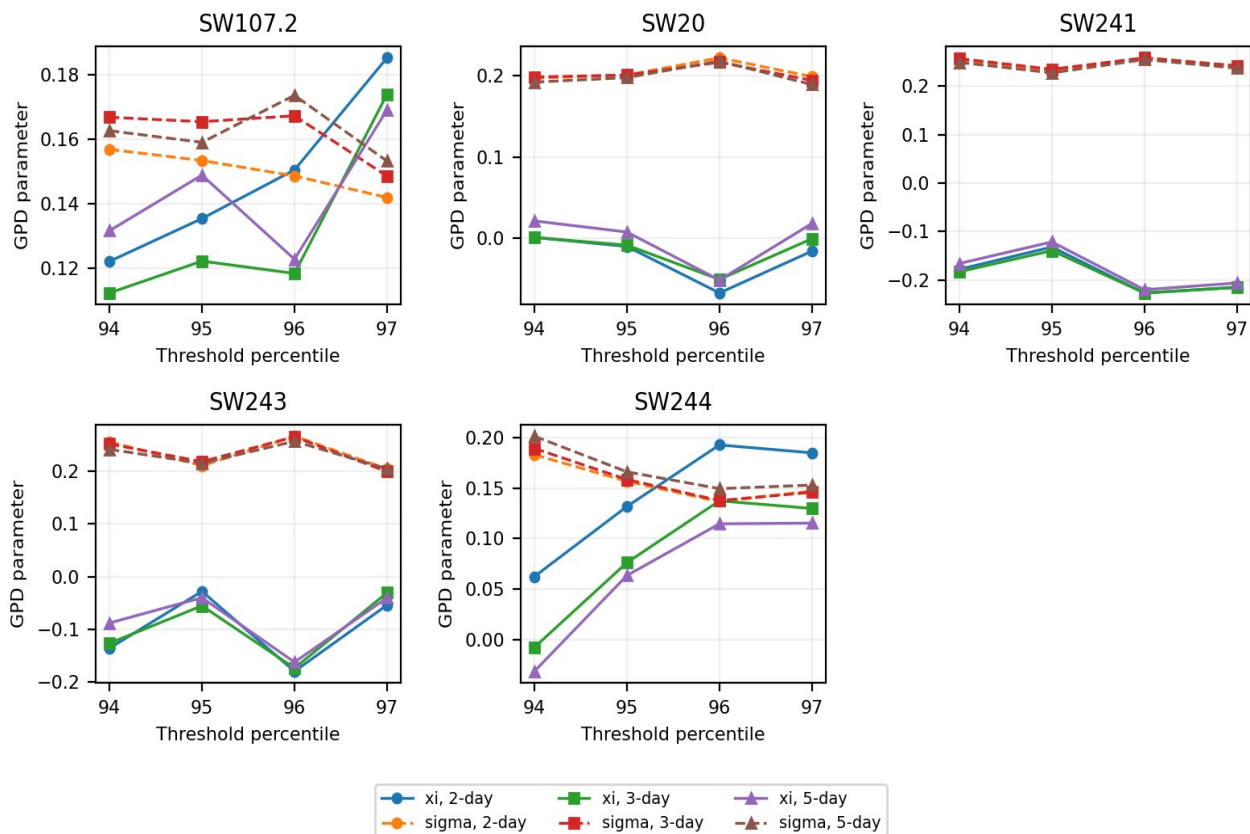
Sensitivity is defined as the maximum absolute percentage deviation of the 100-year POT-GPD estimate from the baseline 95th-percentile/3-day estimate. It is not a confidence interval.

Supplementary Table S7. POT sensitivity summary

Station	Baseline_RL100	Min_RL100	Max_RL100	Max_abs_pct_deviation
SW107.2	2.129	2.113	2.187	2.715
SW20	1.836	1.756	1.891	4.353
SW241	1.609	1.524	1.623	5.302
SW243	2.002	1.903	2.056	4.98
SW244	1.906	1.765	2.263	18.75



Supplementary Figure S1. 100-year POT-GPD return levels across 94–97 % thresholds and 2-, 3- and 5-day run lengths.



Supplementary Figure S2. GPD shape and scale parameter stability across POT threshold and run-length scenarios.

S8. Cyclone-event correspondence details

Event dates were specified independently from cyclone documentation, but anomaly magnitudes come from the same BWDB water-level record and therefore constitute correspondence rather than independent surge validation. D−2/D+2 produced the same peak as D−1/D+1 for every evaluable station-event pair.

Supplementary Table S8. Cyclone-event correspondence

Station	Cyclone	Event_date	D1_peak_date	D1_peak_anomaly_m	Percentile_pct	AMS_match_D1	D2_same_peak
SW107.2	Sidr	2007-11-15	NA	NA	NA	False	False
SW107.2	Aila	2009-05-25	2009-05-26	1.102	98.93	False	True
SW107.2	Amphan	2020-05-20	NA	NA	NA	False	False
SW107.2	Yaas	2021-05-26	2021-05-26	1.59	99.46	False	True
SW107.2	Remal	2024-05-26	2024-05-26	1.294	99.18	True	True
SW20	Sidr	2007-11-15	NA	NA	NA	False	False
SW20	Aila	2009-05-25	NA	NA	NA	False	False
SW20	Amphan	2020-05-20	2020-05-20	1.456	99.97	True	True
SW20	Yaas	2021-05-26	2021-05-26	1.502	99.98	True	True
SW20	Remal	2024-05-26	2024-05-27	1.761	100	True	True
SW241	Sidr	2007-11-15	NA	NA	NA	False	False
SW241	Aila	2009-05-25	NA	NA	NA	False	False
SW241	Amphan	2020-05-20	2020-05-21	0.7065	96.5	False	True
SW241	Yaas	2021-05-26	2021-05-27	1.024	99.47	False	True
SW241	Remal	2024-05-26	2024-05-27	1.063	99.58	True	True
SW243	Sidr	2007-11-15	NA	NA	NA	False	False
SW243	Aila	2009-05-25	2009-05-25	1.71	99.98	True	True
SW243	Amphan	2020-05-20	2020-05-19	0.7175	90.11	True	True
SW243	Yaas	2021-05-26	2021-05-27	1.038	96.85	True	True
SW243	Remal	2024-05-26	2024-05-27	0.9346	95.37	False	True
SW244	Sidr	2007-11-15	NA	NA	NA	False	False
SW244	Aila	2009-05-25	NA	NA	NA	False	False
SW244	Amphan	2020-05-20	2020-05-21	0.6775	94.97	False	True
SW244	Yaas	2021-05-26	2021-05-26	1.016	99.31	False	True
SW244	Remal	2024-05-26	2024-05-27	1.11	99.59	True	True

S9. Bootstrap and profile uncertainty

Percentile 95 % intervals are based on 1,000 M0 nonparametric bootstrap fits, 1,000 M1 parametric bootstrap fits and 2,000 POT excess bootstrap replicates. Base seed 20260905 is combined with a deterministic station index to create station-specific substreams. MLE optimization is bounded at $-0.8 \leq \xi \leq 0.8$. The rate-propagating POT sensitivity additionally draws peak counts from a Poisson distribution; the manuscript figure uses this wider event-frequency-aware interval.

Supplementary Table S9. 100-year uncertainty summary

Station	M0_RL100	M0_RL100_lo95	M0_RL100_hi95	M1_RL100_2025	M1_RL100_2025_lo95	M1_RL100_2025_hi95	M1_mu100_lo95	M1_mu100_lo95_profile	M1_mu100_hi95_profile	GPD_RL100	GPD_RL100_lo95_cond	GPD_RL100_hi95_cond	GPD_RL100_lo95_rate	GPD_RL100_hi95_rate
SW107.2	1.913	1.298	2.693	2.01	1.489	2.633	0.01156	0.001361	0.02246	2.129	1.547	2.621	1.569	2.634
SW20	1.89	1.499	3.077	1.894	1.492	2.297	0.01271	0.003606	0.02181	1.836	1.487	2.181	1.475	2.196
SW241	1.753	1.283	2.525	1.781	1.511	2.12	0.02397	0.01987	0.02927	1.609	1.347	1.908	1.336	1.922
SW243	1.882	1.635	2.161	2.245	1.672	3.004	0.01114	-0.000663	0.02074	2.002	1.685	2.279	1.694	2.296
SW244	2.005	1.153	3.675	2.499	1.522	6.947	0.01656	0.01186	0.02196	1.906	1.297	2.606	1.286	2.557

S10. Reproducibility and provenance note

The supplementary archive contains this supplementary document, derived result tables, and a core-statistics verification script. Raw BWDB observations are not redistributed because they remain subject to the provider's access and reuse conditions. The verification script checks the reported core statistics against the supplied derived outputs; it does not reconstruct the full analysis from restricted raw observations.